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Regional differences in intercohort and intracohort trends in obesity in the USA: evidence from the National Health Interview Survey, 1982–2018

Liying Luo [ORCID],[1] Emma Zang [ORCID],[2] Jiahui Xu[1]

[1]Department of Sociology and Criminology, The Pennsylvania State University, University Park, Pennsylvania, USA
[2]Department of Sociology, Yale University, New Haven, Connecticut, USA

Correspondence to
Dr Liying Luo;
liyingluo@psu.edu

ABSTRACT

Objectives Obesity in the USA is more prevalent in younger cohorts than older cohorts and also more prevalent in the South and the Midwest than other regions. However, little research has examined the intersection of cohort patterns and regional differences in obesity. We address the knowledge gap by investigating net of age and period trends, how intercohort and intracohort patterns in obesity may depend on Census regions for black and white men and women.

Design, setting and participants A total of 1 020 412 non-Hispanic black and white respondents aged 20–69 were included from the 1982–2018 National Health Interview Survey.

Outcome measures Obesity is defined as body mass index ≥ 30 kg/m^2 based on participant self-reported weight and height. Obesity ORs were calculated to estimate region-specific age, period and cohort patterns for each demographic group.

Results Although age and period trends in obesity were similar across regions for all demographic groups, cohort patterns depended on region of residence for white women. Specifically, for the white women cohorts born in 1955 or later, living in the South and the Midwest implied higher likelihood of obesity than their peers in other regions even after accounting for average regional differences. These cohorts' disadvantage seemed to persist and/or accumulate over the life course. Socioeconomic factors explained little average regional differences or region-specific cohort variation.

Conclusions Our findings highlight the interdependence of the temporal and geographical processes in shaping obesity disparities.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ Our study is among the first to examine the interactive processes of geographic, temporal and life course factors that affect obesity trends in the USA.
⇒ A new age-period-cohort model was used to examine both intercohort patterns and intracohort life course dynamics in obesity in the USA.
⇒ The long-term and large nationally representative data allow trend analysis and subgroup analyses by region, race/ethnicity and gender.
⇒ Cross-sectional observational design and lack of control for confounding prohibit causal inference.

In addition to better describing obesity trends, an age-period-cohort perspective underscores the important role of early-life social and environmental factors in shaping later-life health behaviours and outcomes.[6 7]

Besides temporal trends, regional differences in obesity prevalence and related diseases are also well documented.[8–10] Extant research showed that obesity prevalence among children and adults was especially high in the South and the Midwest.[8 9] Regions can shape obesity disparities through affecting population composition, socioeconomic factors (eg, education, employment), ecological variables (eg, built environment, access to healthy food) and attitudes towards physical activity, eating habits and body image that may modify individual-level determinants of obesity.[10–12] Because these social and ecological factors are largely modifiable, regional disparities research has important implications for developing effective and targeted interventions to reduce obesity prevalence.[8 13 14]

A major gap in the literature is a lack of studies that examine whether cohort patterns in obesity differ across regions. It is important to investigate regional differences in cohort patterns because it may shed light on the complex local and national contexts in

INTRODUCTION

Obesity prevalence has been rising from 13.4% in 1980 to 42.4% in 2018 in the USA.[1–4] While research on obesity trends often focused on age patterns and/or year-to-year variation, researchers have begun to note the important role of cohort process in shaping the obesity trends. For example, research demonstrated higher risks of obesity among the 1965–1980 cohorts than older cohorts after accounting for age and period trends.[5]

which related factors operate to cause the obesity trends. Although all members of a birth cohort may be exposed to social, political and economic events that occur at the national level, the degree of the exposure and its implications for health outcomes may vary by geographic regions due to distinct historical and social contexts. Have the cohort obesity trends observed at the national level 'masked'[15 16] regional heterogeneity? While extant research may control for regional differences, little is known about whether cohort patterns in obesity differ regions.

