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The link between local environment and obesity: A multilevel analysis in the Lisbon Metropolitan Area, Portugal

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ABSTRACT

Although individual factors have been shown to predict weight gain, contextual determinants have also attracted attention, with some authors stressing the role played by deprivation, urban sprawl, social capital and safety. Recent evidence has implicated environmental factors that facilitate the consumption of excess calories and/or make it more difficult to expend them in routine physical activity. The interrelationships found in some places between physical and social environments (key mediators) and body mass index (BMI), as well as the potential that exists for the development of healthier places, mean that more research is required into the contextual determinants of health.

In Portugal, particularly in the Lisbon Metropolitan Area (LMA), the effects of physical and social environments on physical activity and BMI have not previously been explored in any detail. This study aims to highlight the associations between residential (physical and social) environment and the risk of weight gain and obesity, over and above individual attributes, assessing which indicators are the best predictors of excess weight in the LMA.

The study involved data from 7669 individuals aged 18 and over from 143 neighbourhoods. Self-reported body height and weight were used to define overweight body mass index (BMI $\geq$ 25). BMI and individual (socio-demographic and behavioural) characteristics were linked to contextual data and analysed in a multilevel framework.

Our findings show that different environmental factors are significantly associated with excess weight and obesity, either directly or indirectly (e.g. health-related behaviours such as eating patterns and physical activity, which are key mediators), after adjustment for individual characteristics. The results suggest that a deeper understanding of these mechanisms is critical if we want to tackle the obesity epidemic, and that policies aimed at weight control and obesity reduction must address people and places in order to bear fruit.

Introduction

Obesity has reached epidemic proportions in almost all developed countries (Backett-Milburn, Wills, Gregory, & Lawton, 2006) and in many urban areas in developing countries. Recent estimates suggest that one billion adults in the world are overweight (Kjellstrom, 2007).

Portugal has a significant obesity problem, which is rapidly worsening. In 1996, 10.3% of males and 11.4% of females had a BMI of over 30 kg/m2 (OECD, 2006); by 2006, this had increased to 16% for males and 16.9% for females (ACS, 2008), representing an additional 55.3% and 43.9% for males and females respectively over a period of ten years. Thus, by 2006, 1 in 2 adults were overweight or obese (ACS, 2008). Targets have been set by the National Health Plan (ACS, 2008) to reduce obesity and excess weight in the population by the year 2010. Obesity is a national public health problem: it has damaging effects on the social, economic and health status of individuals, exacerbating their risks of disease and premature death and increasing health care costs.

Several authors have claimed that excess body weight results from multifactorial causes, including polygenic, metabolic, psychosocial and environmental influences, and behavioural aspects (Borders, Rohrer, & Cardarelli, 2006; Ellaway, Anderson, & Macintyre, 1997; Poortinga, 2006a; Poston & Foreyt, 1999). Genes play a role, but the gene pool in industrialised countries has not changed significantly in the few decades in which obesity has rocketed. Therefore, environmental (obesogenic) factors must also contribute significantly to weight gain. Some authors (Cohen, Finch, Bower, & Sastry, 2006; Ellaway et al., 1997; Kim, Subramanian, Gortmaker, & Kawachi, 2006; Poortinga, 2006a; Poston & Foreyt,

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1999; Stafford et al., 2007; Van Lenthe & Mackenbach, 2002) have indicated the potential obesogenicity of certain environmental factors (i.e. the extent to which they could promote caloric intake and/or discourage the expenditure of energy in routine physical activity).

However, the precise cause of the epidemic remains unknown, and no possible solutions are yet in sight. It is important, therefore, to identify exactly what is a "toxic environment" (Poston & Foreyt, 1999) in order to focus upon changing it. Swinburn, Egger, & Raza (1999: 564) argue that "there is an urgent need for a conceptual and practical framework to dissect the rather nebulous concept of the environment into concrete elements which are amenable to measurement and interventions".

Increasing obesity amongst the Portuguese population is associated with trends in: excessive energy intake (3747 calories on average per person, in 2003, representing an increase of 32.6% in the last thirty years, that is 1.6% per year) (OECD, 2006); and low rates of leisure-time physical activity (overall age-adjusted prevalence for a sedentary lifestyle was 62.8% for males and 75.4% for females in 1999) (Demarest et al., 2007). By 2004, 73% of Portuguese people reported that they seldom or never did physical exercise for recreation or as a leisure-time activity, and 54% reported identical levels of inactivity at work (Eurobaromater, 2004). These behavioural risks for obesity, in isolation or together with genetic susceptibilities or vulnerabilities, may vary from individual to individual (in association with socioeconomic status) and according to place of residence (opportunities for healthy behaviours: physical recreation and eating) (Ellaway et al., 1997; Stafford et al., 2007).

The purpose of this paper is to examine the contribution of the local environment and personal attributes to the risk of weight gain in LMA neighbourhoods and evaluate their importance for the understanding and treatment of obesity. This information will be relevant for the design and planning of health promotion interventions, in so far as it will facilitate the identification of areas requiring analysis, major issues and priorities for tackling the obesity epidemic in the Lisbon Metropolitan Area (LMA).

To achieve this, the authors intend to: (1) develop indicators to measure social environment and availability of local resources; (2) link individuals to their neighbourhoods through the characterization of each individual personally and according to the specific features of their place of residence; (3) establish associations between sustainable communities, their citizens' body mass index (BMI) and risk factors for obesity (i.e. behaviours such as physical activity and healthy eating habits).

The next section describes the conceptual framework for obesity, including data and methods used, followed by the main achieved results. Finally, in the last part, possible explanations are suggested, some conclusions are drawn and key proposals are made for changes that could lead to alternative health outcomes.

A conceptual framework for obesity, and hypotheses

How might area characteristics be associated with the risk of increased BMI? Does place act or interact with individual characteristics? How does this happen?

A web of interlinking determinants

In 1997, Macintyre (Macintyre, 1997) presented three types of explanations for geographical variations in health: compositional, contextual and collective. Macintyre, Ellaway, and Cummins (2002: 125) subsequently suggested that the distinction "between composition and context may be more apparent than real …". A conceptual framework linking residential context to obesity, including a plausible causal pathway, was suggested by Stafford et al. (2007) (discussed below). Social and physical environments that define the residential context (physical, social, economic, and political) are shaped by multiple factors and multiple players (national and local government, private sector, civil society) at multiple levels (global and local) (Vlahov, Galea, Gibbe, & Freudenberg, 2005).

