The Impact of the Built Environment on Health across the Life Course: Design of a Cross-sectional Data Linkage Study

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The Impact of the Built Environment on Health across the Life Course: Design of a Cross-sectional Data Linkage Study

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ABSTRACT

Introduction

The built environment is increasingly recognised as being associated with health outcomes. Relationships between the built environment and health differ among age groups, especially between children and adults, but also between younger, mid-age and older adults. Yet few address differences across life stage groups within a single population study. Moreover, existing research mostly focuses on physical activity behaviours, with few studying *objective* clinical and mental health outcomes. The Life Course Built Environment and Health (LCBEH) project explores the impact of the built environment on self-reported and objectively-measured health outcomes in a random sample of people across the life course.

Methods and analysis

This cross-sectional data linkage study involves 15,954 children (0-15 years), young adults (16-24 years), adults (25-64 years), and older adults (65+ years) from the Perth metropolitan region who completed the Health and Wellbeing Surveillance System survey administered by the Department of Health of Western Australia from 2003 to 2009. Survey data were linked to WA Hospital Morbidity Database System (hospital admission) and Mental Health Information System (mental health system outpatient) data. Participants' residential address was geocoded and features of their 'neighbourhood' measured using Geographic Information Systems software. Associations between the built environment and self-reported and clinical health outcomes will be explored across varying geographic scales and life stages.

Ethics and dissemination

The University of Western Australia's Human Research Ethics Committee and the Department of Health of Western Australia approved the study protocol (#2010/1). Findings will be published in peer-reviewed journals and presented at local, national and international conferences, thus contributing to the evidence base informing the design of healthy neighbourhoods for all residents.

ARTICLE SUMMARY

Article focus

- Describes the design and methods for a cross-sectional data linkage study that explores the impact of the built environment (i.e., neighbourhood design) on self-reported and clinical health outcomes of children, young adults, adults and older adults.

Key messages

- Exploring the impact of the built environment on health outcomes across life stage groups within a single population is yet to be explored.
- Comparisons across various life stages are required to build an evidence base for designing healthy neighbourhoods that cater for children through to older adults.
- This study will explore variations in relationships between the built environment, health behaviours, and objectively-measured health outcomes *within* and *across* different life stages for a large study population.

Strengths and limitations

- Data linkage of built environment measures to both self-reported health behaviours and objectively-measured health outcomes builds a stronger case for changing neighbourhood design conducive to healthy living.
- Using the same data to examine associations within and across different life stages is valuable, allowing for consistency in comparisons across life stages.
- Data linkage of available existing data is cost-effective as it includes a variety of data sources for a large sample size representative of the population.
- Using existing data is limited in that the researcher is restricted to pre-constructed measures that may not be specific for the outcome/s of interest.

INTRODUCTION

In the last decade, there has been growing interest in the impact of the built environment on health. Indeed, there is growing evidence that the built environment directly or indirectly encourages active lifestyles, influencing people's physical, mental, and social health and wellbeing [1-3].

The majority of studies exploring built environment and health associations examine physical activity outcomes (e.g., walking, cycling, and recreational physical activity). From a physical activity perspective, the built environment is often conceptualised in terms of its 'walkability', a composite index combining a number of neighbourhood design attributes representing the degree of pedestrian-friendliness [4]. Evidence to date suggests that adults living in more walkable neighbourhoods (i.e., higher residential density with mixed land use and connected street networks) have higher levels of transport-related walking, overall physical activity, and a lower body mass index than those in less walkable neighbourhoods [5, 6]. Other built environment features also appear to be important for health, such as the distribution, accessibility, aesthetics and quality of destinations, including public open space [7-9], the presence of greenery [10, 11], and perceived safety [12, 13].

While the relationship between the built environment and physical activity is gaining momentum, the potential impact of the built environment across a range of other health outcomes is yet to be fully explored. For example, it is widely acknowledged that physical activity is a major modifiable risk factor in the reduction of morbidity and mortality from major chronic diseases such as cardiovascular disease [14], type II diabetes [15, 16], osteoporosis [17], some forms of cancers [18, 19], and is important for mental and social wellbeing [20, 21]. Studies that have explored other physical and mental health outcomes generally use self-reported general indicators from health surveillance systems [22-24]. Examination of objectively-measured health outcomes is greatly improved by linkage of questionnaire responses and environmental attributes to medical records which is rarely available. A Canadian study utilised hospital and physician data to conduct a geographical analysis of Type II diabetes and found a positive association between Type II diabetes prevalence and areas with vacant and placard houses and crime [24]. Conversely, living in walkable areas with green spaces in a densely populated city was found to be positively associated with longevity of older adults living in urban areas [25]. Thus it is important that future research on the effect of the built environment on health outcomes also includes objectively-measured health outcomes [26] to build a stronger case for designing healthy neighbourhoods.