Furthermore, prior research examining cohort effects on obesity often focused on average differences among cohorts. This focus neglects the possibility that a cohort's higher or lower obesity rates may change as a cohort ages. In particular, the cumulative-advantage/disadvantage theory[17 18] posits that because obese children have heightened risks of a range of diseases and are more likely to be severely obese as adults than non-obese children, cohort differences in obesity may persist or widen over the life course. This theoretical account points to the importance of assessing intracohort life course changes in describing and predicting obesity trends.

Using a novel age-period-cohort model,[19] we investigate intercohort and intracohort patterns in obesity prevalence net of age and period effects among demographic groups by analysing pooled cross-sectional data from a large, nationally representative survey from 1982 to 2018. With the intersectional approach to geographic and demographic processes, our analysis provides a more complete assessment of obesity trends by examining whether age, period, intercohort patterns and intracohort life course dynamics in obesity vary by regions. This study is a first step towards understanding the interactive process of geographical, temporal and life course factors that affect obesity trends in the USA.

MATERIALS AND METHODS
Patient and public involvement
We used secondary data from a large national survey.[20] Patients or the public were not involved in the design, conduct reporting, or dissemination plans of the current study.

Data and measures
We used data from the 1982–2018 National Health Interview Survey (NHIS), harmonised and distributed by Integrated Public Use Microdata Series (IPUMS) Heath Surveys.[20] Although the NIHS changed top and bottom code for other heigh and weight variables for the period prior to 1997, the 'BMICALC' variable constructed by IPUMS NHIS from the public use NHIS files is consistent from year 1982 to 2018. For consistency and comparability reasons, we use 'BMICALC' for determining obesity status. Obesity is defined as body mass index (BMI)≥30 kg/m^2.[21] The possible downward bias in estimating obesity prevalence using self-reported height and weight

has been well discussed. Several studies have attempted to correct the bias,[22 23] but there is no consensus about the effectiveness of these methods.[24] This is in part due to the complex differences between survey designs.[15] More importantly, the literature has shown that the bias in self-reported BMI does not bias trends or patterns over time[22 23 25] or sociodemographic disparities in obesity.[26] Because this study focuses on the temporal patterns within race–sex groups, we used the self-reported BMI values in the NHIS without further adjustment. Meanwhile, prior research suggested that the continuous BMI measures were less susceptible to such bias than a binary measure of obesity, so we conducted supplementary analysis using a continuous BMI measure and the results (available on request) are consistent as the main analytical results.

Because of the considerable heterogeneity in nativity and immigration status as well as the relatively small sample sizes for Hispanics and other racial/ethnic groups, this study focuses on non-Hispanic Black and White adults aged 20–69. We use 5-year age intervals (20–24, 25–29, …, 65–69) and period groups (1982–84, 1985–89, …, 2010–14, 2015–18), which give us 10 age groups, 8 periods, and thus 17 cohorts. Note that because of the cross-section design of the NHIS, the youngest and the oldest cohorts were only observed once. Because Census regions capture important structural determinants of obesity[1 9 27 28] and other geographical variables such as county or neighbourhood are not available in our dat, we focus on four Census regions, including the Northeast (Connecticut, Main, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Islandand Vermont), the Midwest (Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota and Wisconsin), the South (Alabama, Arkansas, Delaware, District of Columbia, Florida, Georgia, Kentucky, Louisiana, Maryland, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, Virginia and West Virginia) and the West (Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, Nevada, New Mexico, Oregon, New Mexico, Wyoming and Washington). We assume that a respondent's current residential region mostly stays the same over time, as less than 2% Americans moved across regions in the 1980s and even fewer in recent years.[29 30] We consider a set of sociodemographic covariates including educational attainment, marital status, employment status and poverty that may affect the regional differences and cohort patterns for each race–sex group.

