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Impact of Urban Sprawl on Overweight, Obesity, and Physical Activity in Sydney, Australia

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ABSTRACT *Obesity and inadequate physical activity are major risk factors for many diseases. The built environment plays an important role in influencing participation in physical activity. We aimed to determine whether urban sprawl in Sydney, Australia is associated with overweight/obesity and levels of physical activity. We used a cross-sectional multilevel study design to relate urban sprawl (based on population density) measured at an area level to overweight/obesity and levels of physical activity measured at an individual level whilst controlling for individual and area level covariates in metropolitan Sydney. Individual level data were obtained from the 2002 and 2003 New South Wales Population Health Survey. We had information on 7,290 respondents. The mean population density was 2,168 persons per square kilometer (standard deviation=1,741, range=218–7,045). After controlling for individual and area level covariates, for an inter-quartile increase in sprawl, the odds of being overweight was 1.26 (95% CI=1.10–1.44), the odds of being obese was 1.47 (95% CI=1.24–1.75), the odds of inadequate physical activity was 1.38 (95% CI=1.21–1.57), and the odds of not spending any time walking during the past week was 1.58 (95% CI=1.28–1.93). Living in more sprawling suburbs increases the risk of overweight/obesity and inadequate physical activity despite the relatively low levels of urban sprawl in metropolitan Sydney. Modifications to the urban environment to increase physical activity may be worthwhile.*

KEYWORDS *Urban sprawl, Physical activity, Overweight, Obesity, Multilevel analysis, Adults*

BACKGROUND

Overweight and obesity are currently major health issues both in Australia and internationally. The prevalence of overweight and obesity is high and has been increasing over the last few decades.[1–3] In Australian adults, the rate of overweight/obesity is around 49%[4] and that of moderate to high levels of physical activity is only about 30%.[4] Obesity and inadequate physical activity are major risk factors for many diseases including type 2 diabetes, stroke, certain cancers, and ischemic heart disease and a risk factor for all-cause mortality.[5,6]

The built environment plays an important role in influencing participation in physical activity and obesity.[7–9] Environmental factors such as well-maintained walking surfaces, residential density, public transport accessibility, public open space, and mixed land use are important correlates for higher rates of walking for

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recreation and transport.[10–14] Neighborhoods with higher walkability scores are associated with more walking.[15,16] Access to food outlets and costs of foods can influence obesity.[9] Neighborhood and individual socio-economic status can also impact on both physical activity and obesity levels.[17–20]

Urban sprawl, a feature of the built environment, can be defined as metropolitan areas where large percentages of the population live in low density residential areas,[21] and has been shown to be associated with overweight/obesity[21,22] and physical inactivity.[14,16,23] It is hypothesized that urban sprawl encourages car use and discourages physical activity leading to overweight/obesity.[24] Sydney is Australia's largest city with a population of about 4.1 million (in 2006) covering about 12,000 km^2. Yet, there are no published studies that have investigated the effects of urban sprawl in metropolitan Sydney. In this study, we aimed to determine whether urban sprawl in metropolitan Sydney is associated with overweight/obesity and inadequate physical activity.

METHODS

Design

A cross-sectional multilevel study design was used to relate urban sprawl measured at an area level to overweight/obesity and levels of physical activity measured at an individual level whilst controlling for individual and area level covariates in metropolitan Sydney. Sydney is located in the state of New South Wales (NSW). Metropolitan Sydney was defined as comprising 40 local government areas (LGAs).

Sample

Data from the adult component (persons aged 16 years or older) of the cross-sectional 2002 and 2003 NSW Population Health Survey[25–27] was used for individual health outcomes and covariates. The NSW Population Health Survey is an ongoing telephone survey of residents (from birth upwards) in NSW and is conducted continuously between February and December each year. The target population was all NSW residents living in households with private telephones and the target sample was approximately 12,000 people. Households were contacted using list assisted random digit dialling. One person from the household was randomly selected for inclusion in the survey. Respondents were asked questions from modules on demographics, health behaviors, health status, and access to and satisfaction with health services. Most interviews were conducted in English but the survey was also conducted in five other languages: Arabic, Chinese, Greek, Italian, and Vietnamese.