Although research supporting the relationship between the built environment and health behaviours is accumulating, there are gaps in the evidence. For example, children, adolescents, adults, and older adults are likely to react differently to changes in neighbourhood design and interventions aimed at creating more health supportive environments [27]. Indeed, previous research suggests that there are differences in built environment associations observed at different life stages [28, 29]. For example, more walkable neighbourhoods support walking in adults, however walkable neighbourhoods often have more traffic due to better street connectivity, and exposure to traffic is negatively associated with walking and cycling in children and older adults [30-32]. However, variability in the health behaviour of different life stage groups under the influence of built environment factors is rarely addressed within the scope of a single study. Commonly, studies focus on a particular age group (often adults and increasingly children and older adults), or account for variability by adjusting for age and other socio-demographic factors that are likely to cause differences in the outcomes [28]. This may miss findings relevant to specific life stages. Hence, efforts to change the built environment to enhance health supporting behaviours and influence health outcomes may produce inconsistent results for some population groups, unless variations in responses to the built environment are considered. Thus, studies exploring the effect of the built environment on health across the life course are required.

Methodological issues also require greater exploration across the life course in studying the impact of the built environment, the size and definition of the built environment's area of influence (i.e., the 'neighbourhood') may differ for different population sub-groups [33]. Moreover, the distance over which the built environment is measured may vary for different health behaviours and outcomes. Typically, distances of 400m-1600m around individuals' homes are used to represent the local 'neighbourhood' [33]. However, the importance of geographic scale is relatively understudied. There appears to be no published studies [34] exploring the impact of geographic scale by age group or life stage, although it is recognised that the impact of neighbourhood size is likely to vary for children [35] as well as for older adults [36] compared with adults.

Investigation of the association between the built environment and health behaviour and health outcomes across the life course would address inconsistencies in the evidence base to date. Comparing the impact of different built environment measures across various life stages is required to help develop a consistent evidence-base designed to inform policy and practice about how neighbourhood design can be optimized to meet the health needs of *all* its residents. The Life Course Built Environment and Health (LCBEH) project attempts to address some of these gaps by linking objective built environment measures with self-reported and objectively-measured health data of representative samples at different life stages. This paper describes the design and methods for the LCBEH project.

METHODS

Study rationale, context and design

The LCBEH study was conceptualised using the theoretical framework outlined in Figure 1. Specifically, the goal was to assemble data that would permit the examination of associations between the built environment and: 1) behavioural and protective behaviours (e.g., physical activity, nutrition, sedentary behaviour); 2) self-reported health status (e.g., weight status, physical health, injuries, chronic conditions, mental health); and 3) objectively-measured health outcomes (e.g., cardiovascular events, respiratory problems, anxiety, depression, mental health) for children, young adults, adults, and older adults (Figure 1).

The opportunity to assemble such a dataset was provided by the ongoing Health and Wellbeing Surveillance System (HWSS) cross-sectional survey (herein referred to as 'survey') administered by the Department of Health of Western Australia which continuously surveyed Western Australians in four age groups (children 0 to 15 years, young adults 16-24 years, adults 25-64 years, and older adults 65+ years) and in which respondents were asked to provide permission to link their survey data to other databases. Parents provided answers for children aged 0-15 years. Western Australia's(WA) comprehensive data linkage system (i.e., the WA Data Linkage System) systematically links available administrative health data within WA by matching patient names and other identifiers [37]. Data systems routinely included in the linked system include the Hospital Morbidity Database System (HMDS), and the Mental Health Information System (MHIS). With appropriate approvals and under specified conditions, external survey cohorts may also be linked to the system in order to access linked health data and provision has been made to link environmental data through geocoded residential addresses of survey participants.

