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Optimising measurement of health-related characteristics of the built environment: Comparing data collected by foot-based street audits, virtual street audits and routine secondary data sources

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ABSTRACT

The role of the neighbourhood environment in influencing health behaviours continues to be an important topic in public health research and policy. Foot-based street audits, virtual street audits and secondary data sources are widespread data collection methods used to objectively measure the built environment in environment-health association studies. We compared these three methods using data collected in a nationally representative epidemiological study in 17 British towns to inform future development of research tools. There was good agreement between foot-based and virtual audit tools. Foot based audits were superior for fine detail features. Secondary data sources measured very different aspects of the local environment that could be used to derive a range of environmental measures if validated properly. Future built environment research should design studies *a priori* using multiple approaches and varied data sources in order to best capture features that operate on different health behaviours at varying spatial scales.

1. Introduction

The role of the neighbourhood built environment in influencing diet, physical activity and health outcomes across the life course has received considerable attention in public health research and policy (Bader et al., 2010; Calogiuri and Chroni, 2014; Caspi et al., 2012; Charreire et al., 2010, 2014; Christian et al., 2015; de Vet et al., 2011; Ding and Gebel, 2012; Ding et al., 2011; Dunton et al., 2009; Goodwin et al., 2013; King, 2015; Saelens and Handy, 2008; World Health Organization, 2010). The built environment has been defined as the physical environment constructed by human activity (Saelens and Handy, 2008), and built environment-health research ideally aims to capture and understand the impact of both contextual (i.e. nature of the area such as access to services) and compositional factors (i.e. nature of residents reflecting the collective social functioning of an area) on people's health behaviours (Cummins et al., 2007; Macintyre, 2007; Macintyre et al., 2002).

Potentially relevant built environment factors have been studied using objective measures involving the use of primary and secondary spatial data (Thornton et al., 2011) and there is an extensive body of research using a range of different data collecting approaches (Brownson et al., 2009; Charreire et al., 2010; Krenn et al., 2011; Schaefer-McDaniel et al., 2010). Much research in this area was initially driven by the availability of secondary data (Macintyre et al., 2002). Such routine data combined with Geographical Information Systems (GIS) can be used to construct environmental measures, including density and spatial availability, walkability indices and undertake spatial analysis and modelling to examine the impact of the neighbourhood environment on people's health behaviours and outcomes (Burgoine et al., 2013; Caspi et al., 2012; Leslie et al., 2007). However, routinely available spatial data have well-recognised limitations, including problems with the use of administrative boundaries to define neighbourhoods and the limited types of environmental exposures that can be investigated (Cummins et al., 2005; Lucan, 2015). Secondary data sources may also give rise to issues of specificity (i.e. the proportion of shops that are correctly identified as being specific

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types for an analysis e.g. retail food outlets (Fleischhacker et al., 2013)) and misclassification of environmental exposures. When possible, neighbourhood audits should be conducted to confirm the validity of routine data sources (Cummins and Macintyre, 2009; Fleischhacker et al., 2013; Lucan et al., 2013; Pliakas et al., 2014).

Systematic neighbourhood audits using foot-based or virtual street audit tools, such as Google Street View (GSV) and Bing Maps (or Microsoft Virtual Earth), have been used to collect primary data on factors theoretically relevant but not available in existing routine data (Brownson et al., 2009; Shareck et al., 2012; Wu et al., 2014). The majority of tools available, especially using GSV, have been developed for specific North American towns (Charreire et al., 2014) or for the UK (Griew et al., 2013; Wu et al., 2014). Neighbourhood audits involve direct on-foot or virtual observations by trained observers who use checklists to observe and rate physical and social attributes of neighbourhoods. The geographic unit of recorded observation in audits is the face block (e.g. the block segment on one side of a street (Clarke et al., 2010; Sampson and Raudenbush, 1999)) or street segment (Charreire et al., 2014). Street segment measures are typically developed in GIS by dividing the street network within the study area into road sections termed 'links' (Bethlehem et al., 2014; Griew et al., 2013) or by generating intersection to intersection segments (Badland et al., 2010). Some current audit instruments can be found at http://activelivingresearch.org/. Designing systematic audit tools that have measurement validity, reliability and specificity relevant to both health outcomes of interest and the context of a study have been identified as an important area of methodological research (Shareck et al., 2012; Zenk et al., 2007).

Using GSV to conduct virtual street audits is easy, cheap and safe as well as being transparent as it is available to the general public, public health and planning researchers and practitioners (Charreire et al., 2014). Systematic, foot-based, street audits are relatively expensive and time consuming (Badland et al., 2010; Ben-Joseph et al., 2013; Wu et al., 2014). The growing use of GSV audits to capture exposures relevant to physical activity and food environments have prompted some studies to conduct comparisons with foot-based audits (Charreire et al., 2014; King, 2015). However, the majority of these comparisons have focused on a limited number of environmental dimensions (Charreire et al., 2014).