Outcome Variables

Four outcome variables were used in this study: overweight, obese, inadequate physical activity, and minutes walked in the last week.

Body mass index (BMI; weight in kilograms divided by height in meters squared), based on self-reported height and weight, was used to classify respondents as overweight ($25 \leq \text{BMI} < 30$) or obese ($\text{BMI} \geq 30$). Two dichotomous outcome variables were then created—overweight (overweight versus normal weight) and obese (obese versus normal weight). Given that factors associated with overweight and obese may differ, overweight subjects were excluded from models for obesity and vice versa.[28]

Inadequate physical activity (yes/no) was defined as 'yes' if a respondent did not undertake a total of 150 min or more of exercise per week over five separate occasions, that is, at least 30 min each occasion for five occasions per week (it was assumed that the five occasions per week of exercise were undertaken on five separate days).[29] The weekly duration of exercise was derived from respondents' self-reported total minutes of exercise (calculated by self-reported total minutes spent walking in the last week plus total minutes spent exercising moderately in the last week plus twice the total minutes spent exercising vigorously in the last week) and the total frequency of exercising (calculated from the number of times walked in the last week, number of times exercised vigorously in the last week, and number of times spent exercising moderately in the last week).

Minutes walked in the last week was dichotomized into no walking and some walking and was based on a respondent's estimate of the total time they spent walking continuously for at least 10 min for recreation, exercise, or to get to or from places in the last week. Therefore, some walking was ten or more minutes continuous walking in the last week and no walking was less than 10 min continuous walking in the last week. This variable was dichotomized because of the large proportion of subjects who reported not spending any time walking in the last week.

Individual Level Variables

The following individual variables were included in all models: age (16–24, 25–34, 35–44, 45–54, 55–64, 65+ years), gender (male, female), household income (<$10,000, $10,000–$19,999, $20,000–$39,999, $40,000–$59,999, $60,000–$79,999, $80,000+, don't know/refused), highest level of education completed (university, Technical and Further Education (TAFE) certificate/diploma which is awarded for a vocational tertiary education course and ranks below a university degree, high school, did not complete high school), current smoking status (non-smoker, daily or occasional smoker), adequate diet (yes/no based on adequate fruit and vegetable intake) and how many years have you lived in your local area. In the models for overweight and obese, the measure of inadequate physical activity was included as a covariate. In the models for physical activity, a measure of perceived safety was also included: 'Do you feel safe walking down your street after dark?' (yes/no).

Urban Sprawl

We used population density (population per square kilometer) as a measure of urban sprawl in metropolitan Sydney. Population density for each LGA in our study area was obtained from the 2001 Australian Census.[30] Population densities were calculated for LGAs because it was the smallest geographical area for which we had area level data available from the NSW Population Health Survey. All respondents within a LGA were assigned the same population density (sprawl measure) for that LGA. It should be noted that decreasing population density represents increasing sprawl and vice versa.

Area Level Variables

The 2001 Index of Relative Socio-Economic Disadvantage,[31] classified in quintiles, of each LGA was used in the analysis as a marker of area deprivation to assess the association between urban sprawl and the outcomes after adjusting for area level socio-economic factors. The Index of Relative Socio-Economic Disadvantage was created by the Australian Bureau of Statistics to compare social and economic disadvantage across geographical areas in Australia. The index was derived from the 2001 census variables such as low income and educational attainment, high unemployment, and people working in unskilled occupations. The index has a mean score of 1,000 and standard deviation of 100.