Insert Figure 1 here

The LCBEH project is a cross-sectional linked data study involving people in four life stages from the Perth metropolitan region who completed the survey and who provided consent to link their data to other data sources. The survey was administered to a stratified random sample of the population from 2003 to 2009 and conducted by the Department of Health of Western Australia. Linked data from the Hospital Morbidity Database System and Mental Health Information System were obtained for this project. To enable linking of built environment and health data the study was limited to the Perth metropolitan region. Perth is the capital city of Western Australia with an urban population of approximately 1.7 million, which is 75% of the state [38]. It is one of the smaller, yet fastest growing

Australian capital cities. Perth is isolated, sprawls some 170km along the coast, and has a relatively high standard of living with a Mediterranean climate. The sources of data used in this project are described in Figure 2.

Between 2003 and 2009, a total of 21,347 (3,668 children; 2,175 young adults; 10,821 adults, and 4,683 older adults) respondents from metropolitan Perth took part in the survey. Of those participants, 2,964 children (80.8%), 1,584 young adults (73.2%), 7,795 adults (72.0%), and 3,611 older adults (77.1%) granted permission for data linkage and had a geocoded home address (total 15,954; 74.7%).

Data sources

Insert Figure 2 here

Health and Wellbeing Surveillance System (HWSS) survey

The HWSS survey is a continuous data collection system administered by the Department of Health of Western Australia. It collects self-reported health, wellbeing and lifestyle information from WA residents of all ages via computer-assisted telephone interviews (Table 1) (n=1,959,088; 2006 Census) [39]. Every month, at least 550 people throughout WA are interviewed after being randomly selected from the latest version of the phone directory [39]. The response rate (completed interviews / eligible contacts) ranged from 77-88% over the study period, with a participation rate (completed interviews / completed interviews + refusals) between 82-92%. The consistently high response and participation rates promote confidence that estimates from the HWSS are reliable and representative of the population.

Table 1. Summary of survey variables from the Health and Wellbeing Surveillance System

Category	Types of information available
Socio-demographic	Age, gender, country of birth, education level, marital status, employment status, household income, family structure, living arrangements, housing tenure, concessions (health care card, government pension)
General health status	Physical and mental functioning
Chronic conditions	Arthritis, heart disease, stroke, cancer, osteoporosis, diabetes, asthma, respiratory problems
Injuries	Falls
Mental health	Anxiety, depression, stress-related problem, psychological distress, lack of control over personal life and health, trouble with emotions, need help and/treatment for an emotional problem
Psychosocial events	Moved house, robbed, death of someone close, marriage breakdown, serious injury, serious illness, loss of driver's license, financial hardship
Risk factors	Body Mass Index, sedentary activity (screen time), alcohol intake, smoking status, high cholesterol, high blood pressure
Physical activity behaviours	Walking, Vigorous activity, Moderate activity
Protective factors	Nutrition, social capital (group membership)
Child development	Birth weight, months spent breast feeding, age when liquids, water, and solids were introduced, parent thinks child was late in starting to talk, parent thinks child needed professional help with speech.
Child information	Days absent from school, looks forward to school, progress at school, bullied by other children, bullies other children, has a special friend, has a group of friends,
Family functioning	Family gets along well, planning activities as a family is difficult, avoid

	discussing topics, making decisions is usually a problem in the family

Hospital Morbidity Data System (HMDS) and Mental Health Information System (MHIS) data

The HMDS and MHIS data provides a comprehensive set of objectively-measured clinical health data. The HMDS (herein referred to as 'hospital' data) contains inpatient discharge summary data from all public and private hospitals in WA [40]. The MHIS (herein referred to as 'mental health system' data) contains outpatient and emergency health contact information. For each consenting survey participant we obtained dates and principal diagnosis codes for all linked hospital and mental health system records in a three-year period centred on the calendar year in which they participated in the survey. The primary variables for the LCBEH project are the counts of hospital admissions (in the three-year period) with a primary diagnosis representing 13 clinical health conditions. Similarly, the mental health system records in the three-year period were used to define mental health conditions. Table 2 summarises each clinical health condition and classification according to the International Classification of Diseases ICD-10 [41]. A total of 11,308 (53.0%) participants had a linked hospital record and 695 (3.2%) had a linked mental health system record within the three-year window.