Analytical strategy
Although data visualisation may provide important initial evidence about age, period and cohort patterns in the data,[31 32] an age-period-cohort model quantifies the relative contributions of age, period, and cohort factors to observed trends. We use the age-period-cohort-interaction (APC-I) model[19] to decompose the overall trends into three related yet distinct dimensions of time, namely age, period and cohort. Recognising the interdependence of

age, period and cohort effects, the APC-I method characterises cohort effects as a structure of the age-by-period interactions. This model specification is motivated by the demographic concept of cohort[33 34] and qualitatively different from traditional APC models that seek to sperate and independent effects of age, period and cohort. The APC-I model has three advantages over traditional APC models. First, the APC-I model is fully identified with the usual coding scheme (eg, effect coding where the effects of a variable sum to zero or dummy coding where the first or last group is set as the referent). In contrast, traditional APC models suffer from the long-standing identification problem and require at least one more constraint on top of the usual coding scheme.[35 36] Second, the model is flexible enough to include other important predictors and the results have meaningful interpretations. Third, compared with traditional methods that focus on intercohort average differences, the APC-I method permits simultaneously estimating intercohort average differences and intracohort life course dynamics. This method thus provides a more comprehensive assessment of cohort effects on body weight in a cohort's life course. See online supplemental appendix 1 for a detailed discussion about the difference between the APC-I model and traditional methods.

To investigate regional variation in temporal patterns in obesity for each race–sex group, we extend the APC-I model to include a three-way interaction term among region, age and period and estimate the model separately by race–sex groups. In addition to estimating general trends in age groups, time periods and cohorts, this modelling strategy provides a means for estimating and testing regional heterogeneity in the three time-related patterns.

Lastly, we added the aforementioned socioeconomic status (SES factors including education, employment, marital status and poverty to the model to assess how these factors may account for the regional differences and temporal trends in obesity for each demographic group. All analyses were conducted in R V.4.0.3 using the APCI package.[37] We report ORs using the R package epitools.[38–40]

RESULTS

Our analytical sample consists of 63 332 black men, 90 318 black women, 419 785 white men and 446 977 white women respondents. Table 1 reports descriptive statistics for all variables in the analysis.

Table 2 reports average regional differences in obesity OR within each race–sex group, with the national average for each demographic group as the reference. Residing in the Midwest was significantly associated with 22.3% (95% CI for white men: (4.8% to 42.8%)) to 81.5% (95% CI for black women: (12.6% to 192.6%)) higher odds of obesity than their group average. Black men residing in

Table 1 Descriptive statistics for all analytical variables, the NHIS 1982–2018

Description		Black men # Obs	Black men Mean/% (SE)	Black women # Obs	Black women Mean/% (SE)	White men # Obs	White men Mean/% (SE)	White women # Obs	White women Mean/% (SE)
Obesity (body mass index ≥30 kg/m²)		63 332	26.0	90 318	35.2	419 785	21.7	446 977	19.7
Age		63 332	40.5 (13.4)	90 318	40.5 (13.5)	419 785	42.6 (13.7)	446 977	42.8 (13.8)
Region	Northeast	10 456	15.5	15 864	16.9	86 627	19.9	92 741	20.1
	Midwest	12 114	18.2	17 679	18.2	118 125	28.1	124 098	27.8
	South	34 091	56.9	48 621	57.0	131 150	32.8	141 624	33.2
	West	6671	9.4	8154	7.9	83 883	19.2	88 514	18.9
Educational attainment	<High school	14 429	16.6	19 160	16.1	51 660	9.7	51 166	9.0
	High school	9225	17.5	13 185	17.9	121 369	31.3	110 832	28.8
	College or more	39 678	65.9	57 973	66.0	246 756	59.0	284 979	62.2
Marital status	Never married	12 280	16.6	27 889	26.8	50 444	11.7	87 368	17.9
	Currently married	19 907	34.8	31 399	37.7	84 802	21.8	64 780	16.0
	Formerly married	31 145	48.6	31 030	35.5	284 539	66.5	294 829	66.1
Employment	Out of labour force	14 520	20.7	28 714	29.1	63 804	15.7	143 355	31.0
	Unemployed	4485	7.9	6132	7.1	14 468	3.7	13 423	3.0
	Employed	44 327	71.4	55 472	63.7	341 513	80.6	290 199	65.9
Poverty	Below poverty	11 819	16.8	27 118	26.8	26 788	6.4	38 085	8.2
	Above poverty	51 513	83.2	63 200	73.2	392 997	93.6	408 892	91.8