Analysis

Multilevel logistic regression was used to estimate the associations between urban sprawl (at an area level) and health outcomes (at an individual level), controlling for individual and area covariates. Multilevel logistic regression accounted for the non-independence of observations within LGAs as each respondent in a LGA was assigned the same area level value and to partition the variance of the outcome into two components—the variance due to individuals and the variance due to areas. From the variance estimates, it was possible to calculate how much of the variation in the outcome variables was due to the areas and how much this variation was reduced after area and individual variables were accounted for in the model.[32–34] We used MLwiN v2.02 (University of Bristol, Bristol, UK) in our analyses.

Five models were run for each outcome: model 1, the null model, did not contain any covariates so that the area level variance in the outcomes in the absence of any explanatory variables could be assessed. Covariates were then added sequentially to model 1 to assess the relationship between the covariates and the outcomes and assess the change in the area level variance. Model 2 contained only the individual level covariates; model 3 contained only the population density; model 4 contained both the individual level covariates and the population density; and finally model 5 contained the individual level covariates, the population density, and the area level covariate socio-economic index of relative disadvantage. All models were two-level random intercept models.

For each model, the amount of variation in the outcome due to the areas, the intra-class correlation coefficient (ICC), and the proportion of the area level variance in model 1 (null model) explained by the addition of covariates in the models 2, 3, 4, and 5 were calculated. The ICC was calculated as the area level variance/(area level variance $+\pi^2/3$).[35] The proportion of the area level explained was calculated by (area level variance (null model) − area level variance of the model in question)/area level variance (null model).[34]

Cross-level interactions between the area and individual variables were not significant and were therefore excluded from all models. All estimates were weighted to adjust for differences in the probabilities of selection among subjects and for differences between the age and sex structure of the sample and Australian Bureau of Statistics mid-year population estimates for New South Wales.

RESULTS

There were 12,622 adult respondents in the 2002 NSW Population Health Survey and 13,008 adult respondents in the 2003 NSW Population Health Survey, a total of 25,630 respondents aged 16 years or older. Of these respondents, 7,290 (3,658 from the 2002 survey and 3,632 from the 2003 survey) resided in metropolitan Sydney. Only 2.8% of all NSW respondents had a missing value for LGA. The final sample size was 7,290 subjects.

There was a mean of 187 respondents per LGA (range = 0 to 630). The mean population density was 2,168 persons per square kilometer (standard deviation =

1,741, median=1,789, range=218–7,045; inter-quartile range=2,755). Of the 40 LGAs, 27.5% were considered to be in the least disadvantaged socio-economic quintile, 20.0% in second quintile of disadvantage, 27.5% in the third quintile of disadvantage, 12.5% in the fourth quintile of disadvantage, and 12.5% in the most disadvantaged socio-economic quintile.

Table 1 shows the distribution of the sample for each of the individual variables in the study and the distribution of the outcome variables within each category, weighted to population. Overall, 29.5% of adults in metropolitan Sydney were overweight, 13.5% were obese, 53.2% had an inadequate level of physical activity, and 20.5% did not spend any time walking in the past week.

The estimates from the multilevel logistic regression models for the relationship between urban sprawl and the outcomes (overweight, obese, inadequate physical activity, and no walking) after adjusting for individual and area level covariates are shown in Table 2. The association between urban sprawl and outcomes are presented as odds ratios for a decrease of 1,000 persons per square kilometer (2,564 persons per square mile).

Overweight

There was a significant positive association between urban sprawl and the likelihood of being overweight (OR=1.096, 95% CI=1.046–1.149), and this association remained after adjusting for individual covariates (OR=1.084, 95% CI=1.033–1.139), and both individual and area level covariates (OR=1.087, 95% CI=1.035–1.141).

Obese

There was a significant positive association between urban sprawl and the likelihood of being obese (OR=1.183, 95% CI=1.102–1.269), and this association remained after adjusting for individual covariates (OR=1.142, 95% CI=1.067–1.223), and both individual and area level covariates (OR=1.150, 95% CI=1.080–1.225).