Excess weight and residential area deprivation

A large body of literature has established links between the neighbourhood environment and BMI, directly or indirectly (pathways). A greater prevalence of obesity in more deprived neighbourhoods was reported by a number of studies (Ellaway et al., 1997; Van Lenthe & Mackenbach, 2002).

The association between neighbourhood deprivation and excess weight may be modified by individual socio-demographic factors due to the different amounts of time spent in the neighbourhoods by different groups and the nature of their presence. For lower socioeconomic groups, females (housewives) and the elderly (retired), the environment may have a larger impact on daily life than for subjects in higher socioeconomic groups, males and younger people (Van Lenthe & Mackenbach, 2002).

It has been argued that local social organization, which may be inversely related to area deprivation (Wilkinson, 2005), plays a major role in promoting healthy behaviours. Cohen et al. (2006) suggested that collective efficacy, defined as social cohesion among neighbours, stimulates various positive health behaviours, including physical activity, and exerts some measure of social control over deviant behaviours, such as smoking and alcohol abuse. Individuals living in neighbourhoods that are socially and physically disadvantaged are at increased risk of engaging in unhealthy behaviours, such as physical inactivity, often as a response to a stressful and hazardous environment (McNeill, Kreuter, & Subramanian, 2006; Stafford et al., 2007). Poortinga (2006a) indicated positive associations between obesity and the "presence of social nuisances", and between social support, social capital and higher levels of physical activity. Sampson, Raudenbush, and Earls (1997) reports a positive association between deprivation and violence which make areas unsafe, while Van Lenthe, Brug, and Mackenbach (2005) stressed the role of neighbourhood attractiveness and safety in encouraging physical activity.

Area deprivation is associated with the decline in healthy life styles (Santana, 2002), promoting excess weight and obesity, physical inactivity (Kim et al., 2006; Poortinga, 2006a), availability of fast-food outlets (Cummins et al., 2005) and fast-food consumption (Macdonald, Cummins, & Macintyre, 2007). The poorest settings are experienced as having an adverse "obesogenic" impact (Schoeppe & Braubach, 2007). The emergence of the "obesogenic" environment has been both rapid and multifactorial, involving changes in eating habits (including the availability, portion size and low cost of fast-food) together with decreasing energy expenditure (active lifestyle decrease). Healthy behaviour, such as planned physical activity (e.g. walking, running or sports) and healthy eating (fruit and vegetable intake) are related to residential environment, categorized into four types: physical (availability), economic (costs), political (rules) and sociocultural (the attitudes and beliefs held by the community or society) (Swinburn et al., 1999).

Neighbourhood walkability and behaviour weight gain related

On the other side of the energy equation is energy expenditure. The literature suggests that local urban planning and design influence weight in a number of ways. Residential density and mixed land use, combined with street connectivity, provide opportunities for physical activity (Calthorpe & Fulton 2001; Doyle, Kelly-Schawartz, Scholossberg & Stockard, 2006; Frank et al., 2006;

Jochelson, 2004), while neighbourhood attractiveness and safety (i.e. low crime and accident rates) encourage outdoor activities (Calthorpe & Fulton 2001; Doyle et al., 2006; Jochelson, 2004; Stafford et al., 2007). Ellaway et al. (1997) and Stafford et al. (2007) suggested that the provision of and access to local public facilities and spaces for recreation and play are directly correlated with individual level planned physical activity.

Factors related with urban sprawl (for example, areas with low population density and low street connectivity), land use (living in homogeneous land use areas), location of facilities (sports and leisure centres, public services, shops, parks and green spaces located far from area of residence) (Frank et al., 2006) and community perceptions (unsafe and unpleasant environments) could create "unwalkable" communities. Cerin, Leslie, du Toit, Owen, & Frank (2007: 723) presented the results of the PLACE (Physical Activity in Localities and Community Environments) study in Adelaide, Australia. The authors concluded that this study "strengthens the evidence base for a causal effect of the built environment on physical activity". Access to destinations (workplace proximity) from home has been shown to be positively correlated with walking for transports, especially among women.

The environmental characteristics have been related to the prevalence of excess weight and obesity (Doyle et al., 2006), even after controlling the individual variables usually implicated in weight gain (Kim et al., 2006; Poortinga, 2006a).

Data and methods

The LMA comprises 19 municipalities, 216 neighbourhoods and over 2.5 million inhabitants. The mean population of neighbourhoods was 12,420 inhabitants, ranging from 341 to 81.845 inhabitants (INE, 2001). Population density ranges from 9.3 to 34.474 inhabitants/km^2 at the neighbourhood level. The sampling universe consisted of the residents of the LMA. A sample of 7.669 individuals, living in 143 neighbourhoods, was collected by trained interviewers (National Health Survey – NHS – 1998–99). Individual characteristics were linked to residential environment data at the neighbourhood level, since all data was geocodified.

Outcome measure

This study has four binary outcome measures, based on self-reported weight, height, leisure activities, and fruit and vegetable intake. Excess body weight was assessed through body mass index (BMI), defined as a ratio between self-reported weight (kilograms) and squared height (metres). The BMI variable was categorised into two groups: normal ($18 \leq \text{BMI} < 25$) and overweight ($\text{BMI} \geq 25$).

The planned physical activity variable was divided into two categories (vigorous and moderate activity), both based on self-reported leisure-time activities. Vigorous physical activity was considered to be competitive sports, jogging or other recreational sports, while moderate activity included walking, cycling and other light activities.

A healthy diet was defined in accordance with self-reported fruit and vegetable intake on the day before the interview.

Predictor variables

Individual and contextual variables tested in the models vary according to previous work (Santana, Nogueira, & Santos, 2007) and theoretical support.

At the *individual level*, some key characteristics related to weight gain were collected from the NHS. These were: demographic factors (age, gender); marital status (single, married, divorced/separated); economic activity (employed, unemployed, student, retired and housewife); educational level (less than 4 years, between 5 and 12 years and more than 12 years); occupational class (manual, non-manual workers); income (household income divided by number of relatives living in the household) and health-related behaviours (moderate or vigorous physical activity, smoking and healthy diet) (see Table 1). All individual variables were included as dummy variables, except age, which was included as continuous, centred and squared, in order to model the curvilinear relationship between age and BMI. In fact, it was expected that BMI would increase with age through mid-adulthood and then decline in old age (Robert & Reither, 2004).

