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Built environment configuration and change in body mass index: The Caerphilly Prospective Study (CaPS)

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ABSTRACT

There exist no long term longitudinal studies assessing BMI trends of older adults in relation to the built environment. We employed cohort data from the Caerphilly Prospective Study (CaPS) to analyze the long term independent associations between a broad set of built environmental factors and change in BMI measured at three time points over a 12-year period. Built environment morphological metrics (morphometrics) used include measures of land use accessibility and space syntax modelled street network accessibility. A multilevel modelling framework was adopted wherein measurement occasions were nested within individuals and individuals were nested within LSOA census areas. BMI was observed to be significantly ($p<0.05$) associated with a number of built environment factors including mix; density of retail, churches, recreational and leisure services; street network accessibility as well as slope variability. Controlling for socio-demographic and lifestyle factors and for vascular diseases had negligible impact upon the influence of built environmental factors highlighting the importance of urban design and planning in community public health interventions.

1. Introduction

The past three decades have witnessed a two-fold increase in the prevalence of obesity (Caballero, 2007) posing serious public health risks. In 2008, approximately 34% of adults (1.46 billion) worldwide were overweight with a Body Mass Index (BMI) ≥ 25 kg/m^2, of which 502 million were obese with BMI ≥ 30 kg/m^2 (Kimokoti and Millen, 2011). Current trends project 65 million more obese adults in the USA and 11 million more obese adults in the UK by 2030 (Wang et al., 2011). In the UK, 7.3% of all disability adjusted life years (DALYs) are directly attributable to overweight and obesity, accounting for 66,737 directly related deaths. The direct annual health costs of overweight and obesity to the NHS have been estimated to be around £3.23 billion, while, a separate study attributed £1.06 billion towards the costs of physical inactivity (Allender et al., 2007; Allender and Rayner, 2007). Although the impact of obesity on mortality is smaller in the oldest old (85+years), obesity remains an important predictor of mortality from all causes in older people, being a particularly strong predictor of vascular mortality (Stevens et al., 1998). The projected doubling (11% to 22%) of the older adult population (60+ years) by 2050 will, therefore, exacerbate the global obesity problem (WHO, 2007).

Obesity is associated with increased risk of vascular, metabolic, neoplastic and mental disorders (Flegal et al., 2007; Haskell et al., 2009; James, 1998; Kopelman, 2000; Ogden et al., 2007; USDHHS., 1996; Warburton et al., 2006; Wiles et al., 2007; Xavier Pi-Sunyer, 2002). Furthermore, the health risks posed by obesity are significantly attenuated by the compositional changes occurring in the body with the ageing process. There is a progressive increase in body fat mass which usually peaks at the age of 65 years in men and later in women. This is accompanied by a simultaneous loss of muscle mass and decline in muscle strength. This is often termed sarcopenic obesity, a condition that increases the risk of physical disability, morbidity and mortality (Roubenoff, 2004; Zamboni et al., 2008).

In addition to the inherent physiological, lifestyle, and socio-demographic factors, the built environment has been implicated in explaining the sharp rise in obesity as well as its socio-spatial distribution. The constituent components of the built environment, especially its design and the configuration of land use and street networks, governs the distribution of resources and services, configures the neighbourhood activity space, and thereby influences individual physical activity behaviours and weight outcomes. Enhanced accessibility to health promoting community resources improve local opportunities for physical activity, walking and social interactions (Bernard et al., 2007;

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Pearce et al., 2006) and hence, have been linked to reduced body weight. Recent research has highlighted the positive influences of mixed land use (Frank et al., 2004; Saelens et al., 2003), green spaces and recreational facilities (Björk et al., 2008; Diez Roux et al., 2007; Nielsen and Hansen, 2007; Norman et al., 2006; Wolch et al., 2011) transit stops (Bassett et al., 2008; Brown and Werner, 2008; Edwards, 2008), supermarkets (Black et al., 2010; Inagami et al., 2006; Morland et al., 2006), and sports facilities (Giles-Corti et al., 2003; Rutt and Coleman, 2005) upon individual weight outcomes. In contrast, street network segments associated with higher connectivity and higher global accessibility, are generally synonymous with higher traffic density and speed, increasing levels of pollution and reduced perception of safety; hence they are associated with higher odds of obesity under the hypothesis that these factors deter walking (Boer et al., 2007; Jerrett et al., 2010; Norman et al., 2006; Timperio et al., 2005). Several measures have been developed to quantify salient parameters of the built environment factors. Cervero and Kockelman (1997) introduced the 3D's: density, diversity and pedestrian oriented designs as measures of the built environment that have statistically significant influence upon walking and physical activity behaviour. Subsequently, two more D's – destination accessibility and distance to transit stops – were added to make it 5D's (Ewing and Cervero, 2001). Lee and Moudon (2006) were able to isolate a statistically significant subset of built environment correlates of walking which were grouped as destination, distance, density, and route i.e., 3D+R. To underscore the importance of these effects of the built environment, the term *neighbourhood walkability* has emerged in the recent years which may be conceptualized as the degree to which the attributes of the built environment may promote/inhibit walking and physical activity behaviour (Leslie et al., 2007).

