Accumulated exposure to rural areas of residence over the life course is associated with overweight and obesity in adulthood: A 25-year prospective cohort study

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Abstract

Purpose: This prospective cohort study investigated whether BMI and weight status in mid-adulthood was predicted by trajectories of urban-rural residence from childhood to adulthood.

Methods: Participants aged 7-15 years in 1985 (n=8,498) were followed up in 2004-06 (n=3,999, aged 26-36) and 2009-11 (n=3,049, aged 31-41). Area of residence (AOR) was classified as urban or rural at each time point. BMI/weight status was calculated from self-reported weight and height (2009-11). We tested which of three life-course models ('accumulation', 'sensitive period', 'mobility') best explained the AOR-BMI/weight status association using a novel life-course modelling framework.

Results: Accumulation and sensitive period models best described the effect of AOR on mid-adulthood BMI and weight status. Those with greater accumulated exposure to rural areas had a higher BMI (β=0.29kg/m2 per time in a rural area, *P*=0.005) and were more likely obese (RR=1.13 per time in a rural area, *P*=0.002). Living in rural areas at ages 26-30 years was also associated with a higher BMI and obesity in mid-adulthood.

Conclusions: Greater cumulative exposure to rurality and exposure during the 'sensitive period' of young adulthood is associated with obesity in middle-aged adults. This study highlights the important contribution of context to the development of obesity over the life-course.

Key Words

Obesity, rural health, longitudinal studies, life course, Body mass index, Body weight

List of abbreviations

BMI: Body Mass Index

CDAH: Childhood Determinants of Adult Health

SEP: Socio-Economic Position

SOS: Section of State

Introduction

Obesity significantly increases the risk of all-cause mortality, stroke, type 2 diabetes and cardiovascular disease (1-3). People living in regional and rural areas are more often overweight or obese than those living in urban areas (4-7). Although those living outside of urban areas tend to be of lower socioeconomic position (SEP) (8,9) rurality increases the risk of being overweight or obese, independent of compositional factors such as age, education, income, race/ethnicity and marital status (5,6). This suggests that the rural context has an important role to play in obesity development. However, because most studies investigating the effects of rural areas on BMI and weight status rely on cross-sectional data (4-7), it is currently unclear how exposure to rural areas across the life course affects the development of obesity longitudinally.

Using an exposure measured at a single point in time and ignoring a persons' exposure of geographic residence over the life course may underestimate the effects that urban-rural area of residence may have on BMI. There are various models describing how exposures such as SEP may operate across the life course (10). The accumulation of risk model, which is the most common model within the literature, suggests that exposures across the life course accumulate having adverse effects on health in the longer term (11). A sensitive period model suggests that an exposure has a stronger effect at one time period than at other time periods (e.g. both childhood and adulthood have independent effects, but the effect of the exposure in childhood may be greater) (10,11). Some researchers have also highlighted the possible importance of a mobility model, which focuses on the importance of change of an exposure to adult health (11-13). A systematic review of models on life course socioeconomic factors recommended that future analyses should examine multiple life course models within the same study, to identify all possible patterns of association in the data (13).

Mishra *et al*. (14) described a statistical model selection approach to delineate the different life course models by comparing a set of nested life course models, each corresponding to a life course hypothesis, to an all-inclusive (saturated) model. Most of the current literature comparing different life course models (critical period, accumulation) has primarily investigated the relationship between SEP and health outcomes such as BMI or mortality. However, there have been no reports of studies applying these theoretical life course models to understand the impact of urban-rural area of residence on BMI, and no research to date has sought to establish statistically which of these theoretical life course models best explain geographic influences on weight and obesity.

This study therefore aimed to investigate whether BMI and weight status in mid-adulthood was predicted by trajectories of urban-rural area of residence from childhood to adulthood.

Methods

The Childhood Determinants of Adult Health (CDAH) study is the 20- and 25-year follow-ups of a nationally representative sample of Australian school children (7-15 years) who participated in the 1985 Australian Schools Health and Fitness Survey (n=8,498) (15). Details of the response proportions and loss of data are included in Figure 1, and on the study sample in Appendix S1.

