Title: Residential Proximity to Urban Centres, Local-Area Walkability and Change in Waist Circumference among Australian Adults

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Conflict of Interest

All authors declare no conflict of interest.

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ABSTRACT

Consistent associations have been observed between macro-level urban sprawl and overweight/obesity, but whether residential proximity to urban centres predicts adiposity change over time has not been established. Further, studies of local-area walkability and overweight/obesity have generated mixed results. This study examined 4-year change in adults' waist circumference in relation to proximity to city centre, proximity to closest suburban centre, and local-area walkability. Data were from adult participants (n=2080) of a cohort study on chronic conditions and health risk factors in Adelaide, Australia. Baseline data were collected in 2000-03 with a follow-up in 2005-06. Multilevel regression models examined in 2015 the independent and joint associations of the three environmental measures with change in waist circumference, accounting for socio-demographic covariates. On average, waist circumference rose by 1.8 cm over approximately 4 years. Greater distance to city centre was associated with a greater increase in waist circumference. Participants living in distal areas (20 km or further from city centre) had a greater increase in waist circumference (mean increase: 2.4 cm) compared to those in proximal areas (9 km or less, mean increase: 1.2 cm). Counterintuitively, living in the vicinity of a suburban centre was associated with a greater increase in adiposity. Local-area walkability was not significantly associated with the outcome. Residential proximity to city centre appears to be protective against excessive increases in waist circumference. Controlled development and targeted interventions in the urban fringe may be needed to tackle obesity. Additional research needs to assess behaviours that mediate relationships between sprawl and obesity.

Keywords: environment; sprawl; urban planning; central adiposity; longitudinal study

INTRODUCTION

The relationship between local-area attributes and residents' obesity is the focus of an emerging body of research (Kirk et al., 2010; Sallis et al., 2012). A recent review on obesogenic environments found mixed associations, however, between environmental measures and obesity (Mackenbach et al., 2014). Walkability has been examined frequently, on the basis of its link with physical activity (Freeman et al., 2013; Van Dyck et al., 2010; Villanueva et al., 2014). However, among 19 studies that examined walkability in the review, fewer than half (8 studies) reported associations with measures related to obesity, and the rest reported either statistically non-significant associations or significant associations only for subgroups (Mackenbach et al., 2014). The most consistent relationships were found for urban sprawl (expansion of low-density residential areas at the urban fringe), with seven of nine studies reporting associations between sprawl and overweight/obesity, and the remaining two reported non-significant relationships (Mackenbach et al., 2014). More recent cross-sectional studies also attest to a relationship between urban sprawl and higher levels of obesity (Berrigan et al., 2014; Ewing et al., 2014). In addition, longitudinal studies indicate that moving to a new residential location with greater levels of sprawl is associated with subsequent weight gain (Arcaya et al., 2014; Plantinga and Bernell, 2007).

Sprawl is often operationalised as 'county sprawl index' (Arcaya et al., 2014; Berrigan et al., 2014; Ewing et al., 2014), a county-level measure calculated for US studies from population density and block size (Ewing and Hamidi, 2014). However, counties are a spatially large administrative unit with a median size of 1600 km^2 (United States Census Bureau, 2010). It would be quite possible that overweight and obese individuals are not evenly distributed within such a large spatial unit. It is thus arguably just as important to examine how sprawl measured within a metropolitan region relates to changes in weight status over time. Distance to city centre can be a reasonable measure in examining the relationship of sprawl and adiposity given that such development is often characterised as taking place at the periphery a city (Resnik, 2010), and car commuting, in particular long commutes, is known to be associated with greater levels of adiposity (Hoehner et al., 2012; McCormack and Virk, 2014; Sugiyama et al., 2016). It might be hypothesised that locations distal to city centre where residents are more likely to rely on cars for commuting might be conducive to weight gain. We are not aware, however, of any research that has examined the relationship between distance to city centre and adiposity changes over time. A similar urban-scale measure, distance to a suburban centre (shopping area with a transportation hub), which represents a local-scale access to various destinations, might also relate to changes in adiposity over time. Although this is not a measure directly corresponding to sprawl, living near such a centre (even if not close to a city) may promote active living, which could support maintaining healthful body weight.

