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Qi Zhang
Old Dominion University, qzhang@odu.edu

Youfa Wang

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Using concentration index to study changes in socio-economic inequality of overweight among US adolescents between 1971 and 2002

Qi Zhang[1]* and Youfa Wang[2]

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Background The prevalence of overweight among adolescents continues to increase in the United States. This study examines the changes in socio-economic status (SES) inequality of overweight among US adolescents in the past three decades.

Methods Concentration Index (CI) was utilized to measure changes in the SES inequality in prevalence of overweight among US adolescents. Data collected from 15 286 adolescents in four waves of the National Health and Nutrition Examination Surveys (NHANES) between 1971 and 2002 and Hispanic Health and Nutrition Examination Survey (HHANES) (1982–84) were used.

Results Changes in the SES inequality of overweight among US adolescents and considerable gender and ethnic differences were detected. For boys, CI varied from 0.04 in NHANES I to −0.04 in NHANES 1999–2002; for girls, CI varied from −0.12 in NHANES I to −0.18 in NHANES III. Among whites, SES disparity peaked in NHANES III and declined thereafter. Patterns in black and Mexican-American adolescents were mixed.

Conclusions Patterns of SES disparity of overweight among US adolescents varied across ethnic and gender groups, and have changed over time. Disparities have decreased since the early 1990s with the rise of the obesity epidemic. Obesity prevention and management efforts should target all SES groups in the United States.

Keywords Body mass index, obesity, overweight, inequality, adolescent, socio-economic status

Introduction

The prevalence of overweight among children and adults continues to increase in the United States.[1,2] Overweight during childhood and adolescence is an important predictor of adult obesity,[3,4] and increases the risk of a number of diseases and health conditions, including cardiovascular disease, hypertension, type 2 diabetes and certain types of cancer.[5–7] Due to the difficulty of treating obesity in adulthood and due to the cumulative adverse effects of childhood obesity, prevention of obesity among children is a public health priority.[8]

Previous studies show that minority and low-socioeconomic status (SES) US adult groups have a disproportionately high prevalence of obesity.[9–12] One reason for this may be that SES influences individuals' energy intake and energy expenditure, which affects body fat storage.[7,13] Literature suggests SES inequality in obesity could emerge during adolescence.[3,14,15] However, findings from previous studies, which are based on cross-sectional data, are inconsistent and some do not support a clear association between SES and overweight in young people in the United States.[16–20] Few studies have investigated the changes in socio-economic inequality of overweight in young people over time.[21] Such research will enhance our understanding of the relationship between SES and overweight among youth. A thorough understanding of trends in the relationship between SES and overweight prevalence will

[1] School of Community and Environmental Health, Old Dominion University, Norfolk, VA, USA.

[2] Center for Human Nutrition, Department of International Health, Bloomberg School of Public Health, Johns Hopkins University, Baltimore, MD, USA.

* Corresponding author. Assistant Professor, School of Community and Environmental Health, Old Dominion University, Room 3138, Health Sciences Building, Norfolk, VA 23529, USA. E-mail: qzhang@odu.edu

provide useful insights for developing effective overweight intervention programmes and policies.

Our recent analysis, based on logistic and linear regression analyses, shows an overall trend of a waning relationship between SES and obesity in US adults over the past three decades. However, these patterns varied across ethnic and gender groups,[22] and were more complex among US children and adolescents.[23] One limitation of these extant studies[21–23] was the simple categorization of SES using a few discrete categories (e.g. poverty/non-poverty or low-medium-high), prohibiting measurement of the full-spectrum socio-economic inequality. Use of different proxy variables for SES as well as different cut-offs may account for some of the inconsistency in findings.[21,23]

Our study of US adults suggests that an approach for studying inequality used in the field of economics, the Concentration Index (CI), is useful in studying the socio-economic inequality in obesity.[12] CI provides a summary measure of socio-economic inequality and enables comparisons across demographic groups and over time.[12] While the original application of CI was to study income inequality,[24] health economists have since extended the application of CI to study social inequality in health.[25–27]

In the present study, we applied the CI approach to examine changes in the socio-economic inequality of overweight in US adolescents using data collected in the National Health and Nutrition Examination Surveys (NHANES) between 1971 and 2002 and the Hispanic Health and Nutrition Examination Survey (HHANES) (1982–84).

Methods

Data sets

We used the NHANES data collected between 1971 and 2002 (four waves) for adolescents aged 10–18 years old. The NHANES include a series of cross-sectional surveys that provided nationally representative information on the nutrition and health status of the US civilian population. The National Center for Health Statistics (NCHS) conducted the first, second and third NHANES surveys (NHANES I, II and III) in 1971–75, 1976–80 and 1988–94, respectively. Since 1999, NHANES has been a continuous survey. The data for the first four years (1999–2002) were recently made available and pooled in our analysis. All four waves of NHANES surveys used a stratified, multistage probability cluster sampling design. Detailed descriptions of the sample design, interview procedures and physical examinations conducted were published elsewhere.[28–31]

In each survey, standardized protocols were used for all interviews and examinations. Data on weight and height were collected for each individual through direct physical examination in a mobile examination center. In NHANES I and II, race-ethnic group was classified as white, black and 'other' based on observation. In NHANES III and in 1999–2002, subjects were classified as non-Hispanic white, non-Hispanic black, Mexican-American and other ethnic groups, based on self-reported race and ethnicity. Because of the small sample size of Mexican-American in NHANES I and II, we used data from HHANES (1982–84), which was similar in content and design to the previous NHANES surveys. HHANES was not a nationally representative survey. However, HHANES was the best data source available to study health status of the Hispanic population in US during the specified period.