Ethics

At baseline, the Directors of Education in each state and territory granted ethical approval, and consent was obtained from children and parents. At follow-up, ethical clearance was obtained from the Southern Tasmanian Health and Medical Ethics Committee and participants provided informed consent.

Area of residence over the life course

At each time point, urban-rural area of residence was defined using the Australian Bureau of Statistics, Section of State (SOS) classification. While there are more contemporary measures of remoteness in Australia (e.g. ARIA (16)), the SOS indicator was used because it is the only indicator that was available for all three time points. This indicator defines residence based on the population of a region as: major urban (populations ≥100,000), other urban (population range 99,999 to 1,000), bounded locality (population range 999 to 200) or rural balance (everyone else) (17). These categories were dichotomised as urban (major urban) and rural (other urban, bounded locality and rural balance).

Body mass index and weight status

BMI (kg/m^2) at CDAH-2 (2009-11) was calculated using self-reported weight at CDAH-2 and height clinically measured at CDAH-1, or self-reported height if no clinic height was reported. A correction factor, derived from those who had both measured and self-report height and weight at CDAH-1 (18), was applied to account for possible self-report errors of weight at CDAH-2. BMI was used to categorise weight status as normal weight (18.5-24.9 kg/m^2), overweight (25-29.9 kg/m^2) and obese ≥30kg/m^2) (19).

Covariates

Potential covariates included age, sex, own highest level of education (university degree or higher, diploma/vocational/year 12, less than year 12), marital status (single, married/living as married, separated/divorced), and number of children self-reported at CDAH2 (2009-11). Area-level disadvantage at CDAH-2 was estimated using the Index of Relative Socio-Economic Disadvantage scores from the Socio-Economic Indexes for Areas (SEIFA), assigned at the level of Census Collection Districts based on participants' residential addresses. Baseline (1985) BMI, calculated from clinically measured height and weight, was also considered as a covariate. We were careful not to adjust for factors that are or might be more proximal (intermediate) on the causal pathway; therefore, other covariates such as dietary patterns, consumption of fast food, alcohol use, physical activity and stress were not adjusted for in the current analyses.

Statistical analyses

Means (standard deviations) and proportions were used to: describe socio-demographic characteristics at CDAH-2; area of residence characteristics at each time point and for each life course model; and examine the association between BMI and weight status at CDAH-2 for each life course model. Comparisons between the different categories of each life course model for BMI and weight status separately were performed using t-tests (BMI) and chi-squared tests (weight status).

To test which life course model(s) best described the association between urban-rural area of residence and BMI, we used the regression modelling framework proposed by Mishra *et al*. (14). The accumulation hypothesis is usually tested by summing the number of times that an individual has lived in a rural area of residence across the early life span to form an overall score, which is then used as the exposure in the regression models. The sensitive period model allows the effects of urban and rural area of residence to vary across the early life course, which can be modelled by simultaneously including all area of residence indicators in the model. Lastly, the geographic mobility model assumes that all downward changes (moving to a rural area) are equally harmful to the outcome and all upward changes (moving to an urban area) are equally beneficial. Model specifications are provided in Table S1.

The fit of each nested model compared to the fully saturated model (which includes terms for the main effects of urban-rural status at each time point, all two-way interactions and the three-way interaction) was determined through the calculation of partial *F* tests for BMI and through likelihood ratio tests for weight status. As stated by Mishra *et al*., (14) a larger p value (>0.05) represents a better model fit as this indicates that the nested model is not significantly different from the saturated model in fitting the data, unless the *P*-value for the 'no effect' model was >0.05. If the *P*-value was >0.05 for the 'no effect' model, this indicates that there was no association between urban-rural area of residence at any time point with the outcomes. Importantly, it is possible that several models may be supported by this statistical approach.

To examine the association between the best fitting life course model(s) and BMI and weight status, linear regression to obtain beta coefficients and 95% confidence intervals for BMI was used, and log-multinomial regression (20) to obtain relative risks and 95% confidence intervals for weight status was used.

Lost to follow-up

To explore the impact of loss to follow-up on our results, we: compared the baseline (1985) data of participants and non-participants; compared our sample to the Australian population; and conducted sensitivity analyses using inverse probability weighting using variables from the full 1985 sample and examined the differences in magnitude of effect between weighted and unweighted results.