This prospective observational study evaluated in a population-based cohort in Adelaide, Australia, how proximity to city centre, proximity to suburban centre, and local walkability were associated with change in waist circumference. We examined the independent and joint associations between these environmental measures and change in waist circumference to evaluate the unique and potential synergetic effects of proximity measures and walkability. In light of previous mixed findings regarding the associations between walkability and overweight/obesity, we also assessed whether the relationship between walkability and increasing waist girth was modified by individual demographic variables, area-level socioeconomic characteristics, and proximity measures.

METHODS

Data Source and Study Setting

This study was part of the Place and Metabolic Syndrome (PAMS) project, a study that assessed the relationships between local-area social and built environmental factors and cardio-metabolic health (Baldock et al., 2012; Coffee et al., 2013). The PAMS project links spatial data derived from a geographic information system (GIS) with biomedical data from the North West Adelaide Health Study (NWAHS), a population-based cohort that examined chronic diseases and health risk factors. Detailed descriptions of the NWAHS have been reported elsewhere (Grant et al., 2009). Participants were adults over 18 years randomly selected from the north-western metropolitan region of Adelaide, the capital city of South Australia (population: 1.15 million in 2006) (Australian Bureau of Statistics, 2007). The study sample was representative of the target population, except for an overrepresentation of those with middle-level education and middle-level income (Taylor et al., 2006). The study area comprises both older, more traditional residential areas to the west of the city centre and newer, more car-oriented residential areas to the north of the city centre (Figure 1). This area was chosen because it reflects the demographic profile of the State's population by covering a diverse spectrum of socioeconomic status and ethnic background.

(FIGURE 1 ABOUT HERE)

Study Participants

Baseline data were collected from 4056 adults in 2000–03 (wave 1), with two additional waves of data collection in 2005–06 (wave 2, N=3205) and 2008–10 (wave 3, N=2996). Data for the present study were drawn from 3182 adults who took part in both the baseline (wave 1) and the first follow-up data collection (wave 2) with measured waist circumference at both time points. Participants who lived outside the Adelaide urban areas at baseline (n=72), and those who changed addresses between baseline and first follow-up (n=591) were excluded. Non-urban areas (population density ≤ 200 persons/hectare) were excluded on the basis that walkability was designed for use in urban areas. Participants who had difficulty walking at least 100 metres at baseline (n=486) and/or follow-up (n=450), and those who received a home visit (instead of visiting a clinic) for the follow-up data collection (n=41) were also excluded because neighbourhood environments are unlikely to have impact on obesity for those with reduced physical mobility. Participants who were 85+ years at follow-up (n=54) were also excluded due to a high possibility of mobility difficulty in this age group (Rantakokko et al., 2013; Stessman et al., 2009). For those with limited mobility, their activities may be confined to a space near residence and locations of urban centres may not have major impact on their adiposity. The final sample size was 2080. Data from wave 3 were not used due to a higher attrition rate and a larger number of participants who moved residence: the sample size had we extended our analysis to include wave 3 would have been 1229 rather than 2080, applying the same criteria. Written informed consent was provided by all participants at each wave of data collection. The PAMS Project was approved by the Human Ethics Committees of the University of South Australia, the Queen Elizabeth Hospital, and the South

Australian Department for Health and Ageing.

Measures

The outcome variable was change in clinically-measured waist circumference (Δ waist circumference=follow-up measure – baseline measure). Waist circumference was assessed by clinical staff, trained by a clinical coordinator of the project. Three measures were recorded, and the mean was provided. Waist circumference rather than weight was used as the outcome as waist circumference is a stronger marker of cardio-metabolic risk than general obesity measured by body mass index (Janssen et al., 2004). The median time period between baseline and follow-up was 3 years 11 months (25th–75th percentile: 2 years 4 months – 4 years 2 months).