Detailed data collected by direct observation can produce valuable information for those who can act on the findings, such as urban and transport planners and policy makers (Brownson et al., 2009). Most foot-based audit studies have focused on single risk factors, e.g. physical activity (Lee et al., 2005; Pikora et al., 2002) or diet (Glanz et al., 2007; Saelens et al., 2007) or occasionally a combination of the two (Bethlehem et al., 2014), despite the complex, multifactorial aetiology of cardiovascular and other chronic diseases. To date there are no tools simultaneously capturing dimensions of the built environment that may be relevant for influencing multiple health behaviours (e.g. diet, physical activity and alcohol intake) that together contribute to improving complex population health outcomes such as obesity.

This paper aims to explore objective measurement approaches for health related aspects of the built environment by comparing built environment data captured by secondary data sources, foot-based and GSV audits. To our knowledge, no other study has simultaneously compared primary data from foot-based audits with remote-sensing virtual street audits and secondary data sources. This methodological comparison aims to enable researchers to make better informed decisions in the design and analysis of large scale epidemiological studies of the effect of the built environment on health outcomes.

2. Methods

2.1. Audit tools

We developed a new instrument, the 'Older People's Environments and CVD Risk' (OPECR) tool, initially as a foot-based audit tool to capture detailed features of the local environment particularly relevant to older people's health behaviours. OPECR was designed as a data collection pro-forma document (i.e. paper form) to collect geographical data relevant to older people's behaviours by direct observation of local neighbourhoods. The tool consists of 100 indicators, including density measures (i.e. density of food shops and alcohol outlets), price and availability of selected food, alcohol and tobacco products, measures of "walkability" of the environment for older people (e.g. connectivity of streets, road speed, traffic volume, quality of pavements and pedestrian crossings), transport accessibility and connectivity (e.g. bus stops and routes) and land use mix. The audit tool is available as supplementary material (Appendix S1). The comparisons presented here are nested within a wider study of the association between aspects of the neighbourhood environment and physical activity, dietary behaviours and cardiovascular disease risk in older adults in 20 UK towns (Hawkesworth et al., 2015).

The OPECR tool was modified to assess neighbourhood environments remotely using GSV to allow for the comparison of the two techniques. Only minimal adaptations of the street-audit tool were required as it was still possible to assess the majority of environmental features virtually. Information on prices in shops, traffic volume and litter were removed, whilst variables to capture the quality and date of the GSV image were added.

2.2. Primary data collection

Fieldworkers were recruited to conduct foot-based audits in 20 towns across the UK (17 in England and 3 in Scotland) that were included in two national cohort studies, the British Regional Heart Study (BRHS) (Walker et al., 2004) and the British Women's' Heart and Health Study (BWHHS) (Lawlor et al., 2003). Fieldworkers were fully trained in the use of the OPECR tool and supervisors conducted frequent field visits in each town to ensure data collection quality. A street segment was the unit of data collection and was defined as the length of a road that does not change in name or distinctly in character. The start and end point of the segment were recorded and these were used as reference points for the GSV audit. The lower layer super output area (LSOA) was used to draw maps of the audited areas using Google Maps.

We piloted the audit tool in two towns, Bristol and Guildford, in September-October 2009. Fieldworkers were asked to conduct concurrent independent repeat audits of specific segments in order to assess inter-rater reliability. Data collection for the foot-based audits for the remaining towns took place between October 2011 and September 2014. Fieldworkers worked in pairs and recorded all relevant aspects of the OPECR tool for both sides of the segment. All street segments were audited in all LSOAs in study towns where study subjects lived. Foot-based audit data were entered into an Access database before being exported into Stata 14.1 (StataCorp LP, 2015).

The GSV audit was conducted in a subset of two study towns (Ipswich and Newcastle-under-Lyme) chosen from the original 20 because they were towns of similar population size located in different English geographical regions with different deprivation rankings (Index of Multiple Deprivation 2010) to increase the variability of the environmental data. In 2012, Ipswich, located in east England, had a population of 134,500 and was ranked 87 out of 326 English local authorities in terms of area deprivation, while Newcastle-under-Lyme, located in north west England, had a population of 124,000 and was ranked 152 in terms of area deprivation (Department for Communities and Local Government, 2013). Foot-based audits in Ipswich were conducted between October 2011 and December 2011 and in Newcastle-under-Lyme between November 2013 and December 2013. GSV audits in Newcastle-under-Lyme were conducted between May 2014 and August 2014 and in Ipswich between December 2013 and May 2014. In Ipswich, the majority of GSV imagery was uploaded