All results are shown for men and women combined as tests of interaction revealed no significant differences. All analyses were conducted using STATA software (version 12.1, Statacorp, College Station, TX).

Results

Loss to follow-up analysis

Using baseline (1985) characteristics, compared with those lost to follow-up, participants with data at CDAH-2 were more often female (58% versus 45%), from rural areas (41% versus 35%), from higher SEP postcodes (26% versus 23%) and were slightly more likely to be classified as normal weight (90% versus 86%), and have a lower childhood BMI (18.1 versus 18.3 kg/m^2). In addition, when using CDAH-1 (2004-6) characteristics, those with follow up data were more likely to be university educated (45% versus 31%), more likely to be classified as normal weight (54% versus 49%), and had a lower BMI (25.2 versus 25.9kg/m^2) in 2004-6 than those without follow-up data at CDAH-2.

Compared with the Australian general population of a similar age, a higher percentage of CDAH participants were married/living as married (82% versus 61%), were employed as professional/managers (52% versus 31%), were university educated (41% versus 31%) (21), and a lower percentage were classified as obese (20% versus 28%) (22).

Associations between urban-rural area of residence and BMI or weight status at different stages of the early life course

The characteristics of participants at CDAH-2 are shown in Table 1, while the details of participant socio-demographic characteristics across the eight possible trajectories of urban-rural area of residence are presented in Table S2. Living in a rural area at any of the three time points across the early life course was associated with a higher BMI at CDAH-2 in mid-adulthood (Table 2). Similarly, when using weight status at CDAH-2 as the outcome, those who were living in a rural area at any of the three time points were more likely to be obese.

Comparison of life course models

For both BMI and weight status at CDAH-2 the sensitive period model and the accumulation model explained the data equally as well as the saturated model which is reflected in the high (non-significant) *P*-values (Table 3). The geographic mobility model showed particularly poor fit for both BMI and weight status as the *P*-value was <0.05. Therefore, the sensitive period and accumulation models were selected for further analyses.

The accumulation model showed that, compared to those who stayed in urban areas across the three time points, those who had greater accumulated exposure to rural areas throughout the early life course had a higher BMI at CDAH-2, with a 0.29kg/m^2 increase in BMI per time point in a rural area (Table 4). This result was consistent for weight status at CDAH-2, with those who accumulated time living in a rural area being 13% more likely to be obese per time point in a rural area.

The sensitive period model showed that, compared to the urban group, those living in rural areas at 26-36 years of age (CDAH-1) had a 0.81kg/m^2 higher BMI at CDAH-2 when they were aged 31-41 years (CDAH-2). A similar result was seen for weight status in the sensitive period model, with those living in rural areas at CDAH-1 (26-36 years) being 27% more likely to be obese at CDAH-2 (31-41 years). Given that there is an overlap in age groups in CDAH-1 and CDAH-2 (the oldest CDAH-1 participants and the youngest CDAH-2 participants are the same age) we needed to explore whether the association at CDAH-1 that was observed for the sensitive period, was a period or age effect. Figure 2 shows the interaction between age and urban-rural area of residence at CDAH-1 when the participants were 26-36 years old. The figure shows that those who were younger and living in rural areas at CDAH-1 had a greater BMI than those who were older and living in urban areas at the same time point. Therefore, the association that was observed for the sensitive period when the participants were 26-36 years, could potentially be an age effect, whereby living in rural areas as a younger adult may have a greater risk on BMI than living in rural areas in mid-adulthood.

Sensitivity analyses

The associations between the selected life course models and BMI and weight status were slightly stronger in the results from the sensitivity analyses compared to the results from the complete case analyses (Table S3), suggesting that loss to follow-up was not a major source of bias.

Discussion

This study is the first to examine the effects of urban-rural area of residence on BMI and weight status across the early life course using a novel method to distinguish between theoretical life course models. Our findings indicate that greater cumulative exposure to rurality and exposure during the 'sensitive period' of young adulthood is associated with obesity in middle-aged adults. These findings have important implications as they suggest that contextual factors play an important role in the development of obesity across the life course.