Inadequate Physical Activity

There was a significant positive association between urban sprawl and the likelihood of inadequate physical activity (OR=1.111, 95% CI=1.064–1.160), and this association remained after adjusting for individual covariates (OR=1.120, 95% CI=1.068–1.174), and both individual and area level covariates (OR=1.123, 95% CI=1.071–1.177).

Walking in the Last Week

There was a significant positive association between urban sprawl and the likelihood of not spending any time in the last week walking (OR=1.175, 95% CI=1.099–1.256), and this association remained after adjusting for individual covariates (OR=1.179, 95% CI=1.095–1.271), and both individual and area level covariates (OR=1.179, 95% CI=1.095–1.271).

For all four outcomes, the area level variance was generally small but significant in all models indicating that there was variation between the areas in the outcomes independent of individual and area level covariates. The exceptions were models 4 and 5 for overweight and model 5 for no walking where the area variance was not significant. The area variances were reduced (by 7.8–94.5%) after individual and area level covariates were included. The ICC was also generally small (0.1–5.4%) for all models for all outcomes.

TABLE 1 Characteristics of the overall sample (*N*=7,290) and outcome variables weighted to the population[a]

		% Overweight[c]	% Obese	% Inadequate physical activity	% No time spent walking
	n	*n*=2,125	*n*=1,063	*n*=3,971	*n*=1,515
Overall[b]		29.5	13.5	53.2	20.5
Age (years)					
16–24	857	15.8	5.5	37.5	12.6
25–34	1,196	26.2	11.9	51.7	19.6
35–44	1,184	33.0	12.9	55.6	20.0
45–54	1,250	35.2	18.0	55.9	22.3
55–64	1,140	35.8	19.9	56.5	21.8
65+	1,663	33.4	15.0	64.2	28.4
Gender					
Female	4,235	21.8	12.7	56.8	18.2
Male	3,055	37.5	14.3	49.5	22.8
Household income (AUD$)					
<$10,000	480	27.7	15.7	57.1	21.0
$10,000–$19,999	927	30.2	16.3	59.2	23.4
$20,000–$39,999	1,065	30.2	13.9	58.3	23.3
$40,000–$59,999	1,036	32.4	15.7	56.7	21.1
$60,000–$79,999	791	30.4	17.4	50.8	17.0
$80,000+	1,524	31.0	11.1	46.1	17.3
Highest education level completed					
University	2,132	28.3	10.2	51.3	17.0
TAFE Certificate/diploma[d]	2,067	33.1	15.3	55.1	22.4
High school	946	24.1	10.6	43.7	16.1
Did not complete high school	1,763	29.6	17.3	58.4	24.6
Smoking status					
Current smoker	1,403	27.5	13.2	53.7	21.8
Non-smoker	5884	30.1	13.6	53.0	20.1
Adequate diet					
Yes	903	27.0	14.4	45.3	16.4
No	6,351	30.0	13.4	54.2	20.9
Years lived in local area mean (standard deviation)	7,278	16.9 (16.22)			
Do you feel safe walking down your street after dark?					
Yes	4,348	30.2	13.0	49.5	19.0
No	2,769	28.1	14.8	60.2	22.6

[a]Weighted to adjust for differences in the probabilities of selection among subjects, and for differences between the age and sex structure of the sample and Australian Bureau of Statistics mid-year population estimates for New South Wales

[b]287 (3.6%) respondents did not report BMI

[c]Does not include obese subjects

[d]*TAFE*=Technical and Further Education certificate/diploma is a vocational tertiary qualification ranked below a university degree

TABLE 2 Multilevel logistic regression model estimates for the relationship between urban sprawl (population density) and outcomes (odds ratios are for a decrease in population density of 1,000 persons per square kilometer)