At the *neighbourhood level*, we addressed the challenge of accurately assessing a range of specific features from the local environment that may influence each of the four health outcomes considered. Observations were originally made and data collected at two different levels, municipality and neighbourhood. However, in the present study, all the contextual variables were converted to neighbourhood. We theorized a range of environmental domains related with weight gain, some of which were operationalized using statistical procedures. Three composite ecological indices (local resources, social capital and public health services availability) were created through Principal Components Analysis (PCA) (Cummins et al., 2005; Nogueira, Santana, & Santos, 2006). In these cases, a large number of variables were assigned to the environmental domains (32). Then, PCA was performed to explore and reduce these data. In order to maximize component feasibility, all were extracted using orthogonal rotation, and rejected when considered irrelevant using Kaiser's criterion. Throughout the extraction process, we systematically modified the number of entered variables, discarding those with a low loading into components. This procedure allows the generation of a single strong component in each of the conceptualized environmental domains (Cummins et al., 2005). To assess the internal consistency of the generated indices, a reliability analysis was performed. The high values of the Cronbach's Alpha scores (ranging from 0.51 to 0.90) show that created indices are reliable scales, confirming their consistency and capacity of measuring the latent environmental domains. The other composite ecological measure was a deprivation score, operationalized following the methodology of Carstairs and Morris (1991) (standardization and sum of three census variables). All the other indicators were single measures, i.e. proxies of housing inadequacy, urban sprawl, mixed land use and availability of sport features (see Table 2). Some of these single measures were standardized since this transformation produces more interpretable (centred in mean and standard variation of 1) and better fitted results from the regression model (Long, 1997). Moreover, contextual variables were previously correlated, providing feedback about the more accurate mix of variables to use in each health outcome model. Interactions between variables were calculated and tested in all models (see Appendix A and B, Supplementary material).

Multilevel logistical model

Behavioural and social data commonly have a nested structure. This means that individuals within a neighbourhood are more alike than individuals living in different neighbourhoods. Goldstein (1995) claims that even in extreme cases when groupings are established randomly (as when subjects are allocated to different experimental groups), once grouping is established, they will tend to become differentiated. This implies that both the group and its members can influence and be influenced by the group composition. Ignoring this hierarchical structure in regression models leads to an underestimation of standard errors, and a subsequent overstatement of statistical significance.

Multilevel models avoid this bias, allowing the assessment of health variations across neighbourhoods (random intercept), after controlling for individual level variables (Sundquist & Yang, 2007).

Table 1
Description of contextual information.

Domain		Mean (min; max)
Characteristics of environmental disadvantage		
Unsafe environment	Crimes against the property per 1000 inhabitants*	10.81 (7.13; 18)
	Traffic accidents with victims per 1000 inhabitants**	3.97 (0; 35.7)
Housing inadequacy	No. of shanty households (standardized)**	55.6 (0; 732)
Deprivation Score	Male unemployment**;	0 (−4.3; 15.79)
	Unskilled worker employment**;	
	Individuals living in shanty households**	
Urban Sprawl	Population density per squared km**	4891 (9.32; 34,474.2)
Characteristics of environmental opportunity		
Groceries	No. of groceries (standardized)**	0 (−1.02; 3.8)
Supermarkets	No. of supermarkets (standardized)**	0 (−0.79; 6)
Post offices	No. of post offices per 1000 inhabitants**	0.38 (0; 5.71)
Green parks	No. of green parks (standardized)**	0 (−0.89; 2.9)
Sports facilities	No. of gymnasiums (standardized)**	0 (−0.7; 3.44)
	No. of swimming pools (standardized)**	0 (−0.59; 3.9)
Social capital	No. of clubs for recreational or sports activities**	5.3 (0; 9)
	No. of local newspapers**	2.5 (0; 6)
	Local newspaper circulation per inhabitant**	12 (0; 34,2)
Diverse local resources	No. of dental practices**	3.5 (1; 28)
	No. of banks**	4.7 (1; 37)
	No. of ATMs**	5 (0; 9)
	No. of shopping centres**	1.2 (0; 9)
	No. of opticians**	3.3 (1; 13)
	No. of sports shops**	2.1 (0; 18)
	No. of bookshops**	0.95 (0; 13)
Public health services	No. of nursery staff in Primary Care services per 1000 inhabitants**	0.63 (0.38; 1.31)
	No. of public health doctors in primary care services per 1000 inhabitants**	0.4 (0.18; 0.77)
	No. of GP and family doctors per 1000 inhabitants**	0.66 (0.36; 0.85)

*Measured at municipality spatial scale; **measured at neighbourhood spatial scale. Note: we have defined neighbourhood from the administrative boundaries of the wards.

We applied a two-level logistic model with individuals at the first level, which are nested within neighbourhoods at the second level. According to Raudenbush and Bryk (2002), although any number of levels could be represented, the essential statistical features are found in this basic two-level model.

In developed models (presented below), we tested the association between the probability of having overweight, healthy diet, moderate physical activity and vigorous physical activity and neighbourhood features (housing inadequacy, socioeconomic deprivation, urban sprawl, unsafe environment, social cohesion, sport facilities, public health services and mix-land use), adjusting for demographic, economic activity, education level, income and behavioural variables that can be considered as confounders in the relation between the dependent variables and neighbourhood features. Cross-level interactions (between economic activity status and deprivation score) and interactions between the neighbourhood variables were calculated and tested in the models. The random intercept was compared between models as a measure of how much those variables included in the model explain away the variation between neighbourhoods.

The results of the models are analysed in terms of odd-ratios that indicate the influence of individual and neighbourhood predictors upon the probability of having an overweight BMI, engaging in vigorous or moderate physical activity or of having a diet that includes fruit and vegetables.

The two-level binomial logistic models were formulated according to the method described by Rasbash et al. (2008) and Raudenbush and Bryk (2002) considering a fixed part and a random term. The fixed part includes the overall relationship between the dependent variable (BMI overweight, healthy diet, moderate physical activity and vigorous physical activity) and both individual and neighbourhood level predictors, while the random term summarizes the variations between neighbourhood in the dependent variable that cannot be accounted for by the included predictors, i.e. expresses the variability around the global trend that is differentiated between neighbourhoods.

We specified four two-level logistic hierarchical regressions in which excess weight ($BMI \geq 25$), healthy diet (fruit and vegetable intake), vigorous and moderate physical activity were each regressed on contextual characteristics and adjusted for a full set of individual attributes. We proceeded in four steps:

(1) Selection of the variables to be included in each model in accordance with the state of art.

Table 2
Description of National Health Survey 1998–99 for Lisbon Metropolitan Area.