It is difficult to make comparisons with other studies as this is the first to utilise this approach, but our findings are consistent with the mostly cross-sectional literature that has found rurality to be associated with a higher BMI and a greater risk of being overweight or obese (5-7). While some studies have applied a life course approach to understand the effect of SEP on BMI (e.g. 14,23,24), to our knowledge no studies have applied this method to examine the effect of urban-rural status on BMI and weight status. Although low socioeconomic position is associated with a higher BMI across the life course, previous literature has also shown that that living in a rural area is associated with being overweight and obese and having a higher BMI, independent of individual-level SEP factors (5,6).

Our findings show strong support for the accumulation of risk model. Those people who accumulated more time living in a rural area from childhood to mid-adulthood were more likely to have a higher BMI and be obese. This is consistent with another study by Jokela *et al.* (25) that also found cumulative exposure to rurality (childhood to adulthood) predicted higher adulthood BMI when compared to urban residence. This could be due to rural areas being associated with higher levels of physical inactivity in leisure time (6,26), increased alcohol consumption (6, 27), and poorer dietary behaviours (5,6,28).

The findings from the current study also showed support for the sensitive period model. Living in a rural area in young adulthood (aged 26-30 years) was more strongly related to BMI and weight status in mid-adulthood than was living in a rural area in childhood or mid-adulthood. There is considerable evidence that suggests young adulthood (18-31 years) is a high risk period for the development of obesity as well as unhealthy diet and physical activity practices (29,30). One study by Lewis *et al.* (31) examined 10-year increases in weight and found that the largest gains were seen among those in their twenties, as compared to those in their thirties. Furthermore, other studies have shown that younger adults living in rural areas gain more weight compared to those living in rural areas in mid-adulthood and in older adulthood (32,33). Again, this could be due to differences in health behaviours and lifestyles, or to social or cultural norms apparent in rural areas. A major concern for the development of obesity as a young adult is that there is a high degree of tracking over time (34,35) and overweight and obesity are extremely difficult to correct after becoming established (34). Therefore, preventive measures and health promotion strategies to modify risk factors, particularly for young adults living in rural areas, may be important to adopt lasting healthy behaviour patterns.

While the geographic mobility model showed less of a fit to our data, it is still important to consider causes of mobility (e.g. social selection) and how this might influence these results. People in their late teens and twenties are often motivated to move to urban environments as they provide more education and work opportunities (36,37). This can result in people migrating from rural to urban areas achieving higher SEP than their counterparts staying in rural areas (37), which is consistent with the findings from the current study. Further to this, those who do migrate to urban areas from rural areas tend to come from higher SEP backgrounds or are from upper rural social classes (25, 37), with these people being less likely to be overweight or obese (9). This could potentially lead to a widening gap in socioeconomic and health factors between urban and rural areas, which is an important avenue for future research.

There are some potential limitations of this study. Loss to follow-up was substantial and we cannot discount the possibility that the participants at follow-up differed in their association between urban-rural area of residence and BMI and weight status. However, statistical analysis using inverse probability weighting suggested that bias, if any, was small and may have resulted in underestimation of the magnitude of effects. Our choice of time points for urban-rural area of residence that could be analysed as potential sensitive periods was driven by data availability in the CDAH study. While these time points included broad age ranges, a greater number of time-points may have allowed us to delineate the sensitive period more preciously. Self-reported measures of weight at CDAH-2 could result in misclassification of BMI and weight status. However, we used a correction factor derived from measured and self-report height and weight, reducing the possibility of bias, and the tendency for most people to under-report their weight (38) which may lead to an underestimation of effects. Another potential limitation was the use of an older indicator of rurality (SOS) but reassuringly, the percentage of participants classified as urban (71%) was very similar to the general population using a more contemporary indicator (ARIA) (74%) (21). Classifying area of residence into a binary variable prevented us from examining differences across other regional areas. Further, the duration of the exposure (urban or rural area) is unknown; therefore, our accumulation model does not reflect the exact length of exposure. Study strengths included the large, national sample of men and women, the novel methodological approach, the multiple methods for examining loss to follow-up, and our predominantly clinic-based measures of the outcomes. The current study adds to the existing literature by examining and testing multiple life course models in the same sample, which is the best approach to testing which theories best describe the links between exposures and outcomes across the life course (13).