Table 2. Summary of clinical health outcomes for patients with primary diagnosis

Source	Outcome	ICD 10
HMDS	Arthritis	M000-25
HMDS	Coronary heart disease	120-25
HMDS	Cerebrovascular disease	160-68
HMDS	Cancer	D000-48; Z00-02
HMDS	Osteoporosis	M80-82
HMDS	High cholesterol	E78
HMDS	High blood pressure	I10-13; I15
HMDS	Diabetes	E10-14
HMDS	Asthma	J45-46
HMDS	Other respiratory diseases*	J, excluding J45-46
HMDS & MHIS	Anxiety or stress	F40-99
HMDS & MHIS	Self-harm	X60-84
HMDS & MHIS	Depression	F30-39

HMDS: Hospital Morbidity Data System (inpatient information); MHIS: Mental Health Information System (outpatient and emergency information); ICD: International Classification of Diseases [41].
*Other respiratory diseases: relates to respiratory diseases other than asthma.

Built Environment and Destinations Data

For survey participants who gave permission for linkage to other datasets (n=15,954), built environment and (accessible) destinations data were calculated. The list of geocoded home addresses was provided by the WA Department to Health Epidemiology Branch to the Centre for Built Environment and Health (CBEH) at The University of Western Australia (UWA) and specific built environment and destinations variables calculated for each geocoded address. To protect the identity of study participants, the built environment and destinations variables were returned to the WA Department to Health Epidemiology Branch which linked these data to survey, hospital, and mental health system data and returned a (de-identified) file to CBEH.

The Centre for the Built Environment and Health (CBEH) at The University of Western Australia (UWA) has a comprehensive Geographic Information Systems (GIS) built environment and destinations data platform, an objectively-measured source of built environment features for each participant. Built environment and destinations measures that are likely to influence health behaviour and health outcomes were chosen based on the literature. To examine the association between built environment features and health outcomes of interest, it was necessary to first define a spatial unit that best represents the participant's local environment or 'neighbourhood' [42]. Service areas (i.e., the area that is accessible via the road network up to a specified distance from a participant's home) are typically used to represent an individual's 'neighbourhood' environment [42]. For this project, environment variables at geographic scales ranging from 200m to 1600m distances were calculated. A 1600m service area is typically used in studies with adults, as this represents how far they could walk from home at moderate to vigorous intensity within 15 minutes, which is half of the recommended level of daily physical activity for adults [43]. However, as mentioned earlier, the impact of neighbourhood size is likely to vary depending on the age of the participant e.g., 'neighbourhood' size may be smaller for children and older adults, compared with an able-bodied adolescent or adult [33]. Indeed, previous research suggests that a walkable distance for children could range between 250 to 1600 metres [31, 44, 45].

A series of scripts were developed by the Centre's GIS team to compute the GIS environment measures using PYTHON v2.6 [46], a scripting software compatible with ArcGIS v10. Moreover, distance to destinations within 10km of each participant's home was computed. Count of, and closest road network and Euclidean (as 'crow flies') distance to destinations within 10km of each participant's home were computed using a script based on the Origin-Destination (OD) Cost Matrix tool in ArcGIS v10. Destination types were obtained from a variety of sources. Table 3 describes the environment variables that were computed at 200m, 400m, 800m, and 1600m service areas around participants' homes. Table 4 describes the type of destination, source of destination information, and years for which destinations information were obtained. Intensive processing was required to derive each environment measure at 200m, 400m, 800m, and 1600m service areas, and distance to each destination within 10km around participants' home addresses.

Table 3. Built environment measures computed for Life Course Built Environment and Health participants