		N	%
Gender	Female	4101	53.5%
	Male	3568	46.5%
Age	18–29	1502	19.6%
	30–44	1741	22.7%
	45–64	2722	35.5%
	65+	1704	22.2%
BMI	Normal ($18 < BMI < 25$)	3794	49.5%
	Overweigh and obesity ($BMI \geq 25$)	3875	50.5%
Educational Level	<4 yrs	3487	45.5%
	5–12 yrs	3118	40.7%
	>12 yrs	1064	13.8%
Occupation	Employed + student	4804	62.6%
	Unemployed + housewife + retired	2865	37.4%
Manual (vs non-manual) worker		1022	13.13%
Self-rated health	Less than good	5962	77.7%
	Good or very good	1707	22.3%
Life styles	Vigorous PA	620	8.1%
	Moderated PA	1891	24.7%
	Diet	5590	72.9%
	Daily smoker	1767	23%
Income	First quintile (lower)	1679	22.3%
	Second quintile (low)	1307	17.4%
	Third quintile (mean)	1800	23.9%
	Fourth quintile (high)	1415	18.8%
	Fifth quintile (higher)	877	11.4%
	Missing	591	6.8%

(2) Creation of a first set of models that included only the variables that were intrinsic to the individuals involved (demographic, economic and life style variables), which allowed us to define a baseline model.
(3) Creation of a second set of models, developed upon the baseline model estimated in the first step by adding a random intercept coefficient, specifying $\beta_{0j}x_{0ij} + \mu_{0j}x_{00}$ and then adding the contextual variables mentioned above one at a time.
(4) Finally, development of the full model, which includes only the significant individual and neighbourhood variables that showed significance and the random intercept.

All the models were estimated using *MLwiN* software (Version 2.02) (Rasbash et al., 2008), based upon predictive/penalized quasi-likelihood approximation of a second-order Taylor linearization procedure (Goldstein & Rasbash, 1996). We estimated the odds ratio (OR) and 95% confidence intervals (CI) for each individual and neighbourhood predictor. Moreover, to obtain the Deviance Information Criterion (DIC) we used MCMC estimation procedure of MLwiN. DIC was used in each of the four models as a tool with which to compare the diverse estimated models until the final model (Spiegelhater, Best, Carlin, & van der Linde, 2002), for each of the four outcomes.

Results

Multilevel models

We present in Table 3 the models that showed the better fit according to DIC, for the four models developed. The values of variance between neighbourhoods and DIC for the null models are presented to highlight the reduction of variance between neighbourhoods after taking into account the included variables and of DIC.

Age, gender, occupation, education and income, marital status, lifestyles and overall health /initial health status (self-rated) were included, although there were some differences in the variables reported (see Table 3).

Healthy Diet

Women, married couples, the employed, non-smokers, the better educated and those on a higher income all showed increased odds of fruit and vegetable intake. A similar association was found for manual workers but without statistical significance. Age shows that older individuals (over 48) are more likely to eat healthily. When adjustments were made for these individual attributes, empirical evidence was found for an environmental effect on diet, as there were significant variations in diet between neighbourhoods. Fruit and vegetables intake was negatively associated with the number of crimes against property, showing a direct association between neighbourhood disorder and healthy diet. Moreover, relevant associations were found between contextual measures, although without statistical significance. Less deprived neighbourhoods have more supermarkets (see correlations, Appendix B, Supplementary material), and the inhabitants of those areas have a greater fruit and vegetable intake, results that corroborate previous studies in this field (cf. Stafford et al., 2007). However, this relation changes with different types of food retail provision. A negative association was found between healthy diet and the presence of groceries shops, which are more prevalent in more deprived neighbourhoods. These findings suggest that the type and quality of food retail outlets, and their accessibility, are contextual determinants of diet, shaping dietary patterns, which have a well-known relationship with obesity.

Physical activity

Two physical activity models were developed, distinguishing between vigorous and moderate physical activity.

Moderate exercise – walking

It was found that women, the less well educated and people with a poor (self-rated) health status and lower income are less likely to engage in moderate physical activity. Age shows that older individuals (i.e. over 48) are less likely to engage in moderate exercise. After adjusting for individual characteristics, important neighbourhood effects upon levels of moderate physical activity were found. Strong positive associations were found between moderate physical activity and population density, social cohesion, availability of public health services and availability of high street facilities (the higher the density, social cohesion and availability, the higher the level of physical activity), while a negative significant association between violence and moderate PA was found (the more crimes against property, the lower the levels of physical activity). Moderate physical activity was negatively associated with traffic accidents involving victims, and positively with the number of swimming pools, green parks and spaces, and post offices (not significant). Moreover, cross-level interactions suggest that individuals that are outside the labour market, living in more deprived areas, are less likely to engage in moderate physical activity. Testing for interactions between contextual variables, we found a significant positive relation between individuals living in the *higher* population density tercile and more deprived areas, and levels of moderate physical activity.

Vigorous exercise

Women, those with lower levels of education, low (self-rated) health status and smokers are less likely to engage in vigorous sports activities, while lower income show a similar impact on vigorous physical activity, though without statistical significance. Age shows that older individuals (i.e. over 48) are less likely to engage in vigorous exercise.

Strong evidence was found for neighbourhood effect on vigorous physical activity, after controlling for individual characteristics. Vigorous physical activity was negatively associated with traffic accidents involving victims, lack of gymnasiums and swimming pools, and weaker social cohesion. Furthermore, living in areas characterized by higher population density, higher levels of violence (crimes against property), lack of green parks decreases the likelihood of engaging in sports activities, although without statistical significance.

Testing for interactions, we found a significant positive relation between individuals living simultaneously in the *higher* population density tercile and more deprived areas and levels of vigorous physical activity. We also found a significant negative relation between individuals outside the labour market living in deprived areas and levels of vigorous physical activity.

BMI

Men, people with lower education levels and those with a poorer health status were more likely to be overweight. Age shows the expected relationship; older individuals are more likely to be overweight. However, this effect is not linear (Robert & Reither, 2004). In fact, a squared age term, included in the model assesses the curvilinear relationship between age and BMI. As expected, poor quality diet, characterized by a low fruit and vegetables intake, is associated with a high BMI, though without statistical significance. Adjusting for individual attributes, urban sprawl (lower population density), inadequate housing (shanties) and unsafe environment (violence measured through crimes against property and traffic accidents involving victims) show

Table 3
Two-level binomial multilevel odd-ratios for overweight BMI, diet, moderate and vigorous PA models.