In conclusion, rurality was associated with higher BMI and increased risk of obesity, which was greatest in those exposed to rural areas of residence for longer and those exposed to rural areas during young adulthood. The findings from the current study help build a more complete picture of the relationship between urban-rural area of residence and BMI across the early life course, which may have important implications for policy makers and health practitioners. Reasons explaining why these differences exist need to be explored in greater detail to better identify targets for health promotion and prevention.

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Disclosure

The authors declared no conflict of interest.

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Figure Titles

Figure 1. Flow chart of participants in the Childhood Determinants of Adult Health (CDAH) Study, Australia, 1985-2009/2011, detailing loss to follow-up and final participant sample used in this study (n=1,775).

Figure 2. Interaction between age and urban-rural area of residence in 2004-6 (CDAH-1) when the participants were aged 26-36 years, Childhood Determinants of Adult Health Study, Australia, 1985-2009/2011

Table 1. Characteristics of Participants at the Final Follow-up (CDAH-2 2009-2011) from the Childhood Determinants of Adult Health Study, Australia

Socio-demographic characteristics			Total (n=1,775)
Age (years), M (SD)			37.6 (2.1)
Sex, % (n)			
Male			44.6 (792)
Female			55.4 (983)
Highest level of education, % (n)			
University			41.7 (740)
Dip/voc/year12			33.6 (596)
<Year 12			24.7 (439)
Marital status, % (n)			
Single			12.4 (221)
Married/living as married			82.2 (1,459)
Separated/divorced			5.4 (95)
Number of children, % (n)			
None			22.8 (405)
One			14.8 (262)
Two			38.9 (691)
≥Three			23.5 (417)
SEIFA disadvantage[a], M (SD)			1024.4 (88.4)
BMI, M (SD)			26.5 (5.3)
Weight status, % (n)			
Normal weight			43.9 (779)
Overweight			36.0 (639)
Obese			20.1 (357)
Area of residence characteristics			
Baseline 1985, % (n)			
Urban (0)			60.5 (1,074)
Rural (1)			39.5 (701)
CDAH-1 2004-6, % (n)			
Urban (0)			69.4 (1,232)
Rural (1)			30.6 (543)
CDAH-2 2009-11, % (n)			
Urban (0)			70.8 (1,256)
Rural (1)			29.2 (519)
AOR trajectories across three time periods[b], % (n)			
1985	2004-6	2009-11	
0	0	0	48.8 (866)
0	0	1	1.9 (34)
0	1	0	3.1 (56)
0	1	1	6.7 (118)
1	0	0	16.4 (291)
1	0	1	2.3 (41)
1	1	0	2.4 (43)
1	1	1	18.4 (326)

Accumulation: number of times rural, % (n)	
0	48.8 (866)
1	21.4 (381)
2	11.4 (202)
3	18.4 (326)
Geographic mobility, % (n)	
Stable urban	48.8 (866)
Out migration (moving into rural area)	8.6 (152)
In migration (moving into urban area)	18.8 (334)
Variable	5.5 (97)
Stable rural	18.4 (326)

Abbreviations: AOR, area of residence; BMI, body mass index; CDAH, childhood determinants of adult health; DIP, diploma; M, mean; SD, standard deviation; SEIFA, socioeconomic index for areas; VOC, vocational education.

[a] The national average is a score of 1000, all values lower than the national average indicates relatively greater disadvantage and all values higher than the national average indicates a relative lack of disadvantage.

[b] Urban area of residence denoted by 0 and rural area of residence denoted by 1

Table 2. BMI and Weight Status in 2009-11 (CDAH-2) by Urban and Rural Area of Residence Life Course Models, Childhood Determinants of Adult Health Study, Australia[a]