Analysis includes US-born respondents of 20–69 years old who participated in the 1982 through 2018 NHIS and for whom all analytical variables were available. Numbers in parenthesis are SD. Descriptive statistics are weighted using the NHIS person weight.
NHIS, National Health Interview Survey.

Table 2 Average regional differences in obesity before and after adjusting for socioeconomic factors, the National Health Interview Survey, 1982–2018

Model	Region	Black men Coef.	Sig	95% CI	Black women Coef.	Sig	95% CI	White men Coef.	Sig	95% CI	White women Coef.	Sig	95% CI
Model 1	Northeast	0.38	**	(0.19 to 0.77)	0.97		(0.59 to 1.60)	1.06		(0.88 to 1.27)	0.82	*	(0.68 to 0.99)
	Midwest	1.75	*	(1.05 to 2.91)	1.82	*	(1.13 to 2.93)	1.22	*	(1.05 to 1.43)	1.27	**	(1.10 to 1.48)
	South	1.22		(0.81 to 1.83)	1.11		(0.80 to 1.54)	1.07		(0.92 to 1.23)	0.92		(0.80 to 1.06)
	West	1.23		(0.63 to 2.42)	0.51	*	(0.28 to 0.96)	0.73	***	(0.61 to 0.87)	1.04		(0.87 to 1.24)
Model 2	Northeast	0.39	*	(0.19 to 0.80)	0.94		(0.56 to 1.58)	1.07		(0.89 to 1.28)	0.84		(0.70 to 1.01)
	Midwest	1.71	*	(1.02 to 2.87)	1.8	*	(1.11 to 2.92)	1.19	*	(1.02 to 1.39)	1.25	**	(1.07 to 1.45)
	South	1.17		(0.78 to 1.76)	1.08		(0.77 to 1.52)	1.05		(0.91 to 1.22)	0.9		(0.78 to 1.04)
	West	1.27		(0.65 to 2.50)	0.55		(0.29 to 1.04)	0.75	**	(0.62 to 0.89)	1.06		(0.89 to 1.27)

Table values are obesity OR compared with the national average based on coefficient estimates from the weighted logistic age-period-cohort-interaction model for each race–sex group. All models are estimated using effect coding, so the four coefficient estimates of regional differences and age-by-period interaction terms are sum to zero. Numbers in parenthesis indicate 95% CIs. Model 1: adjusted for age, time periods and cohort effects. Model 2: adjusted for age, time periods, cohort effects, education, marital status, employment and poverty.
*p<0.05; **p<0.01; ***p<0.001.

the Northeast appeared to have 62% (95% CI (23.2% to 81.2%)) lower odds of obesity than the group average. Adjusting for SES factors did not seem to account for a significant proportion of such regional differences (panel 'model 2 adjusted' in table 2). Note that although not all the regional differences in obesity likelihood were statistically significant among Black men, which is in part due to smaller sample sizes, these regional differences are large in magnitude. For example, though not statistically significant at the 0.05 level, black men living in the South and West had about 22% higher odds of obesity than the national average of this demographic group.

Figure 1 depicts intercohort differences in obesity for each race–sex group without adjusting for SES factors. The Y-axis indicates cohort deviations from the expected obesity odds averaged across the ages or time periods observed. The horizontal line of Y=1 represents no cohort deviations, on average, from the expectations determined by age and period main effects. Across all subgroups, the Generation X born in 1965–1979 and the older cohorts born before 1925 had higher-than-expected obesity likelihood, whereas lower-than-expected likelihood was observed among the Baby Boom cohorts born in 1945–1964. In general, cohort patterns in obesity were similar between black men and women, but somewhat different for white men and women. The cohort patterns after adjusting for the SES covariates presented in online supplemental figure S1 were largely similar to the cohort patterns without adjusting for these factors shown in figure 1, suggesting that SES explains little variation in the observed cohort patterns in obesity for blacks or whites.