		BMI overweight & obesity		Healthy Diet		Moderate PA		Vigorous PA	
Independent variables		OR	OR 95%CI	OR	OR 95%CI	OR	OR 95%CI	OR	OR 95%CI
Constant		**2.21**	**1.36–3.59**	**9.92**	**6.88–14.32**	1.76	1.06–2.93	0.42	0.21–0.81
Individual variables									
Gender (female)		**0.65**	**0.56–0.74**	**1.22**	**1.09–1.37**	**0.60**	**0.52–0.70**	**0.38**	**0.29–0.49**
Age (centred)		**1.43**	**1.06–1.09**	**1.02**	**1.01–1.02**	0.99	0.99–1.00	**0.97**	**0.96–0.98**
Age squared		**0.99**	**0.99–0.99**						
Educational level	Less than 4 yrs	**2.56**	**2.04–3.21**	**0.59**	**0.48–0.73**	**0.51**	**0.40–0.66**	**0.43**	**0.28–0.67**
	Between 5 and 12 yrs	**1.50**	**1.22–1.85**	**0.71**	**0.59–0.85**	**0.79**	**0.63–0.97**	0.76	0.55–1.04
	More than 12 yrs (base)	1		1		1		1	
Marital status	Married (base)			1					
	Single			0.88	0.75–1.03				
	Divorced/separated			**0.68**	**0.53–0.88**				
	Widowed			**0.69**	**0.56–0.85**				
Occupation	Employed + student (base)	1							
	Unemployed + housewife + retired			**0.85**	**0.74–0.98**				
Manual (vs non-Manual) worker				0.92	0.78–1.08				
Self-rated Health	Less than good	**1.20**	**1.03–1.39**			**0.71**	**0.60–0.83**	**0.62**	**0.46–0.82**
	Good or very good (base)	**1**							
Life styles	Vigorous PA	**0.70**	**0.54–0.92**						
	Moderated PA	**0.71**	**0.61–0.83**						
	Diet	0.99	0.88–1.17						
	Daily smoker	**0.58**	**0.49–0.68**	**0.64**	**0.56–0.73**	0.92	0.77–1.10	**0.59**	**0.44–0.79**
Income	First quintile (lower)			**0.65**	**0.53–0.79**	**0.73**	**0.57–0.94**	0.86	0.54–1.36
	Second quintile (low)			0.82	0.67–1.02	0.78	0.60–1.01	0.91	0.59–1.43
	Third quintile (mean)			0.96	0.79–1.17	0.88	0.70–1.11	0.86	0.58–1.27
	Fourth quintile (high)			1.04	0.85–1.27	0.90	0.72–1.13	0.97	0.66–1.43
	Fifth quintile (higher) (base)	1		1		1		1	
	Missing			0.77	0.57–1.02	0.84	0.57–1.23	0.52	0.26–1.04
Contextual variables									
Neighbourhood variables									
Population density	First tercile (low) (base)	1							
	Second tercile (mean)	0.84	0.68–1.04			1.03	0.75–1.41	0.82	0.57–1.18
	Third tercile (high)	0.97	0.77–1.24			1.09	0.75–1.56	0.86	0.56–1.32
Shanties households		1.02	0.99–1.05						
Traffic accidents with victims		1.00	0.98–1.02			0.98	0.95–1.01	0.97	0.93–1.02
Crimes against property		**1.02**	**1.01–1.03**	**0.98**	**0.98–0.99**	**0.98**	**0.97–0.99**	0.99	0.98–1.01
Swimming pool						1.04	0.91–1.18	**1.17**	**1.01–1.35**
Green parks						0.99	0.88–1.12	1.03	0.89–1.18
Supermarkets		0.95	0.85–1.06						
Post office		0.95	0.82–1.11			1.10	0.92–1.30		
Gymnasiums								**1.17**	**1.01–1.36**
Contextual									
Deprivation score									
Social cohesion		0.98	0.88–1.09			**1.28**	**1.09–1.52**	**1.24**	**1.01–1.52**
Diverse local resources		0.99	0.91–1.10			1.07	0.95–1.20	1.04	0.84–1.30
Public health services		**0.84**	**0.74–0.95**			**1.38**	**1.14–1.66**		
Interactions									
Third population density tercilee(higher) × deprivation score		1.08	0.98–1.19			1.02	0.89–1.18	1.01	0.85–1.19
(Unemployed + housewife + retired) × deprivation score						0.97	0.75–1.27	0.56	0.30–1.05
Groceries × deprivation score				1.03	0.95–1.11				
Supermarkets × deprivation score				0.98	0.91–1.05				
Random parameters									
Variance between neighbourhood's of final model (of null model)		**0.073 (0.064)**	**0.026 (0.020)**	**0.39 (0.643)**	**0.06 (0.105)**	**0.294 (0.276)**	**0.059 (0.076)**	0.085 **(0.483)**	0.067 **(0.081)**
DIC of final model (of null model)		5826.50 (10,587.54)		8187.81 (8413.60)		4793.61 (8156,72)		1966.94 (4235.32)	

Note: **bold** indicates statistical significance at the 5% level.

a positive association with BMI; the higher these area disadvantage characteristics, the higher the individual BMI. Other relevant associations were found, but were not statistically significant. The availability of supermarkets and post offices reduces the odds of being overweight, as do social cohesion and public health services.

In addition to the positive relation between urban sprawl (low population density) and excess weight, reported above, the interaction between living in the *higher* population density tercile and more deprived areas showed the opposite trend, increasing the odds of being overweight.

The significant associations of the four estimated models are summarized in Fig. 1 (with the exception of the association between health diet and overweight BMI).

Discussion

This paper considers the features of the local social and physical environment that may affect body mass index (BMI) by encouraging behaviours such as physical activity and eating patterns.