		Model (covariates included in the model)				
Outcome	Fixed and random effect terms	1. (Null—no covariates)	2. (Individual covariates[b] only)	3. (Population density only)	4. (Individual covariates[b]+ population density)	5. (Individual covariates[b]+ population density+area level covariates[c])
Overweight (N=5,940)	Population density (OR (95% CI))	–	–	1.096 (1.043–1.149)***	1.084 (1.033–1.139)**	1.087 (1.035–1.141)**
	Area level variance	0.055**	0.035**	0.019	0.011	0.003
	ICC[a]	0.016	0.011	0.006	0.003	0.001
Obese (N=4,878)	Population density (OR (95% CI))	–	–	1.183 (1.102–1.269)***	1.142 (1.067–1.223)***	1.150 (1.080–1.225)***
	Area level variance	0.187***	0.130**	0.097**	0.074**	0.033*
	ICC[a]	0.054	0.038	0.029	0.022	0.010
Inadequate physical activity (N=7,290)	Population density (OR (95% CI))	–	–	1.111 (1.064–1.160)***	1.120 (1.068–1.174)***	1.123 (1.071–1.177)***
	Area level variance	0.100***	0.100***	0.066***	0.061**	0.044**
	ICC[a]	0.029	0.029	0.020	0.018	0.013
No walking (N=7,290)	Population density (OR (95% CI))	–	–	1.175 (1.099–1.256)***	1.179 (1.095–1.271)***	1.179 (1.095–1.271)***
	Area level variance	0.153***	0.141**	0.060**	0.037*	0.016
	ICC[a]	0.044	0.041	0.018	0.011	0.005

*$p<0.05$, **$p<0.01$, ***$p<0.001$

[a]ICC=(area level variance)/(area level variance+$\pi^2/3$)

[b]Individual covariates include: age, gender, household income, education, smoking status, adequate diet and years lived in local area for all outcomes; inadequate physical activity for the overweight and obese outcomes; and feel safe walking down street after dark for physical activity outcomes

[c]The area level covariate is the quintile of Index of Relative Socio-Economic Disadvantage of the local government area

DISCUSSION

Significant, positive associations between urban sprawl and the likelihood of being overweight, obese, inadequate physical activity, and no time spent walking during the past week after controlling for individual and area level covariates were demonstrated in this study. The results shown are for a decrease of 1,000 persons per square kilometer. However, if the odds ratios for an inter-quartile increase in urban sprawl (a population decrease of 2,755 persons per square kilometer) is considered, where this increase is similar to moving from an inner city suburb to an outer suburb of Sydney, an adult living in the outer suburbs of Sydney has 1.28 times the odds of being overweight (95% CI=1.10–1.44), 1.47 times the odds of being obese (95% CI=1.24–1.75), 1.38 times the odds of inadequate physical activity (95% CI=1.21–1.57), and 1.58 times the odds of not spending any time walking during the last week (95% CI=1.28–1.93) compared to an adult living in an inner city suburb.

The findings for the association between urban sprawl and overweight/obese and physical activity from the few published studies are mixed at best. Our results corroborate other published studies that have investigated associations between urban sprawl and health behaviors and health status. Ewing et al.[22] reported, in a cross-sectional study, associations between county level sprawl index (based on residential density and street accessibility) and overweight and obesity. However, they were not able to demonstrate a similar association between their sprawl index and BMI growth curves in a longitudinal analysis. Lopez[21] found associations between urban sprawl and overweight and obesity, and Ewing et al.[23] found that residents of sprawling counties were likely to walk less for leisure and weighed more. However, although Kelly-Schwartz et al.[24] were able to show that street connectivity was associated with higher self-rated health and greater population density was associated with lower self-rated health, they were unable to demonstrate associations between their sprawl measure and walking or BMI.

There are a number of neighborhood characteristics that impact on walking and physical activity, and subsequently on overweight/obesity. Less sprawling areas have higher levels of population density, greater land use mix, more identifiable centers, and greater connectivity.[24] These characteristics are more likely to promote walkability and physical activity.[7,10,14,36] Further, people living in sprawling suburbs are more likely to drive their car[7,37] and more likely to have a higher BMI.[38] Not all aspects of high urban sprawl, however, may be detrimental to health. Kelly-Schwartz et al.[24] suggest that, although areas with dense and highly connected street systems encourage walking and therefore promote health, relatively less dense areas can also promote health as they may be more inviting and less stressful.