Proximity measures included distance to Adelaide city centre (Adelaide General Post Office) and distance to the closest suburban centre. The seven 'suburban centres', defined as a shopping area with a transportation hub, included Arndale, Elizabeth, Gawler, Marion, Port Adelaide, Salisbury, and Tea Tree Plaza (Figure 1). For each participant, the road network distance to Adelaide city centre and each suburban centre centroid was calculated using ArcGIS Network Analyst (ESRI, Redlands, CA). Walkability was comprised of dwelling density, intersection density, land use mix, and net retail area ratio (Coffee et al., 2013). Each of the four walkability components was ranked from 1 (lowest) to 10 (highest). The walkability score was calculated at baseline for each participant as the sum of the four decile scores for a one-kilometre road network buffer of their residential location. This measure has been shown in previous research to correspond to walking behaviour. For instance, another study in Adelaide has shown walkability to be associated with walking for transport (Owen et al, 2007). Distance measures and walkability were standardised to facilitate comparison of results. Standardised distance measures were reversed so that larger positive values denote proximity. These measures were also categorised into quartiles to better illustrate the magnitude of waist circumference change at different levels of proximity and walkability. Table 1 summarises the operationalisation of these exposure measures.

(TABLE 1 ABOUT HERE)

Individual-level covariates at baseline included age, gender, education (high school or less; vocational education; Bachelor's degree or more), marital status (couple, single), having children in the household or not, annual household income (AUD 20,000 or less; AUD 20,001–50,000; AUD 50,001 or more), alcohol consumption, smoking status, and glycaemic risk. Alcohol consumption was coded 'at risk' or 'not at risk' according to the 2001 National Alcohol Guidelines (National Health and Medical Research Council, 2009). Self-reported smoking status was coded into 'smoker' or 'non-smoker' (including ex-smokers). Glycaemic risk was defined as fasting plasma glucose ≥ 5.6 mmol/L and/or physician-diagnosis of diabetes according to the American Diabetes Association criteria (American Diabetes Association, 2015). As work status changes during the study period could influence commuting and other potentially relevant behaviours, analyses accounted for change in work status: working (full or part time); having ceased working; having commenced working; or not working. As the follow-up interval varied widely, the number of days between baseline and follow-up measurements was also accounted for in analyses. Area-level socio-economic covariates were defined at the State Suburb level, and included the proportion of households having low income and the Index of Relative Socioeconomic Disadvantage (IRSD), a composite area-level measure of deprivation (Australian Bureau of Statistics, 2008).

Statistical Analysis

Characteristics of study participants and summary statistics of outcome variables were computed (means and standard deviations for numeric variables; proportions for categorical variables). Given the clustered nature of the data with participants nested within suburbs, analyses were conducted using multi-level linear regression models. There were 138 suburbs in the study area, and the median number of participants in these suburbs was 12 (25th–75th percentile: 4–19). To control for clustered errors, we included a random intercept in the model, and used the compound symmetry as the model specification for the within-cluster error correlation. Our recent study has shown that the suburb was associated with the greatest level of clustering among different spatial units (Paquet et al., 2016). We also used robust standard errors to address the problem of heteroscedasticity in errors. Analyses relied on the full information maximum likelihood approach for missing data handling, which assumes that data are missing at random.

The independent and joint associations of proximity and/or walkability (expressed as continuous measures) with Δ waist circumference were examined in the following models. First, each environmental measure was examined individually in Model 1. In Model 2, proximity to city centre and walkability were examined simultaneously. In Model 3, proximity to closest suburban centre and walkability were similarly examined simultaneously. In Model 4, the two proximity measures were examined simultaneously to check whether the main effect of proximal locations to city centre, for instance, was explained by their relative location to suburban centres. Quartiles of proximity and walkability measures were then employed as predictors to provide covariate-adjusted mean waist circumference change at each level of proximity and walkability quartiles.

As the literature regarding the association between walkability and obesity shows mixed findings, it is possible that walkability is associated with obesity only for certain subgroups or areas. Thus, further analyses evaluated whether the relationship between walkability (expressed continuously) and Δ waist circumference was modified by the individual-level demographic measures (age and gender), area-level socioeconomic status (IRSD), and environmental factors (proximity measures). Stratified analyses were conducted when interaction terms were statistically significant.

All models including interaction analyses were adjusted for participant-level and suburb-level covariates discussed above. Analyses were conducted in 2015 using STATA version 12 (StataCorp, College Station, TX). Statistical significance was set at alpha=5% except for interaction effects for which alpha was set at 10% on the basis that interaction analyses tend to have less power (Twisk, 2006).