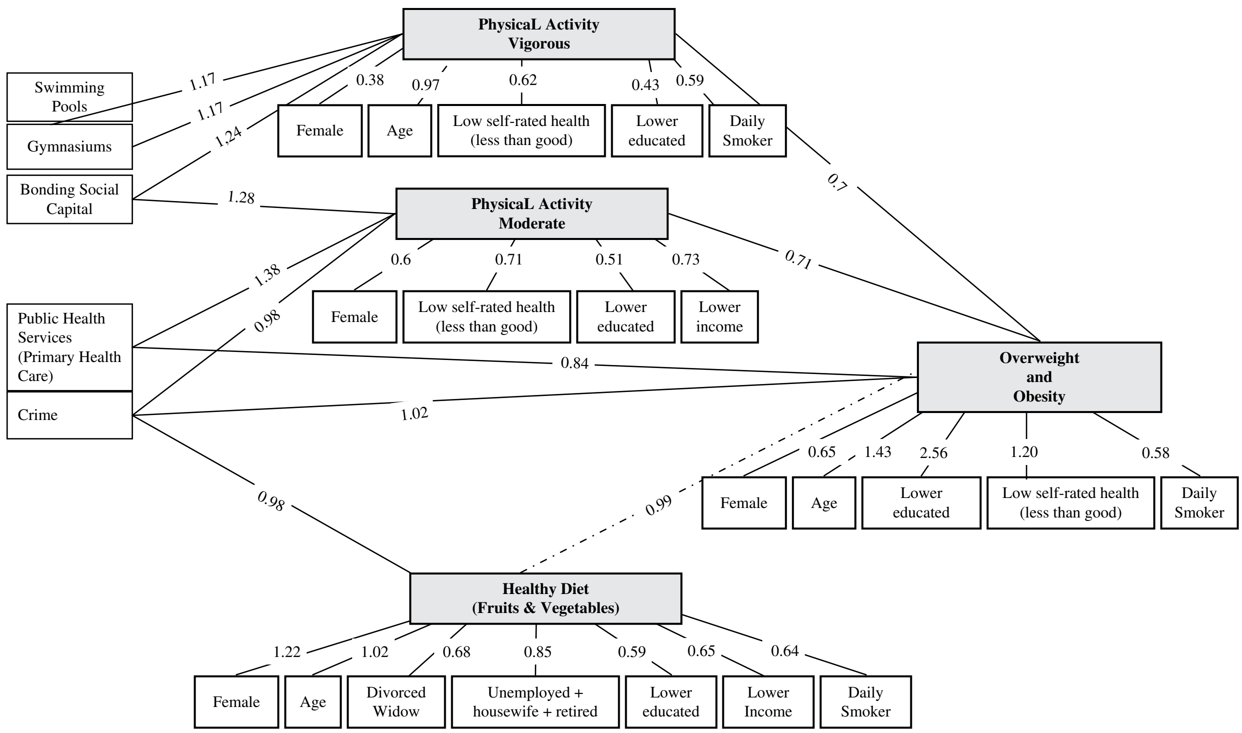

Fig. 1.

Our results from Lisbon are in concordance with previous empirical work elsewhere (Kim et al., 2006; Poortinga, 2006a) and generally with theoretical reviews on weight gain and its pathways – diet and physical activity – (Stafford et al., 2007). The literature suggests that levels of physical activity (walking for transportation and recreation, and vigorous exercise) increase in neighbourhoods with "traditional" or "walkable" designs and where there are pleasant safe parks and green spaces (Bauman et al., 1999; Ellaway, Macintyre, & Bonnefoy, 2005). Walkabillity, was associated with higher levels of moderate PA (Physical Activity) (Cerin et al., 2007), and reduction in body mass index (Frank et al., 2006; Leslie et al., 2007; Pendola & Gen, 2007).

In this study, the associations between population density, post offices and diverse local resources and moderate PA did not achieve statistical significance but nevertheless suggested that the provision of local amenities within walking distance may encourage residents to walk and thus represent key characteristics of a healthier environment. On the other hand, it has been postulated that urban sprawl may discourage walking. We used population density to represent urban sprawl (i.e. as an indicator of the proximity of essential relevant places where people can go on foot, as part of their daily routine or in leisure time) and a positive association between population density and walking was also found in the LMA (Lisbon Metropolitan Area).

LMA is a territory with an area of 3133 km^2, comprising high-density central neighbourhoods (34,474 inh/km^2 in the most compact ones) along with peripheral sprawling ones (9.32 inh/km^2), the latter being characterized by a rapid urbanization (in some on this areas, population increased by 40% between 1991 and 2001) (INE, 2001). In these sprawling areas, physical structures have changed dramatically over the last years; land use has become majority residential, thus, homogeneous; public transport is underdeveloped, due to the extent of the population sprawl. In short, "unwalkability" has become unavoidable (Santana and Nogueira, 2008).

The social capital and social support of the neighbourhood (bonding social capital; Poortinga, 2006b) is also related with walking. Our measure of bonding social capital was composed of local recreational/sports associations and local newspapers. In addition to the obvious role played by local recreational/sports associations in influencing health behaviours, local newspapers are also important in shaping those behaviours (i.e. diet and physical activity) through advertising (e.g. concerned health attitudes) (Macintyre et al., 2002) and marketing (e.g. local health services and local recreational/sports associations) (Swinburn et al., 1999). We found that strong social capital increases the levels of physical activity, an association that has previously been reported elsewhere (Poortinga, 2006b). Some LMA neighbourhoods are characterized by low levels of social interactions and weak social networks, in part resulting from the high residential mobility related with the above mentioned process of persistent urbanization. Moreover, homogeneous, residential land use damages the emergence of spaces able to promote social interactions, such as a green park or a simple post office. On the other hand, an unsafe environment, measured by crimes against property and traffic accidents involving victims, implies lower levels of "walkability" (moderate PA). Parkes and Kearns (2006) have reported a similar relation between walking and safety.

Another result suggested that individuals walked more if they live in more deprived neighbourhoods. This result is probably related to their propensity to be more affected by neighbourhood (if they spend more time there), to their more limited incomes, or to a combination of these two factors. Indeed, it has been argued that residents of deprived areas walk more, possibly due to a lack of transport options in those deprived neighbourhoods (Stafford et al., 2007; Van Lenthe & Mackenbach, 2002). Furthermore, our results point to an interaction between higher deprivation and higher population density, showing increased odds of moderate PA in dense and poor areas (despite the fact that residents of these areas are less likely to engage in vigorous physical activity). In addition to the influence of the context on healthy behaviours, we also observed a direct influence of context upon BMI.

Policy implications

The results of this study may contribute to the prioritization of interventions designed to reduce obesity amongst the population of the Lisbon Metropolitan Area, where a quarter of the Portuguese population live. Targets have been set by the National Health Plan (NHP) (ACS, 2008) to reduce the obesity in the population by the year 2010 (e.g. by 8% for men and 10% for women in the 55–64 age band).

In 2007, this problem has been identified in Portugal, and as an intersectorial solution is required (the problem cannot be solved by the health sector alone), a national anti-obesity platform has been created as a strategic measure. This measure has been politically taken up at national level and focuses upon intersectorial synergies. The Platform involves representatives from the Departments of Health, Education, Economics and Agriculture, the National Association of Portuguese Municipalities and various other civil associations. We believe that our study provides crucial information for understanding the pathways to obesity and the local factors associated with excess BMI. The challenge is to inform the policy makers of the best options to create supportive environments for making individual healthy choices/behaviours.