Environment measure	Description	Core input data# and sources used	Processing required	Main output/s computed
Land use mix (Transport and Recreation)	Measures the diversity (or mix) and distribution of the area of destinations/land use classes of interest (e.g., recreation vs. transport land uses) against each other within a participant's service area. The creation of two land use mix measures reflect previous work by Christian and colleagues (2011), which assessed land uses representative of transport and recreational walking.	Service areas, Cadastre, Land tenure information, Reserve Vesting Reports, (VGO points to identify residential features).	Land use classifications were developed from land tenure information (taxation/rating records) and reserve vesting reports. Nine categories of land use classifications were used to calculate two land use mix measures: 1) transport; and 2) recreation. Land use was assigned to cadastral parcels on a mutually exclusive basis (with overlaps eliminated) based on a hierarchy of preference [47].	Area (square metres) for all nine land use types within a participant's service area. Land-use mix was calculated according to an entropy formula [47], which is a variation of that originally used by Frank et al., 2005.
Street connectivity	Measures the inter-connectedness of the road (i.e., street) network within a participant's service area.	Road network nodes representing three-way or more intersections, service areas.	Streets with ≥3 intersections were identified using road network data.	Count of three (or more) intersections divided by the area (square metres) of the participant's service area.
Road exposure	Proxy measure for the level of traffic volume on roads within a participant's service area.	Road network, Service areas, Functional Road Hierarchy (FRH)* information.	'Road function' detailing exposure to number of vehicles/day was used as a proxy for traffic volume.	Total length (metres) of each road type within the service area.
Residential density	Measures the density of residential dwellings on residential land within a participant's service area.	Service areas, Cadastre, Land use (VGO points used to identify residential features).	Area of residential land within a service area was estimated by geographically selecting cadastral parcels that intersect VGO points classified as residential features.	Number of residential dwellings divided by the area of residential land (square metres) within the participant's service area.
Gross density	Measures the density of residential dwellings on participant's total service area.	Service areas, Land use (VGO points used to identify residential features).	Number of residential dwellings was obtained from VGO points classified as residential features.	Number of residential dwellings divided by the total area of the participant's service area (hectares). Not calculated for 1600m service area.
Lot density	Measures type of dwelling on the participant's residential lot.	Participant's geocoded home address, Cadastre, Land Use (VGO points)	'Lot type' was computed using the spatial join tool in ArcGIS v10. Participant's homes that intersected cadastral parcels with	Lot type classification (e.g., house, duplex), Zoning information such as zonal code and classification, Residential

			VGO 'dwelling' information (e.g., house, duplex, apartment) were identified.	dwelling (yes, no). 'Lot density' for each participant was determined by a count of 'lot types'.
Greenness	Measures the presence of greenness in a neighbourhood	Service areas, Normalised Difference Vegetation Index (NDVI) raster layer (25m x 25m cells)[2]	Greenness was calculated using the Extract NDVI tool. Water features were removed before the NDVI values were calculated [11].	Minimum, maximum, mean, range, standard deviation, and sum for NDVI values within each participant's service area.
Slope (terrain)	Measures the on-ground terrain or topography.	Service areas, Digital Elevation Model (DEM) for slope (90m x 90m cells)[3]	Percentage slope was calculated from a 90m x 90m DEM using a spatial analyst tool, Slope.	Minimum, maximum, mean, range, standard deviation, and sum for each service area from the slope raster that intersected the road network.
Walkability index 1 & 2 (not calculated in GIS)	Measures the 'pedestrian-friendliness' of a neighbourhood i.e., how supportive a neighbourhood is of active living through encouraging walking for transport (for utilitarian reasons such as accessing destinations) or recreation (walking for fitness or enjoyment).	Index is comprised of standard z-scores for street connectivity, land-use mix, and residential density.	Two walkability indices were created for each participant: 1) Transport walkability index; and 2) Recreational walkability index, based on transport and recreation land use mix measures [47].	Walkability score (integers) Walkability quartiles

All environment measures were processed at 200m, 400m, 800m, and 1600m service areas around each consenting participant's home, unless otherwise specified.

Cadastre, Reserve Vesting Reports, VGO points, and Road network data were provided by the Western Australian Land Information Authority.

VGO: Valuer General's Office;

[#]Core input data: Refers to cadastre, road network etc. The years of core input data which best reflects the year the participant completed the survey was used. E.g., GIS core input data for years 2005, 2006, 2008, and 2009 were used for participants completing the survey in four groups respectively: 1) February 2003-June 2005; 2) July 2005-December 2006; 3) January 2007-June 2008; 4) July 2008-December 2009.

[1]Functional Road Hierarchy (FRH): The hierarchy designated the function of all roads in Perth: 1) Access Roads (≤3000 vehicles/day); 2) Local Distributor (≤6000 vehicles/day); 3) District Distributor B (>6000 vehicles/day); 4) District Distributor A (>8000 vehicles/day); 5) Primary Distributor (>15,000 vehicles/day); and 6) Regional Distributor (>100 vehicles/day; connects metropolitan distributors 1-5 to regional areas) [48].

[2]Normalised Difference Vegetation Index (NDVI) layer was derived from annually updated Landsat TM remote sensing imagery. NDVI values ranged from -1 to +1. Values of -1 generally represent water, while values of zero (-0.1 to 0.1) correspond to bare surfaces such as rock, sand, rooftops and roads. Higher values (0.2 to 0.4) represent grassland or bush land and values of +1 represent green vegetation [49].

[3]Digital Elevation Model (DEM) layer for slope was provided by Geoscience Australia [50].