RESULTS

Table 2 shows the characteristics of the study sample. On average, waist circumference rose by 1.8 cm across the median follow-up interval of approximately 4 years. The mean increase in waist circumference was 1.6 (SD: 5.8) cm for men and 2.0 (SD: 6.3) cm for women (difference not statistically significant: p=0.07). Distance to city centre ranged from 2.3 to 45.6 km. Distance to the closest suburban centre ranged from 0.2 to 11.7 km. The correlation between the two distance measures was r= -0.57 (p<0.001). Correlations between distance to city centre and walkability, and distance to closest suburban centre and walkability were r= -0.47 and r=0.17 (both p<0.001), respectively.

(TABLE 2 ABOUT HERE)

The results of regression analyses are given in Table 3. Living near the city centre was significantly associated with lesser Δ waist circumference, accounting for covariates (Model 1) and walkability (Model 2). Living near a suburban centre was associated with greater Δ waist circumference, accounting for covariates (Model 1) and walkability (Model 3). Statistically significant associations between Δ waist circumference and proximity to city centre and proximity to suburban centre were nullified when both predictors were included in the same model (Model 4). Walkability was not associated with Δ waist circumference in any models (Models 1-3).

(TABLE 3 ABOUT HERE)

Table 4 shows the adjusted mean Δ waist circumference (and 95%CI) according to the quartile groups of the proximity and walkability measures. Relative to participants living farthest from the city centre (QG1), those closest to the city centre (QG4) had lesser Δ waist circumference (p=0.01). With regard to proximity to suburban centre, participants in the most proximal and second proximal categories (QG4 and QG3) had a significantly greater Δ waist circumference (p=0.01, p=0.03, respectively) than did those in the farthest quartile (QG1). Each 10 km increment in the distance from city and suburban centre was associated with 0.42 cm (95%CI: 0.06, 0.78) greater and 1.08 cm (95%CI: 0.12, 2.04) lesser increases in waist circumference, respectively. No statistically significant differences were observed between the categories of walkability.

(TABLE 4 ABOUT HERE)

For tests of interactions, gender interacted with walkability in effects on Δ waist circumference (p=0.09). Stratified analyses suggested a stronger inverse association between walkability and Δ waist circumference for men (β= -0.35, 95%CI: [-0.76, 0.05], p=0.09) compared to women (β= -0.02, 95%CI: [-0.38, 0.41], p=0.93). These associations were not, however, statistically significant. Interactions with walkability were not statistically significant for age (p=0.36), IRSD (p=0.22), proximity to city centre (p=0.47), and proximity to closest suburban centre (p=0.98).

DISCUSSION

The study found that adults living further from the city centre experienced a greater increase in waist circumference than those living in vicinity to the city centre, over nearly four years. As shown in Table 4, participants in more distal areas (20 km or farther from the city centre) had a greater increase in waist circumference compared to those in areas more proximal to city centres (9 km or less). Adelaide is a highly car-oriented city. The 2011 Australian Census confirms that among seven capital cities, Adelaide had the highest mode share for car commuting (82%), the third lowest mode share for public transport use (10%), and the second lowest mode share for walking (3%) (Mees and Groenhart, 2012). Research has documented that daily car use for commuting is known to be related to weight increase (Sugiyama et al., 2013), and longer distance from home to work is detrimentally associated with markers of cardio-metabolic risk (Hoehner et al., 2012). Car commuting amongst study participants may have been prevalent and longer in duration in more distal study areas, and this may have contributed to a larger increase in central adiposity.

Contrary to expectations, this study found that living in proximity to a suburban centre was associated with greater increases in waist circumference. Although each suburban centre has a transportation hub (railway or bus transit), these transportation resources may not be enough to promote active travel.

Census data indicate that public transport use for commuting is less common in Adelaide (10%) versus other capital cities including Sydney (23%) and Melbourne (16%) (Mees and Groenhart, 2012). As some suburban centres included in this study are located along a major arterial road with a ‘big box’ shopping centre and large car parking area, residents living nearby may be encouraged to use cars more often than to walk or cycle. Shopping centres are also likely to have more fast food options, which can impact on residents’ eating behaviours.