The results suggest that area vulnerability, characterized by urban sprawl, long distances to facilities, unsafe and unpleasant environments, poor housing conditions, and sociomaterial deprivation, could create communities with unhealthy behaviours; as they are "unwalkable", they discourage planned physical activity, leading to unhealthy diets and higher obesity rates. Environmental constraints which reduce "walkability" and increase unhealthy behaviours are powerful mechanisms linking environment to obesity.

This study shows that it is crucial to promote walkable and safe environments, which may be possible by improving local health policies through healthy urban planning. This will encourage the population to walk and use bicycles, not only as a leisure occupation but also as a means of transport, thereby promoting physical activity levels and social interactions and contributing to the creation of a sense of place and community, with positive consequences not only on BMI but also on general health status. This should be complemented by improved education campaigns in schools and primary health care centres, and via the mass media (i.e. free local newspapers, television advertising and news), which directly or indirectly influence society's beliefs and attitudes.

Results show that a deeper understanding of these mechanisms is critical if we are to find effective solutions for the obesity epidemic. Besides, it clearly shows that policies aimed at weight control and obesity reduction must address both people and places in order to bear fruit. When new residential areas are planned and built in growing urban areas (such as the LMA), consideration needs to be given to all of these issues in order to achieve truly health-promoting living conditions (i.e. housing quality; mixed land use; access to destinations – health services, shops, recreational facilities and parks; public transport system; safety from violence, traffic accidents and environmental hazards). For example, the existence of safe urban green spaces in the vicinity of residential neighbourhoods encourages physical exercise, walking and recreational activities, thereby helping also to raise the quality of life for all residents, irrespective of their socioeconomic situation. By identifying the most relevant issues for the use of green spaces, direct intervention can take place designed to increase their usage by people. One can expect in the future more attention to the way in which urban environment change impacts on physical activity, including walking, and their consequences on populations' health and well-being.

Limitations

Different institutions and organisations collect data in different ways. This has implications for the analysis of such data through issues of comparability, generation and interpretation and scale.

Information at the individual level, collated from the NHS, is of limited use for the design of the Survey: i) behaviours and even height and weight are self-reported, which can introduce some bias (although there is no strong evidence of systematic bias); ii) the question concerning fresh vegetables and fruit consumption is "did you consume fresh fruits or/and vegetables yesterday?" with no information about the size of the portion; iii) from the NHS, it was not possible to assess the respondents' perception of safety. In fact this strongly limits the study, making it impossible for us to achieve a broader and more accurate understanding of the influence of neighbourhood environment over walkability. As we have no "fear of crime" score, the neighbourbood safety level has been measured using the crime against property figures, since this is sociologically linked to fear perception.

Another weakness is related to time of environmental exposure. As Cummins, Curtis, Diez-Roux, and Macintyre (2007) argue, information is required concerning the time of exposure to different contexts in space and time, if the aim is to further our knowledge of environmental effects on health. Moreover, we are unable to measure residents' perceptions and reports, usually related with health and health-related behaviours (Van Lenthe et al., 2005; Wilson et al., 2004). Therefore, an effort must be made to generate and collect data concerning individual perceptions of neighbourhood, which can be achieved by integrating qualitative research into our quantitative approach.

Also the analysis here has used a simple binary measure of obesity and further work using continuous BMI scores would provide greater detail of the 'size of effect' on BMI variation due to environmental factors.

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References

ACS. (2008). *Plano Nacional de Saúde: Indicadores e Metas do PNS*. Ministério da Saúde – Alto Comissariado da Saúde. consulted January 3, 2008, http://www.acs.min-saude.pt/pns/.

Backett-Milburn, K., Wills, W., Gregory, S., & Lawton, J. (2006). Making sense of eating, weight and risk in the early teenage years: views and concerns of parents in poorer socio-economic circumstances. *Social Science & Medicine, 63*, 624–635.

Bauman, A., Smith, B., Stoker, L., Bellew, B., & Booth, M. (1999). Geographical influences upon physical activity participation: evidence of a 'coastal effect'. *Australian and New Zealand Journal of Public Health, 23*(3), 322–324.

Borders, T. F., Rohrer, J. E., & Cardarelli, K. M. (2006). Gender-specific disparities in obesity. *Journal of Community Health, 31*(1), 57–68.

Calthorpe, P., & Fulton, W. (2001). *The regional city. Planning for the end of sprawl.* Washington: Island Press.

Carstairs, V., & Morris, R. (1991). *Deprivation and health in Scotland*. Aberdeen: Aberdeen University Press.

Cerin, E., Leslie, E., du Toit, L., Owen, N., & Frank, L. D. (2007). Destinations that matter: associations with walking for transport. *Health & Place, 13*(3), 713–724.

Cohen, D., Finch, B., Bower, A., & Sastry, N. (2006). Collective efficacy and obesity: the potential influence of social factors on health. *Social Science & Medicine, 62*, 769–778.

Cummins, S., Macintyre, S., Davidson, S., & Ellaway, A. (2005). Measuring neighbourhood social and material context: generation and interpretation of