Figure 2 depicts region-specific cohort deviations from the overall cohort trends across the regions (indicated by the horizontal line of Y=1) without adjusting for SES for White women. Little region-specific cohort variation was observed among blacks or white men. However, substantial region-specific cohort deviations were observed

among White women. The higher likelihood of obesity among the 1915–1929 cohorts appeared to be driven by those residing in the Northeast and the Midwest. By contrast, the higher likelihood of obesity among the 1965–1979 cohorts seemed to be driven by those living the South and the Midwest.

For example, compared with the predicted likelihood based on age, period and cohort estimates regardless of region, the older cohorts of white women born in 1920–1929 in the Northeast were 12.0%–25.0% (all p<0.05) more likely to be obese compared with their group average, whereas the later cohorts residing in the same region had a similar, if not lower, likelihood compared to the average. Most cohorts of White women born in 1955–94 in the South showed 8.0%–27.0% (all p<0.05) higher-than-expected odds. White women cohorts born in 1920–1929 and 1990–1999 residing in the West displayed a 21.1%–36.7% (all p<0.05) lower-than-average likelihood. It implies that for White women, the higher-than-expected obesity odds among the 1920–29 cohorts were even higher in the Northeast, but the higher odds among the 1955 and later cohorts were even more severe among those living the South. By contrast, regardless of birth cohorts, White women living in the Midwest had consistently higher-than-expected likelihood of obesity. Such region-specific cohort variation among White women remained largely the same before and after adjusting for SES, although the magnitude of some region-specific cohort variation was slightly reduced (see online supplemental figure S2).