The facilitative role of the built environment in influencing weight outcomes is particularly important in older adults. Although they may have more time for leisure activity, they are also likely to have reduced physical capability. Consequently, built environment factors that promote physical activity, especially design, configuration of land uses, presence of walkable destinations in the form of service utilities, aesthetics, and safety may have an enhanced influence on weight outcomes in the elderly. Several cross-sectional studies have highlighted the positive association between physical activity levels and accessibility to facilities, parks and green spaces, safety, aesthetics, mixed land uses, traffic volume and street connectivity for older adults (Berke et al., 2007; Frank et al., 2010; Gómez et al., 2010; Humpel et al., 2002; Li et al., 2005b; Nagel et al., 2008; Patterson and Chapman, 2004). Other studies have established a direct association between obesity and built environmental attributes like land use mix and density of fast food outlets (Li et al., 2008), aesthetics and pedestrian friendly design (Boehmer et al., 2007), neighbourhood psychosocial hazards (Glass et al., 2006). Even though these studies provide evidence of association, their cross-sectional designs mean that the cumulative effect of the built environment upon weight outcomes may be underestimated and the possibility of reverse causation cannot be discounted. Longitudinal data are required to provide more convincing evidence. One short term longitudinal study has been reported. Li et al. (2009) followed 1145 men and women aged 50–75 years for one year finding that both weight and waist circumference increase according to frequency of visiting fast-food restaurants.

The hypothesis driving the present study is that the various attributes of built environment patterns individual physical activity behaviour thereby affecting adiposity in older adults. This hypothesis was tested using data from the Caerphilly Prospective study (CaPS) which has repeated obesity measurements (Body Mass Index) over a 12 year period which were related to a broad range of built environmental factors.

2. Methods

2.1. Sample population

The Caerphilly Prospective Study (CaPS) was initiated in 1979–1983 with an objective to study the aetiology of heart disease in adult men (Elwood, 1984; SSC&M, University of Bristol, 2007). This population based male cohort has subsequently been an epidemiological laboratory for studying the various parameters of health in older adults with the progression of age. Briefly, the initial wave of the study comprised a cohort of 2512 men aged 45–59 years. Their health was followed up in four subsequent waves: phase II, 1984–1988; phase III, 1989–1993; phase IV, 1993–1997; and phase V, 2002–2004. The present analysis comprised living members of CaPS who had participated in the 3rd, 4th and 5th examinations and resided within the study area. The geographical extent of the study covered the Assembly Constituency of Caerphilly, South Wales, spreading across 114.54 square kilometres. The third examination was employed as a baseline, while the latest follow-up comprised 1225 surviving men aged 65–84 years. Longitudinal BMI data over the period of study were available for 912 individual respondents. However, 70 lived outside the study area, 96 had observations missing on individual level morbidities, and a further 64 individuals had observations missing across life style and socio-demographic variables. Eventually, the study cohort was limited to 684 valid responses distributed over the three time points, across 35 census-defined lower super output areas (LSOAs). The maximum follow-up period was 13.9 years with an average of 11.7 ± 1.0 (standard deviation) years. The respondents had given their written consent at the time of recruitment; the research protocol for phase III being approved by Cardiff Local Research Ethics Committee, and the protocols for phases IV and V being approved by the Gwent Research Ethics Committee.

2.2. Individual level variables

Each phase of the study involved an extensive clinical examination including anthropometry, assessment of blood pressure, electrocardiogram as well as collection of fasting blood samples. Obesity was assessed in terms of Body Mass Index (BMI), calculated as body weight in kilograms divided by height in metre squared. Height was measured in bare feet using a Holtain stadiometer and weight in light clothes was measured using standard scales. Lifestyle, socio-demographic and vascular risk factors were identified from the literature. Occasion-specific life style risk factors included age, alcohol consumption and smoking status. Alcohol consumption was expressed as a continuous variable and measured in ml/week over each time point. Smoking status at each time point was modelled as a three level factor (non-smoker, ex-smoker, and current smoker). Socio-demographic factors comprised marital status, education and social class. Marital status was modelled as a three level factor (married, single, or divorced/separated/widowed), whilst education was also modelled as a three level factor (none/apprenticeship, school certificate/higher technical certificate, professional qualification/degree/higher degree). Social class was assessed using the Registrar General's occupational classification (OPCS., 1980) and, was modelled as a two level factor (manual, non-manual). This was preferred to the more recent National Statistics socio-economic classification given the pre-2001 baseline of the present study as well as the predominantly elderly composition of the respondents beyond retirement age. The study further controlled for the impact of six vascular risk factors, as assessed in the most recent examination (myocardial infarction, angina, high blood pressure, high cholesterol, diabetes and mini stroke).