Table 4. Destination types computed for the Life Course Built Environment and Health study

Destination type	Description	Source of data	Years of data obtained[±]
Sensis destinations	Contains the most comprehensive and current destination data in Perth, WA, mainly of commercial businesses (e.g., retail shops, shopping centres, restaurants, medical centres, recreation venues, libraries, community centres).	Sensis Pty Ltd.	2004, 2005, 2007, 2010
Schools	Government (public) and non-government (private) schools (all years).	Department of Planning and Department of Education	2004, 2005, 2007, 2009
Food outlets	A combination of WADoH data and Sensis food outlet data (e.g., restaurants, cafes, grocery stores). This is the most comprehensive food outlet data layer.	Combination of WADoH[¥] and Sensis Pty Ltd.[#]	2008
Public transport stops	Bus stops, train stations, ferry terminals, free city bus stops in the Perth central business district, and school services stops.	Public Transport Authority	2005, 2006, 2008, 2009
Post Office (PO) box locations	All post-office boxes.	Australia Post	2011
Crime locations (burglary and non-dwelling)	Locations where: 1) actual and attempted burglary; or 2) crimes committed against a person in public (e.g., threats, disorderly conduct, assault, robbery), have been reported.	Western Australian Police Service	2007
Beaches	Beach access trails (i.e., any trail or path that could be seen to be used as an access point to the beach).	CBEH-derived*	2005
Parks 2005	Parks (2 acres or more in size) within 1600m of RESIDE study[1] participants.	CBEH-derived*	2005
Public Open Space 2010 (green space)[2]	*All* green public open space in metropolitan Perth, WA. (e.g., parks, natural and conservation areas, degraded or cleared land, school grounds).	CBEH-derived*	2010

All destination variables were processed up to 10km from consenting participant's homes.
[±]Years of data obtained: The year for which the destination information was obtained. The year closest to the year the participant completed the survey was used.
[¥]WADoH: Department of Health of Western Australia
[#]Sensis Pty Ltd: Food outlet data obtained from the Sensis destinations layer
*CBEH-derived: Destinations that were manually created by the Centre for the Built Environment and Health (CBEH).
[1]RESIDE study: A five-year longitudinal study conducted by CBEH, which examines the impact of the former Western Australian Government's Department for Planning and Infrastructure's (DPI) urban design code, the Liveable Neighbourhood Guidelines [7]. This project collected attribute information on 1906 parks (2 acres or more in size) in metropolitan Perth using the Public Open Space Tool i.e., POST [51].
[2]Parks: A total of 6505 public open space (green space only) were manually digitised by two PhD students at CBEH. Larger parks (n= 2525) were audited for park attributes (e.g., presence of lighting, playground, sport facilities, water features, shade) by PhD students, and work experience students at CBEH using the Public Open Space Desktop Auditing Tool (POSDAT), which is an adaptation of the previous POST tool used for the RESIDE study. Smaller parks (n=714) were audited using the mini-POSTDAT, a shorter version of the POSTDAT. The POSTDAT is currently unpublished but has been tested for inter-rater reliability.

Assumptions were made regarding the most appropriate year of GIS data sources from which to calculate built environment measures matching participants' year of survey (Table 5). Participants were divided into four groups according to date of survey participation: February 2003 – June 2005 (n=4404), July 2005-December 2006 (n=3896), January 2007-June 2008 (n=3189) or July 2008 – December 2009 (n=4465). Survey data was linked with the most temporally relevant GIS data. That is, the year of GIS data used corresponded as closely as possible to the year the survey was completed by participants. The most temporally relevant destination data was obtained for each participant group, but this was not always possible. Table 5 presents the year of GIS data used for the four groups of survey participants.

Table 5. Years of environment and destinations data applied to Life Course Built Environment and Health Survey participants

Participant group (HWSS[1] survey completion period)	1 (February 2003-June 2005)	2 (July 2005-December 2006)	3 (January 2007-June 2008)	4 (July 2008-December 2009)
Environment variables				
Land use mix (Transport and Recreation)	2005	2006	2008	2009
Street connectivity	2005	2006	2008	2009
Road exposure	2005	2006	2008	2009
Residential density	2005	2006	2008	2009
Gross density	2005	2006	2008	2009
Lot density	2005	2006	2008	2009
Greenness	2005	2006	2008	2009
Slope (terrain)	2005	2006	2008	2009
Walkability Index (Transport and Recreation)	*	*	*	*
Destinations variables				
Sensis destinations	2004	2005	2007	2010
Schools	2004	2005	2007	2009
Food outlets	2008	2008	2008	2008
Public transport stops	2005	2006	2008	2009
Post Office (PO) Box locations	2011	2011	2011	2011
Crime locations (burglary and non-dwelling)	2007	2007	2007	2007
Beaches	2005	2005	2005	2005
Parks 2005	2005	2005	2005	2005
Public Open Space (green space) 2010	2010	2010	2010	2010