Online supplemental table S1 report intracohort life course changes in log odds of obesity status. In general, we found few significant life course changes across demographic groups, suggesting that for most cohorts, their lower or higher likelihood of obesity reported earlier remained stable—that is, neither accumulated nor diminished—over the life course. Notable exceptions were White women born 1945 and later and living the Midwest showed increasingly
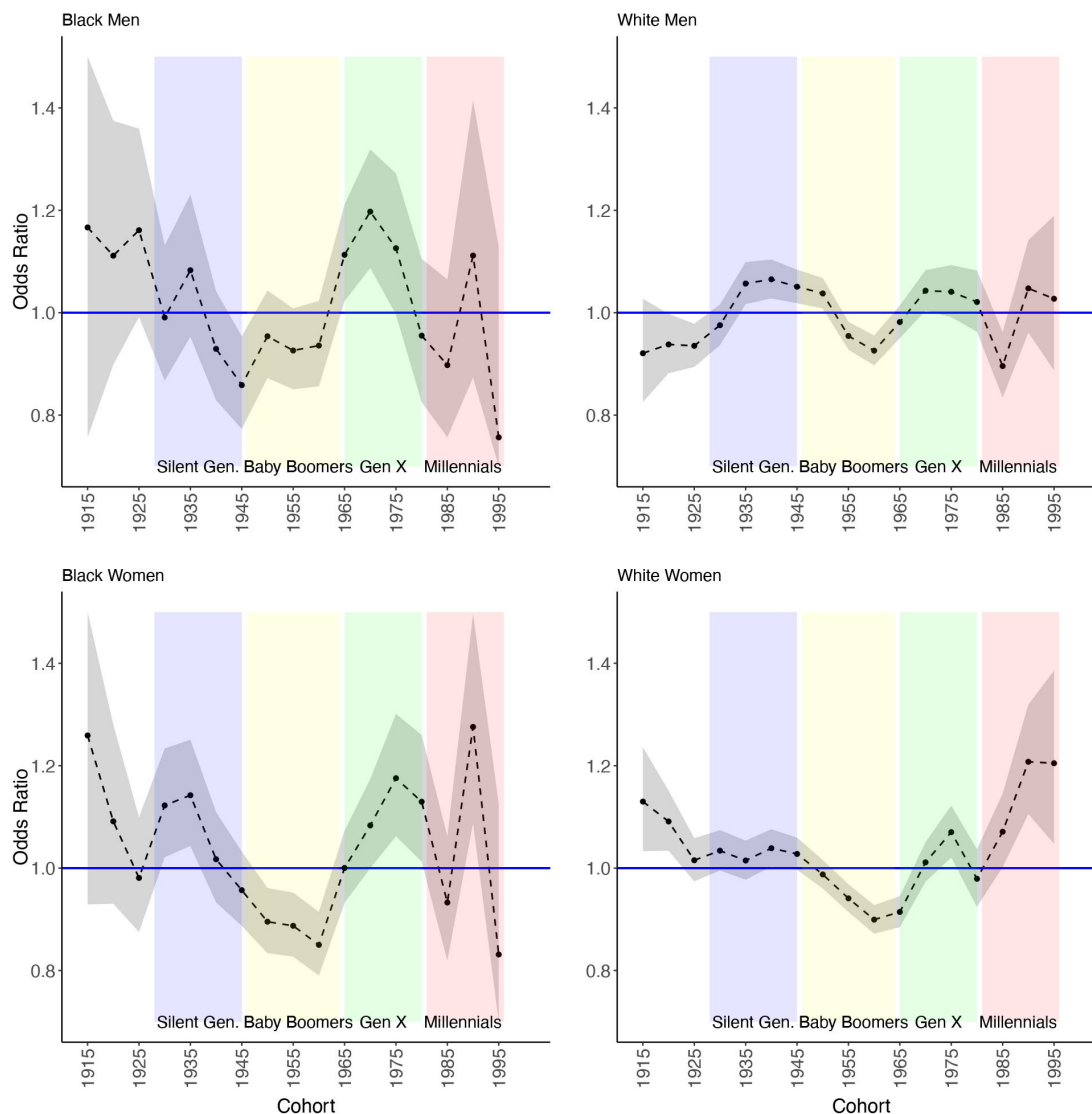
Figure 1 Intercohort differences in obesity among black and white men and women, the National Health Interview Survey 1982–2018. Figures represent average cohort differences from the expected odds of obesity based on age and period main effects in the age-period-cohort-interaction models. Estimates that are greater than one indicate higher-than-expected obesity odds. Estimates that are less than one indicate lower-than-expected obesity odds. Grey bands indicate 95% CIs. Estimates are not adjusted for socioeconomic status (SES) factors. See online supplemental figure S1 for SES-adjusted estimates.

higher odds of obesity as the cohorts age, although not all of their intracohort life course slopes are statistically significant. The life course dynamics estimates were largely similar before and after considering the four SES variables (see online supplemental table S2).

The age and period patterns in obesity for each race–sex group are largely similar across the four Census regions (online supplemental figure S3). Consistent with prior research, the odds of obesity increased with age until age 50 (for men) or 60 (for women) and were about three times higher in the 2010s than in the 1980s (all p<0.05) across all demographic groups.

DISCUSSION AND CONCLUSION
Our study is the first to investigate the intersection of temporal patterns and geographical differences in adult

obesity in the USA. Our APC-I analysis first confirms several findings from prior research including the higher-than-expected obesity likelihood among the Generation X and the lower-than-expected likelihood among the Baby Boom cohorts across demographic groups.[5] We found that within race–sex groups, individuals living in the Midwest and South had higher likelihood of obesity than the group average. This finding does not contradict extant evidence of the South showing the highest obesity prevalence averaged across racial groups because more than half of the black population—the demographic group with the highest obesity prevalence—resides in that region.[41]