Some of the inconsistencies among the published results may be due to the differences in the way that urban sprawl is measured. We used population density as our measure of urban sprawl. Lopez[21] created a sprawl index for metropolitan areas in the USA using population density at the census tract level whereas others[24,36] have used the sprawl index created by Ewing et al.[23] a metropolitan and county sprawl index derived from principal components analysis based on residential density, land use mix, degree of centering, and street accessibility from a number of data sources such as the US Census, American Housing Survey, and the US Census Transportation Planning. We were unable to apply this alternative method of calculating the sprawl index to metropolitan Sydney because most of the required variables such as the percentage of residents with businesses or institutions within half a block from their home and the percentage of blocks 1/100 of a square mile or less in size are not routinely collected in Australia.

We did, however, conduct sensitivity analyses using sprawl index (replicating Lopez's sprawl index[21] but within only one metropolitan region) as an alternative measure of urban sprawl in Sydney. Not unexpectedly, there was a high correlation between the population density we used in our study and the sprawl index (r^2= −0.79). The odds ratios for physical inactivity and overweight/obesity for an interquartile increase in urban sprawl were very similar no matter which sprawl measure we used (population density or the sprawl index according to Lopez[21]) confirming the consistency of our results.

It has been suggested that walking begins to increase at population densities between 1,000 and 3,999 persons per square mile.[39] Of the 40 LGAs in our study, three had a population density of less than 1,000 persons per square mile and eight LGAs had population densities between 1,000 and 3,999 persons per square mile. A salient outcome of our study is that despite the fact that most LGAs were considered to be conducive to walking, we were still able to demonstrate increased risks for overweight/obesity and inadequate physical activity suggesting that modifications to the urban environment to increase physical activity may be worthwhile.

The strengths of our study were that our subjects were part of an ongoing population-based health status and risk behavior survey, we had a large sample size and we took into account the multilevel nature of the data. The relatively high response rates (68%) and the representativeness of the NSW Population Health Survey weighted sample ensures that our results are generalizable to metropolitan Sydney and other similar major Australian cities.[25,27]

The main limitation of our study was that we could only obtain area-based covariates at the LGA level rather than at smaller geographic area levels such as postcodes or census collection districts because the NSW Population Health Survey was designed to be representative at a State and health area level, not at the postcode or census collection district level. By using measures at the postcode or census collection district level, we may have been able to see greater variability in both our sprawl measure and area-based covariates. Further, the NSW Population Health Survey does not collect respondents' addresses and therefore we were also not able to georeference addresses to construct other more sophisticated measures of urban sprawl. Other limitations were that, by using data from an existing cross-sectional survey, we are not able to make a causal link between urban sprawl and the reported health outcomes and that, although we adjusted for a number of important potential confounders, there may yet be some residual confounding. We also only examined the health effects of a single indicator of the urban environment (urban sprawl measured by population density). Lastly, we used self-reported physical activity levels, height, and weight to calculate our outcomes. This will overestimate physical activity and underestimate BMI and obesity prevalence.[40,41] However, despite such misclassification in physical activity and BMI, we were still able to demonstrate significant associations between urban sprawl and physical activity and overweight/obesity.

Our findings add urgency to improve the health-promoting aspects of metropolitan Sydney's urban environment. This is of particular relevance in metropolitan Sydney where there is a shortage of housing stock and there are plans for major new land releases which will accommodate about 180,000 new homes (www.gcc.nsw.gov.au/the-commission.aspx) over the next 20 years with a projected increase in population of about 200,000 people. It is important that town planners, developers, and governments take note of the emerging research now demonstrating relationships between neighborhood-built environment characteristics and health. Unfortunately, most of these studies are cross-sectional or ecological studies and we are unable to infer causal relationships. We would encourage prospective studies be undertaken so as to more clearly elucidate relationships between neighborhood-built environment characteristics and health.

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