*Walkability Index was calculated from summing z-scores of land use mix, street connectivity, and residential density
[1]HWSS: Health and Wellbeing Surveillance System Survey

Data analyses

Using linked data, associations between built environment and destination measures at 200m, 400m, 800m, and/or 1600m and health behaviour and outcomes across the life course will be examined. The survey data will allow opportunities to explore individual, social, and family-environment factors as well as self-reported risk and protective health factors and behaviours (e.g., physical activity, sedentary behaviours, eating behaviours, BMI outlined in Table 1). The availability of hospital and mental health system data for survey participants allows additional analyses of the relationship between the built environment and objectively-measured health status outcomes (e.g., cardiovascular disease, respiratory problems, mental health, and others outlined in Table 2). The health conditions examined will be different across the life stage groups and will focus on common conditions for each life stage group.

With at least 1,500 participants in each life stage, comparisons of factors and outcomes *across* the life stages will have at least 90% statistical power to detect differences in prevalence of 4% (e.g., 10% vs. 14%) and differences in means as small as 0.12 SD. In analyses *within* life stages, with a total of 1,500 respondents there is more than 90% power to detect a difference in prevalence across tertiles of 7% (e.g., 10% vs. 17%) and a difference in means across tertiles of 0.2 SD. For adults, with 6,000 respondents, there is more than 90% power to detect a difference in prevalence across tertiles of 4% (e.g., 10% vs. 14%) and a difference in means across tertiles of 0.1 SD.

Ethics and dissemination

Ethics approval for the project was obtained from The University of Western Australian Human Research Ethics Committee and the Department of Health of Western Australia's Ethics Committee (#2010/1). Given the broad and multidisciplinary scope of the project and richness of data that will be analysed, findings will be of interest to researchers and practitioners from a diverse range disciplines, including public health, urban planning and design, transportation, human and urban geography. Thus, results will be widely disseminated at local academic and practitioner oriented seminars, and national and international conferences. A series of publications in peer-reviewed academic journals across various disciplines will ensue.

DISCUSSION

The last decade has seen a rapid growth in studies on the impact of the built environment on health. However, little is known about the variability of these relationships for different population sub-groups and if different built environment features affect different groups across the life course. Moreover, understanding associations between the built environment and objectively-measured health outcomes remains largely understudied. The Life Course Built Environment and Health project attempts to strengthen the existing evidence base related to the nexus between the built environment and health, and will have important implications for policy and practice.

This appears to be one of the first studies to examine objectively-measured built environment measures and health outcomes, combined with self-reported health behaviour data for different population sub-groups across the life course. Most evidence to date is based on self-reported health measures, and study just one population group. Moreover, the LCBEH project will enable examination of the pathways through which the built environment directly and indirectly impacts health outcomes. Improved understanding of these issues is needed to inform the design of effective interventions for different life stages, and to assist planners and policy makers in creating neighbourhoods that are responsive to different population sub-groups and trends in health and wellbeing.

The LCBEH project has a number of strengths. Data linkage of built environment measures to both self-reported health behaviour data and objectively-measured health outcome data is a strength of this study to build a stronger case for changes to the built environment that are conducive to healthy living. The other major strength of this study is that the data are available in one dataset across the life course. Data linkage of available existing data is cost-effective as it includes a variety of data sources for a large sample size representative of the population. Moreover, using the same data to examine associations within and across different life stages is valuable, allowing for consistency in comparisons across life stages and generalizability across other urban populations living in developed countries. Moreover, built environment features within different neighbourhood buffer sizes have been measured, providing opportunities to explore the impact of scale and the distances over which each built environment feature impacts different health outcomes, and any variation in associations across and within life stages. An important aspect of data linkage studies is the strong collaborative partnerships. For the LCBEH project, collaborative efforts from the Department of Health of Western Australia, organisations that provided GIS data, and CBEH were required. This study would not have been feasible without such collaboration.