More importantly, although age and period trends were similar across regions, cohort patterns in obesity among white women (but not among other demographic
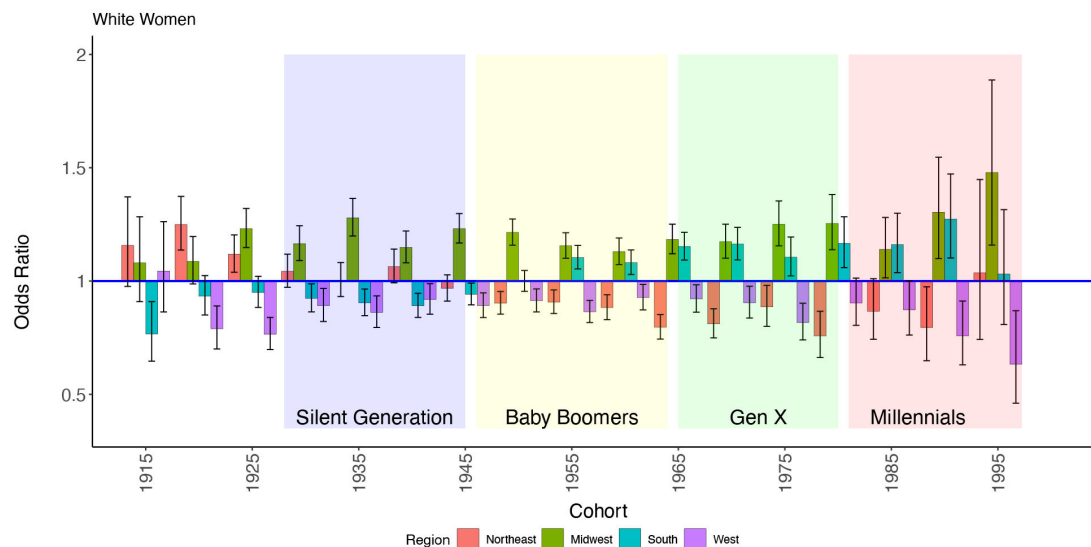
Figure 2 Regional deviations from average cohort differences in obesity among White women, the National Health Interview Survey 1982–2018. Histograms represent region-specific deviations from the average likelihood of obesity for cohorts whose obesity likelihood significantly differs from the expected odds. Estimates that are greater than 1 indicate higher likelihood of obesity than the expectation based on age, period and cohort effects in the white women sample across all regions. Estimates that are less than 1 indicate lower likelihood of obesity than the expectation based on age, period and cohort effects in the white women sample across all regions. Black lines indicate 95% CIs. Estimates are not adjusted for socioeconomic status (SES) factors. See online supplemental figure S2 for SES-adjusted estimates.

groups) largely depended on the region of residence. Specifically, white women who were born in 1955 and later and residing in the Midwest and South had alarmingly higher odds of obesity than their group average, whereas the same cohorts residing in the Northeast and West had lower odds. White women born in 1920–1929 and living in the Northeast and the Midwest also had higher-than-expected odds of obesity, but the 1930 and younger cohorts living in the same region had a similar or even lower likelihood. Our study also reveals that cohort effects on obesity persist over the life course. For example, the 1945 and younger cohorts of white women living in the Midwest—the region with the highest obesity prevalence among white women, had a higher-than-expected likelihood of obesity, which accumulated as the cohorts age. Such distinct intercohort and intracohort trends by region suggest that for some subpopulations, national trends in obesity may obscure important geographical heterogeneity and disparities across cohorts.