Associations between proximity to city centre and Δ waist circumference were nullified when proximity to closest suburban centre was simultaneously modelled. As the two proximity measures were inversely correlated (r= -0.57), residing away from the city centre automatically confers proximity to a suburban centre. Thus, the results can be interpreted to mean that living near the city centre may have a positive impact partly as such locations are farther from suburban centres. Yet, other contextual factors not measured in this study (e.g., access to highways, public transport) could also shape residents’ daily behaviours such as commuting and shopping, and these, in turn, influence adiposity change.

In this study, local-area walkability was not associated with Δ waist circumference. This finding aligns with results of the review article indicating that more than half of the published studies have not observed statistically significant associations between walkability and obesity (Mackenbach et al., 2014). Walkability measures are expressed for a local area (one-kilometre network buffer in this study). It is possible that a local area of this size might not be large enough to capture a range of behaviours that could influence waist circumference. Although local walkability is known to be associated with walking and physical activity (Freeman et al., 2013; Van Dyck et al., 2010; Villanueva et al., 2014), other behaviours that occur outside local areas (e.g., commuting or shopping) can be relevant to adiposity changes. Environmental measures expressed for areas larger than local neighbourhoods may be needed to capture multiple adiposity-relevant behaviours. Further studies examining behavioural mechanisms through which distance to city centre is associated with residents’ obesity are warranted.

This study found that the regression coefficient for the association between proximity to city centre and

Δ waist circumference remained almost the same after further adjustment for walkability. These results suggest that living close to city centre is likely to be protective against excessive increases in central adiposity irrespective of local walkability. Walkability, however, is a ranked measure calculated within a specific area. It assigns a decile score, even when the actual variability in walkability components is small. It is possible that the study area was relatively homogeneous in terms of local environments, and that this may be a reason for not observing statistically significant associations for walkability. This notion is supported by an international study on residential environments and physical activity that included Adelaide as a study site in 12 geographically-diverse countries (geographic information was collected from different suburbs within Adelaide) (Adams et al., 2014). According to this study, suburbs in Adelaide appear to be more homogeneous in residential density and intersection density than other study sites in different countries (Adams et al., 2014). Further research on the impact of walkability on adiposity is needed in different geographical contexts, where more variance in walkability components is expected.

Strengths and Limitations

Strengths of the study include its longitudinal study design, clinically-measured waist circumference, and the use of new measures of sprawl (proximity to urban centres) that differ from the previously-used macro-scale sprawl index. Although further research with refined measures of sprawl would be needed, this study shows that this crude, approximate measure can be used to explain a within-city gradient of waist circumference change over time. This study has a number of limitations. The results may be subject to particular spatial distribution and characteristics of city/suburban centres in Adelaide. Therefore, the findings may not be applicable to other localities. In particular, other major cities in Australia (e.g., Sydney, Melbourne) have larger suburban centres that are well integrated in public transport network. Proximity to such suburban centres may have different impact on residents' adiposity change. The analysis did not account for additional environmental factors that could be relevant to adiposity, e.g., access to public transport stops, major motor ways, recreational facilities, and food environments. Particularly, food environments (e.g., access to fast food outlets) warrant further investigation, as they might explain the association of proximity to suburban centres with the increase in waist circumference. Additional research is needed to assess behaviours such as physical activity, prolonged sitting and diet that might mediate relationships between sprawl and obesity. In addition, waist circumference is just one measure of cardiovascular risk. Further examination of other risk factors or clinical outcomes would help consolidate the findings of this study.

CONCLUSIONS

This longitudinal study indicates that residing in sprawled areas is, through yet unknown behavioural mechanisms, associated with a greater degree of residents' adiposity increase over time. It suggests that low-density residential development away from a city centre may have long-term adverse health impacts for residents. Further collaborative research between the health, planning, and transport sectors on the adverse health impacts of urban sprawl is warranted. Such collaboration has the potential to yield a stronger evidence base to advocate for growth management policies and targeted interventions to help tackle obesity.