Despite the strengths, the study has limitations worth considering. The use of existing data presents its own constraints. In built environment and health literature, there is an increasing importance on using context- and behaviour-specific measures [36]. Using existing data is limited in that the researcher is restricted to pre-constructed measures that may not be specific for the outcome/s of interest. For example, the survey measured general health behaviour and thus is not purpose-designed for studies of the built environment and health. Variables required to examine a multi-level ecological framework that explores the influence of individual, social, and perceived environmental factors [52] on health outcomes were not included in the questionnaire. Second, due to the project's cross-sectional design, causality cannot be assumed. In addition, the computation of a comprehensive set of environment and destination measures using GIS is time-consuming and labor intensive, particularly for a large population over a wide geographic area. Moreover, while objective built environment measures provide potentially unbiased data, the data used (e.g., sources of destinations) were not designed for research purposes. They may be inaccurate or incomplete. For example, GIS data may not accurately represent what is actually present in the environment and was not evaluated for accuracy, which is a limitation [47]. This measurement error may impact on the interpretation of results. Moreover, although we have attempted to use GIS data matched as closely as possible to the survey data, the years for which the datasets were obtained may not exactly match the year the participant completed the survey. Nevertheless, the datasets provide a source of objective measurement for the built environment, and the most temporally relevant source was used.

Conclusion

The Life Course Built Environment and Health project will enable investigation of variations in associations between the built environment, health behaviours, and objectively-measured health outcomes *within* and *across* different life stages for a large study population. It has the potential to explain apparently inconsistent findings evident in the literature in studies of people of different age groups. Comparisons across various age groups are required to build an evidence base for designing healthy neighbourhoods that cater for children through to older adults.

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COMPETING INTERESTS

The authors declare that they have no competing interests.

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CONTRIBUTORS

KV developed the first draft of the manuscript. MK, FB, BGC, LW, HC, SF and DS contributed to the conception and design of the study. GP contributed to project coordination, data linkage, and data cleaning. BJB, SH and BB provided GIS assistance, and computed the GIS measures. SJ de-identified and extracted the data in preparation for data linkage. All authors provided critical feedback during manuscript development. Each author has approved the final manuscript.

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Figure 1. LCBEH project theoretical framework

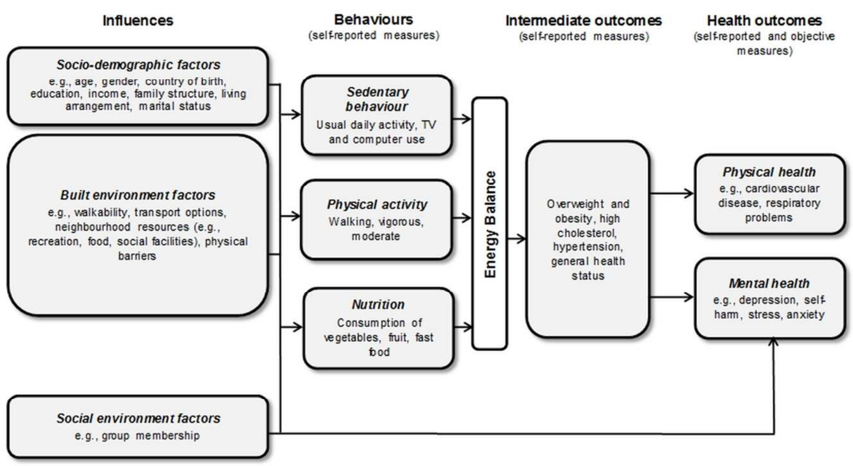

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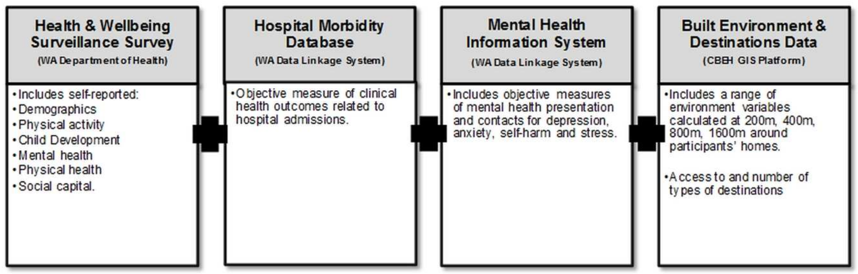
Figure 2. Sources of data used for the Life Course Built Environment and Health project



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