While the high obesity rates observed in the South and the Midwest were comparable (32.0% and 31.4% in 2016[1]), researchers have recently noted an alarming increase in childhood and adolescent obesity prevalence and obesity-related conditions such as the metabolic syndrome in the Midwest, especially among white women in this region.[28 42] Prior research also suggested that the effects of social and ecological factors on obesity and other health outcomes were consistently larger for white women than other demographic groups.[43 44] Another study found that lung cancer rates even increased for white women born in 1950 or later and living in the Midwest and the South.[45] Our finding of the large region-cohort interactive effects on obesity among this subpopulation is consistent

with this emerging literature. If the cumulatively higher likelihood of obesity observed in this study continues for the cohorts born in the 1950s and later, it is possible that the obesity disparities between white women living in the Midwest and their peers in other regions may widen in older ages. Therefore, public health interventions and programmes can be effective by reducing early-life risk factors including children's food, nutrition, sleep, physical activity and poverty rates, especially for individuals living in the Midwest as well as in the South.[9 14]

Prior studies suggested that differential distributions in SES variables such as education and employment may contribute to the observed regional differences.[8 9] Our findings do not fully support this hypothesis: SES factors including educational attainment, employment, marital status, and poverty did not seem to explain the average regional differences for all demographic groups or region-specific cohort patterns among White women. It is possible that other social and economic resources and ecological factors such as built environment and attitude toward physical activity are more powerful in explaining the regional disparities in obesity.

The lower obesity prevalence among black men in the Northeast may be linked to the 'Great Migration' of about 4 million black individuals and families moving out of the southern states to northern cities between 1910 and 1970.[46] Research has shown that both migrants and their children seemed to have more years of schooling and earn higher income than their peers in the South.[47] Unfortunately, we are unable to assess the implications of this demographic movement for geographical disparities in obesity because the public NHIS data does not have state of birth information.

Our study has several limitations. First, we used self-reported weight and height to determine obesity, and future research may benefit from using objective measures. Second, finer geographical code for identifying states, counties and Census tracts in which respondents reside are unavailable in the public NHIS data. We are thus unable to assess variations in obesity at other geographical levels. Third, we only considered a limited number of SES factors because not all potential covariates including smoking and alcohol consumption are available during the study period from 1982 to 2018. Lastly, the NHIS data are cross-sectional, making it difficult to account for between-individual heterogeneity or make causal interpretations. In addition, the NHIS is limited in respect to BMI characteristics such as DXA and BIA data. Future studies may use other data to address more sophisticated obese phenotypes.

Despite these limitations, our intersecting approach to considering temporal, geographical and demographic differences in obesity trends contributes to the literature in important ways. Our findings reveal distinct intercohort and intracohort patterns depending on the region of residence and demographic characteristics. It suggests that future research design should continue to emphasise the role of the cohort succession process and also consider how cohort trends in obesity may vary depending on geographical and demographic characteristics. In particular, the region-cohort heterogeneity in obesity among White women implies that subgroups of the population do not respond to the social and ecological environment in a uniform way. That is, some subgroups may be particularly susceptible to certain contextual characteristics, leading to distinct temporal patterns and geographical disparities in obesity.

Besides documenting demographic heterogeneity and geographical disparities in obesity, our study provides new perspectives about what can be done to address or reverse the obesity trends in the USA. While obesity prevalence has continued to increase in the past decades, our findings imply that contextual factors at the region level may modify cohort patterns and thus temporal trends in obesity. Specifically, White women born in 1955 and later and living the Northeast exhibited lower-than-expected odds of obesity than their peers residing in other regions. Prior studies also found that White women residing in the Northeast had better mortality outcomes than in other regions.[16] Characteristics unique to the Northeast including progressive tax policies, high social expenditure per capita, and growing creative occupations may have played an important role.[16 48] Future research should pay more attention to the intersection between temporal and geographical processes to identify critical social, geopolitical and ecological factors for reducing obesity prevalence and disparities. As prior research shown, obesity is a risk factor of a range of diseases and morbidities.[49–51] Our study, which examines the temporal, geographical and sociodemographic processes in obesity trends, thus has implications for monitoring and understanding trends in obesity-related morbidities such as diabetes, cardiovascular diseases, kidney and liver problems.

ORCID iDs
Liying Luo http://orcid.org/0000-0001-5393-6695
Emma Zang http://orcid.org/0000-0002-5700-3179

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