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FIGURE

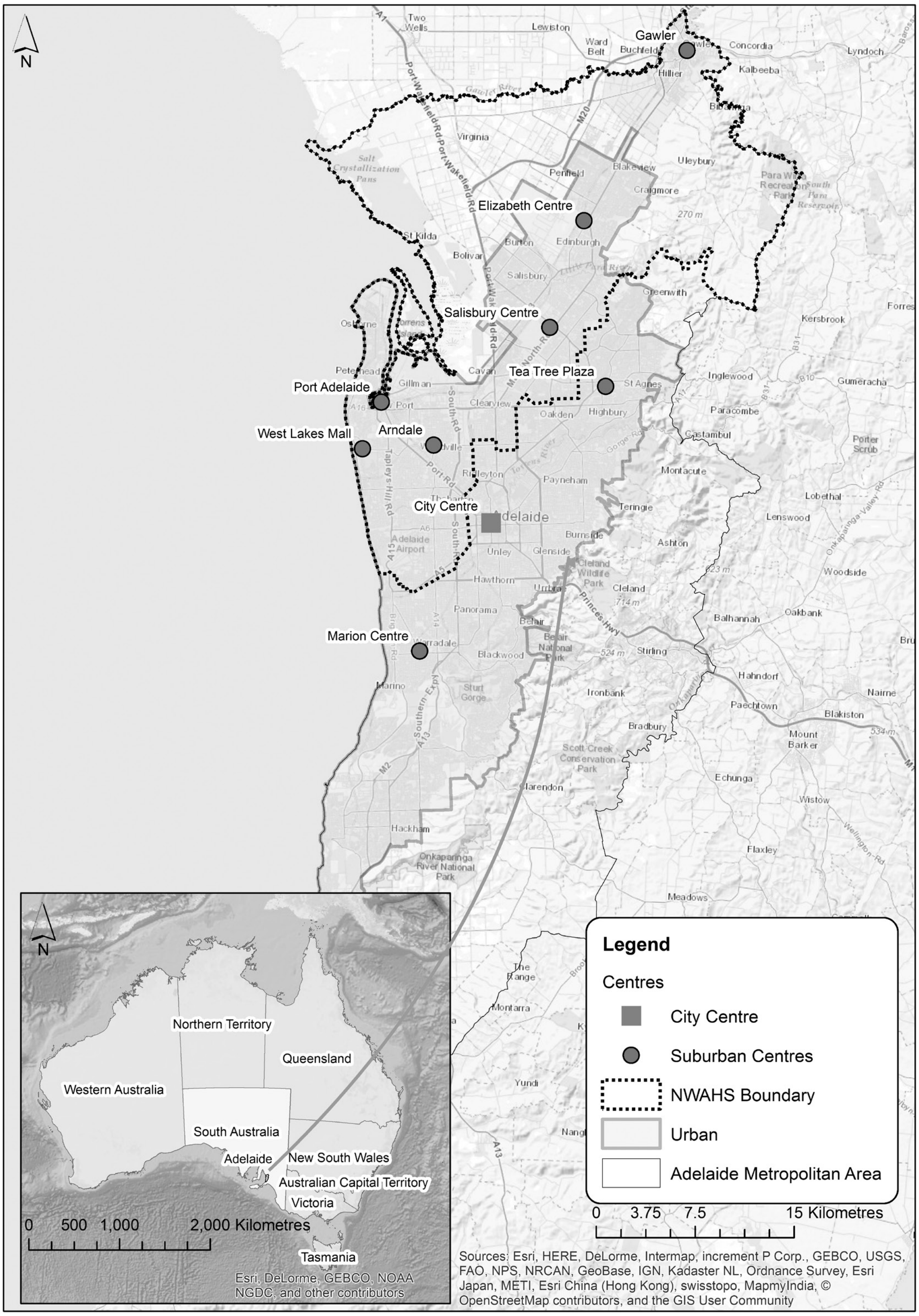

Figure 1. Study area: The north-western metropolitan region of Adelaide, Australia, 2000–03

Footnote: Elizabeth, Gawler, and Port Adelaide are accessible by bus and train. The other suburban centres have a bus interchange.