ecological data from routine and non-routine sources. *Health & Place, 11*(3), 249–260.
Cummins, S., Curtis, S., Diez-Roux, A. V., & Macintyre, S. (2007). Understanding and representing, 'place' in health research: a relational approach. *Social Science & Medicine Special Issue, 65*, 1825–1838.
Demarest, S., Roskam, A., Cox, B., Regidor, E., Van Oyen, H., Mackenbach, J., et al. (2007). Socio economic inequalities in leisure time physical activity. *Tackling health inequalities in Europe: An integrated approach*. EUROTHINE Final Report.
Doyle, S., Kelly-Schawartz, A., Scholossberg, M., & Stockard, J. (2006). Active community environments and health: the relationship of walkable and safe communities to individual health. *Journal of the American Planning Association, I*, 19–31.
Ellaway, A., Anderson, A., & Macintyre, S. (1997). Does area of residence affect body size and shape? *International Journal of Obesity, 21*, 304–308.
Ellaway, A., Macintyre, S., & Bonnefoy, X. (2005). Graffiti, greenery, and obesity in adults: secondary analysis of European cross sectional survey. *BMJ, 331*, 611–612.
Eurobaromater. (2004). European commission, the citizens of the European union and sport. *Eurobarometer Special Surveys*213, Consulted January 3, 2008, from.
Frank, L. D., Sallis, J. F., Conway, T. L., Chapman, J. E., Saelens, B. E., & Bachman, W. (2006). Many pathways from land use of health: associations between neighborhood walkability and active transportation, body mass index, and air quality. *Journal of the American Planning Association, I*, 75–87.
Goldstein, H. (1995). *Multilevel statistical models* (2nd ed.). New York: John Wiley.
Goldstein, H., & Rasbash, J. (1996). Improved approximations for multilevel models with binary responses. *Journal of Royal Statistical Society, Series A, 159*, 505–513.
INE. (2001). *Censos 2001: Recenseamento Nacional da População*. Lisboa: INE. www.ine.pt.
Jochelson, K. (2004). *The Public Health Impact of Cities & Urban Planning*. Report. London Development Agency: King's Fund.
Kim, D., Subramanian, S., Gortmaker, S., & Kawachi, I. (2006). US state-and county-level social capital in relation to obesity and physical inactivity: a multilevel, multivariable analysis. *Social Science & Medicine, 63*, 1045–1059.
Kjellstrom, T. (2007). *Our cities, our health, our future: Acting on social determinants for health equity in urban settings*. Kobe, Japan: WHO Centre for Health Development.
Leslie, E., Coffee, N., Frank, L., Owen, N., Bauman, A., & Hugo, G. (2007). Walkability of local communities: using geographical information systems to objectively assess relevant environmental attributes. *Health & Place, 13*, 111–122.
Long, J. S. (1997). *Regression models for categorical and limited dependent variables* (1st ed.). USA: SAGE Publications.
Macdonald, L., Cummins, S., & Macintyre, S. (2007). Neighbourhood fast food environment and area deprivation–substitution or concentration? *Appetite, 49*(1), 251–254.
Macintyre, S. (1997). The black report and beyond what are issues? *Social Science & Medicine, 44*(6), 723–745.
Macintyre, S., Ellaway, A., & Cummins, S. (2002). Place effects on health: how can we conceptualise, operationalise and measure them? *Social Science & Medicine, 55*, 125–139.
McNeill, L., Kreuter, M., & Subramanian, S. (2006). Social environment and physical activity: a review of concepts and evidence. *Social Science & Medicine, 63*, 1011–1022.
Nogueira, H., Santana, P., & Santos, R. (2006). Linking perceptions of health to neighbourhood environment in the Lisbon Metropolitan Area, Portugal. *The sustainable city IV – Urban regeneration and sustainability*. Witpress. pp. 723–731.
OECD. (2006). *Health data 2006*. Paris: OECD.
Parkes, A., & Kearns, A. (2006). The multi-dimensional neighbourhood and health: a cross-sectional analysis of the Scottish Housing Survey, 2001. *Health & Place, 12*(1), 1–18.
Pendola, R., & Gen, S. (2007). BMI, auto use, and the urban environment in San Francisco. *Health & Place, 13*(2), 551–556.
Poortinga, W. (2006a). Perceptions of the environment, physical activity, and obesity. *Social Science & Medicine, 63*, 2835–2846.
Poortinga, W. (2006b). Social relations or social capital? Individual and community health effects of bonding social capital. *Social Science & Medicine, 63*, 255–270.
Poston, W. S., & Foreyt, J. P. (1999). Obesity is an environmental issue. *Atherosclerosis, 146*(2), 201–209.
Rasbash, J., Steele, F., Browne, W., & Prosser, B. (2008). *A user's guide to MLwiN*. London: Center for Multilevel Modelling, Institute of Education, University of London.
Raudenbush, S. W., & Bryk, A. S. (2002). *Hierarchical linear models, applications and data analysis methods*. Londres: SAGE Publications.
Robert, S., & Reither, E. (2004). A multilevel analysis of race, community disadvantage, and body mass index among adults in the US. *Social Science & Medicine, 59*, 2421–2434.
Sampson, R. J., Raudenbush, S. W., & Earls, F. (1997). Neighbourhood and violent crime: a multilevel study of collective efficacy. *Science, 277*(5328), 918–924.
Santana, P. (2002). Poverty, social exclusion and health in Portugal. *Social Science & Medicine, 55*, 33–45.
Santana, P. & Nogueira, H. (2008). Environment and health: place, sense of place and weight gain in urban areas. In John Eyles & Williams (ed.), Place, sense of place and quality of life, pp. 153–165.
Santana, P., Nogueira, H. & Santos, R. (2007). Comunidades sustentáveis: impacte do contexto social e material no aumento de peso e obesidade. Revista Brasileira de Ciências Ambientais, Dezembro 11, 2007, pp. 23–29.
Schoeppe, S., & Braubach, M. (2007). Tackling obesity by creating healthy residential environments. *WHO Europe*. Copenhagen Ø: Denmark.
Spiegelhater, Best, Carlin, & van der Linde. (2002). Bayesian measures of model complexity and fit. *Journal of Royal Statistical Society, Series B, 64*, 583–639.
Stafford, M., Cummins, S., Ellaway, A., Sacker, A., Wiggins, R. D., & Macintyre, S. (2007). Pathways to obesity: identifying local, modifiable determinants of physical activity and diet. *Social Science & Medicine, 65*, 1882–1897.
Sundquist, K., & Yang, M. (2007). Linking social capital and self-rated health: a multi-level analysis of 11,175 men and women in Sweden. *Health and Place, 13*, 324–334.
Swinburn, M. D. B., Egger, P. D. G., & Raza, M. A. F. (1999). Dissecting obesogenic environments: the development and application of framework for identifying and prioritizing environmental interventions for obesity. *Preventive Medicine, 29*, 563–570.
Van Lenthe, F. J., Brug, J., & Mackenbach, J. P. (2005). Neighbourhood inequalities in physical inactivity: the role of neighbourhood attractiveness, proximity to local facilities and safety in the Netherlands. *Social Science & Medicine, 60*, 763–775.
Van Lenthe, F. J., & Mackenbach, J. P. (2002). Neighbourhood deprivation and overweight: the GLOBE study. *International Journal of Obesity, 26*, 234–240.
Vlahov, D., Galea, S., Gibbe, E., & Freudenberg, N. (2005). Perspectives on urban conditions and population health. *Cadernos de Saúde Pública, 21*(3), 949–957.
Wilson, K., Elliot, S., Law, M., Eyles, J., Jerret, M., & Keller-Olaman, S. (2004). Linking perceptions of neighbourhood to health in Hamilton, Canada. *Journal of Epidemiology & Community Health, 58*(3), 192–198.
Wilkinson, R. G. (2005). *The impact of inequality*. New York: New Press.