Life course model	BMI (n=1,775) kg/m² M (SD)	Weight Status (n=1,775) Normal weight %	(n)	Overweight %	(n)	Obese %	(n)
Individual time periods (sensitive period model)							
Baseline 1985							
Urban (0)	26.3 (5.1)	44.6	(479)	37.5	(403)	17.9	(192)
Rural (1)	26.9 (5.6)	42.8	(300)	33.7	(236)	23.5	(165)
P Value	**0.020**			**0.012**			
CDAH-1 2004-6							
Urban (0)	26.2 (5.1)	45.7	(563)	36.2	(446)	18.1	(223)
Rural (1)	27.2 (5.7)	40.0	(216)	35.5	(193)	24.7	(134)
P Value	**0.001**			**0.004**			
CDAH-2 2009-11							
Urban (0)	26.3 (5.2)	44.9	(564)	36.3	(456)	18.8	(236)
Rural (1)	27.1 (5.6)	41.4	(215)	35.3	(183)	23.3	(121)
P Value	**0.006**			0.088			
Accumulation model: No. times rural							
0	26.1 (5.0)	45.3	(392)	37.9	(328)	16.9	(146)
1	26.5 (5.4)	45.7	(174)	33.1	(126)	21.3	(81)
2	27.1 (5.4)	40.6	(82)	34.2	(69)	25.2	(51)
3	27.2 (5.8)	40.2	(131)	35.6	(116)	24.2	(79)
P Value	**0.004**			**0.026**			
Geographic mobility model							
Stable urban	26.1 (5.0)	45.3	(392)	37.9	(328)	16.9	(146)
Out migration (into rural)	27.1 (5.3)	40.8	(62)	36.2	(55)	23.0	(35)
In migration (into urban)	26.7 (5.4)	44.0	(147)	32.3	(108)	23.6	(79)
Variable	26.3 (5.6)	48.4	(47)	33.0	(32)	18.6	(18)
Stable rural	27.2 (5.8)	40.2	(131)	35.6	(116)	24.2	(79)
P Value	**0.014**			0.065			

Abbreviations: BMI, body mass index; CDAH, childhood determinants of adult health; M, mean; SD, standard deviation.
[a]All bolded values are statistically significant at the 0.05 level

Table 3. *P*-values From Partial *F* Tests for BMI[a] and *P*-values From Likelihood Ratio Tests for Weight Status[a], Comparing Each Area of Residence Life Course Model With the Saturated Model [b], Childhood Determinants of Adult Health Study, Australia (1985 – 2009/2011)

Life course model	BMI (kg/m^2) (n=1,775)	Weight Status (n=1,775)
	P-value	*P*-value
No effect	0.04	0.03
Sensitive period model	**0.37**	**0.12**
Accumulation model	**0.39**	**0.24**
Geographic mobility model	0.02	0.03

Abbreviations: BMI, body mass index.
[a] At CDAH-2 (final time point)
[b] High *P*-values represent a better model fit. Bold indicates the selected models

Table 4. Beta Coefficients (95% CI) for BMI at CDAH-2 and Relative Risks (95% CI) for Weight Status at CDAH-2 for the Best Fitting Life Course Models [a], Childhood Determinants of Adult Health Study, Australia (1985 – 2009/2011)

	BMI (n=1,775) (kg/m^2)		Weight Status (n=1,775) [b]			
			Overweight		Obese	
Selected life course model	β	(95%CI)	RR	(95% CI)	RR	(95% CI)
Sensitive period model						
Baseline 1985 (age 9-15 yrs)						
Urban	1.00	Reference	1.00	Reference	1.00	Reference
Rural	0.30	-0.21, 0.81	0.93	0.82, 1.07	1.10	0.93, 1.31
CDAH-1 2004-6 (age 26-36 yrs)						
Urban	1.00	Reference	1.00	Reference	1.00	Reference
Rural	**0.81**	**0.05, 1.58**	0.93	0.77, 1.12	**1.27**	**1.01, 1.59**
CDAH-2 2009-11 (age 31-41 yrs)						
Urban	1.00	Reference	1.00	Reference	1.00	Reference
Rural	-0.24	-1.03, 0.55	1.03	0.84, 1.25	1.08	0.83, 1.41
Accumulation model						
No. times rural [c]	**0.29**	**0.09, 0.49**	0.97	0.92, 1.02	**1.13**	**1.05, 1.22**

Abbreviations: CDAH, childhood determinants of adult health; CI, confidence interval; BMI, body mass index; RR, relative risk.

All bolded values are statistically significant at the 0.05 level

[a] Adjusted for baseline BMI and the following CDAH-2 covariates: sex, age, number of children, own highest level of education and area-level disadvantage

[b] Normal weight is the reference group

[c] Reference group is those who stayed urban at each time point