TABLES

Table 1. Operationalisation of exposure measures

	Continuous measure	Categorical measure
Proximity		
To city centre	Network distance to city centre (standardised and multiplied by -1)	Quartile of the proximity measure (QG1: distal, QG4: proximal)
To suburban centre	Network distance to the closest suburban centre (standardised and multiplied by -1)	Quartile of the proximity measure (QG1: distal, QG4: proximal)
Walkability	Sum of 4 walkability component scores (standardised)	Quartile of the walkability measure (QG1: least walkable, QG4: most walkable)

Table 2. Sample characteristics (N=2080), Adelaide, Australia, 2000–03

Variable	Mean (SD) or %
Age	50.6 (14.2)
Gender, women (%)	51.0
Education (%)	
high school or less	47.4
vocational education	37.7
Bachelor's degree or more	13.4
missing	1.4
Work status change (%)	
working (full or part time)	51.2
ceased working	6.3
commenced working	5.4
not working	35.5
missing	1.6
Marital status (%)	
couple	67.4
single	32.0
missing	0.6
Having children in the household, yes (%)	31.0
Annual household income in AUD (%)	
20 000 or less	24.4
20 001–50 000	37.7
50 001 or more	33.8
missing	4.1
Drinking, risky drinker (%)	25.1
Smoking, current smoker (%)	16.1
Glycaemic disease, diagnosed (%)	6.7
Index of Relative Socioeconomic Disadvantage	962 (89)
Proportion of low income housing (%)	35.5
Distance to city centre (km)	15.6 (8.9)
Distance to suburban centre (km)	5.7 (2.7)
Walkability index (range: 3–38)	21.3 (7.1)
Waist circumference at baseline (cm)	91.7 (13.6)
Waist circumference at follow-up (cm)	93.5 (13.9)
Waist circumference change (cm)	+1.8 (6.0)

Table 3. Associations between Δ waist circumference, proximity to city/suburban centre and walkability, Adelaide, Australia, from 2000–03 to 2005–06

	Standardised linear regression coefficients (95%CI)			
	Model 1	Model 2	Model 3	Model 4
Proximity [a]				
To city centre	-0.38 (-0.70, -0.05)*	-0.36 (-0.69, -0.03)*	–	-0.23 (-0.61, 0.14)
To suburban centre	0.38 (0.09, 0.67)*	–	0.36 (0.06, 0.66)*	0.26 (-0.08, 0.61)
Walkability [b]	-0.17 (-0.44, 0.10)	-0.03 (-0.31, 0.25)	-0.12 (-0.39, 0.15)	–

[a] negative coefficients indicate less increase in waist circumference for closer proximity, [b] negative coefficients indicate less increase in waist circumference for higher walkability
* $p < 0.05$

Model 1: All environmental variables examined individually (3 separate models)
Model 2: Proximity to city centre and walkability examined simultaneously
Model 3: Proximity to suburban centre and walkability examined simultaneously
Model 4: Proximity to city centre and suburban centre examined simultaneously

Analyses modelled the change in waist circumference (follow-up – baseline) as outcome. All models were adjusted for age, gender, education, work status change, marital status, having child in the household or not, drinking, smoking, glycaemic risk, IRSD, the proportion of low income housing, and the number of days between baseline and follow-up, and accounted for spatial clustering. The final sample size analysed was 2063 due to missing values in covariates.

Table 4. Adjusted mean Δ waist circumference according to the quartile groups (QG) of proximity to city/suburban centre and walkability, Adelaide, Australia, from 2000–03 to 2005–06

	Adjusted mean Δ waist circumference (95%CI)			
	QG1 (ref)	QG2	QG3	QG4
Proximity				
To city centre	2.4 (1.8, 3.1)	1.7 (1.1, 2.2)†	1.7 (1.1, 2.3)	1.2 (0.7, 1.8)*
To suburban centre	1.2 (0.6, 1.8)	1.6 (1.1, 2.1)	2.1 (1.5, 2.7)*	2.2 (1.7, 2.7)*
Walkability	1.8 (1.3, 2.3)	2.1 (1.4, 2.7)	1.7 (1.2, 2.1)	1.6 (1.0, 2.1)

† $p < 0.1$, * $p < 0.05$ (difference from the reference category, QG1)

All models were adjusted for age, gender, education, work status change, marital status, having child in the household or not, drinking, smoking, glycaemic risk, IRSD, the proportion of low income housing, and the number of days between baseline and follow-up, and corrected for clustering. The final sample size analysed was 2063 due to missing values in covariates.

Distance to city centre: QG1 (19.7–45.6 km); QG2 (13.7–19.7 km); QG3 (9.0–13.7 km); QG4 (2.3–9.0 km). Distance to suburban centre: QG1 (7.9–11.7 km); QG2 (5.4–7.9 km); QG3 (3.5–5.4 km); QG4 (0.2–3.5 km).