In the present study, we chose to focus on adolescents and excluded younger children for several reasons. First, adolescence is an important transition period between childhood and adulthood when adolescents gain greater autonomy to make decisions regarding their dietary habits and physical activity. Therefore, SES may potentially be more influential on adolescents' body weights than on that of younger children. Second, our recent analysis shows that this age group manifested some interesting patterns in the time trends in the association between SES and overweight based on regression analysis, while there are no clear corresponding patterns in younger ages.[23]

Measures

Socio-demographic characteristics

According to the World Health Organization's recommendation,[7] adolescence is defined between the ages of 10 and 18 years old. In NHANES III and 1999–2002, respondents were categorized as white, black, Mexican-American and 'other' based on self-reported race and ethnicity. In NHANES I and II, we combined the observation-based race/ethnicity and national origin/ancestry to categorize the participants into white, black, Mexican-American and other groups. Observation-based measures can potentially be biased; however, this was the most appropriate measure available in NHANES I and II. Because of the heterogeneity of the 'other' groups across surveys, we excluded the 'other' group from our analyses of ethnic differences and compared the patterns of SES disparities in overweight. Sample sizes by gender and SES are provided in Appendix 1.

Definitions of overweight

Body mass index [BMI = weight (kg)/height^2 (m^2)] was calculated for each individual based on measured weight and height. Adolescents with missing BMI were excluded from the study. In the present study, adolescents' body weight status was classified on the basis of age–sex-specific BMI percentile provided in the 2000 Center for Disease Control and Prevention (CDC) Growth Chart,[32] which defined (i) 'overweight' as BMI $\geqslant$95th percentile; and (ii) 'at risk of overweight', BMI $\geqslant$85th percentile. Since results were similar with 'at risk of overweight', only results with 'overweight' were presented.

Socio–economic status

The commonly used SES indicators include: education, income and occupational status. Each of these measures has its own strengths and limitations for studying the relationship between SES and health outcomes. The education variable was defined as 'highest grade of school ever attended' in NHANES. Since the adolescent sample included those who had not finished their education when surveyed, this education variable could not be used as a measure of SES. Another option was to use parental education, but NHANES lacked such information. While NHANES III had information about the education level of a family 'reference person' (defined as a person 17 years or older who owned or rented the dwelling unit), the relationship between the sample person and the reference person was

not clear. The majority of respondents indicated the relationship was 'family reference person living with other family member', which did not provide distinct information regarding parenthood. In addition, education levels are a categorical variable and have a much smaller variation than income (as a continuous variable).

Mathematically, CI cannot be appropriately computed based on the available education variable. Therefore, we excluded education as a measure of SES in the present study of adolescents.

Since the calculation of CI requires a strict ranking socio-economic measure and NHANES lacks other SES measures such as parental social class, we used poverty income ratio (PIR) as the indicator of adolescents' SES. The PIR is the ratio of household income to poverty line published by the US Census Bureau for a given family size in a given calendar year. The rate of missing data on income was ~4–8% across surveys (Appendix 2). Those with missing income were slightly more likely to be Mexican-American than other groups. Subjects with missing income were excluded from the CI calculation. We used survey-specific tertiles of PIR to reflect low-, medium- and high-SES.

Concentration Curve and Concentration Index as measures of health inequalities

Wagstaff *et al*.[27] argued that the CI is the most appropriate measure of health inequality, since it meets the three basic requirements of a health inequality index, namely, '...(i) that it reflects the socioeconomic dimension to inequalities in health; (ii) that it reflects the experiences of the entire population; and (iii) that it is sensitive to changes in the distribution of the population across socioeconomic groups...'. CI requires at least one continuous ranking variable of SES, which limits its use and applicability. However, we successfully measured the magnitude of socio-economic inequality in overweight, by extending the application of CI into the obesity research field.[12] CI is particularly useful in the current study because it takes advantage of the whole spectrum of population to overcome the effect of small sample sizes in certain subgroups as shown in Appendix 1. Figure 1 illustrates how CI measures SES inequality of obesity. The cumulative proportion of the overweight population, ordered from lowest to highest (0–100% of overweight members within the population) is plotted against the cumulative proportion of the population, ranked by income (e.g. PIR), from the poorest to the richest. We refer to $L(x)$ as the 'overweight concentration curve'.

The CI is defined as twice the area between the concentration curve and the diagonal, ranging from -1 to $+1$. The value of CI measures the severity of socio-economic inequality, the larger the absolute value of CI, the greater the disparity. CI equals zero when the concentration curve coincides with the diagonal, indicating there is no socioeconomic inequality in overweight. If the curve lies above the diagonal, $CI < 0$: this suggests that overweight is more concentrated among low-SES groups. If the concentration curve lies below the diagonal line, $CI > 0$, this indicates that overweight is more concentrated in high-SES groups. CIs provide a clear visual depiction of socio-economic inequality of overweight.

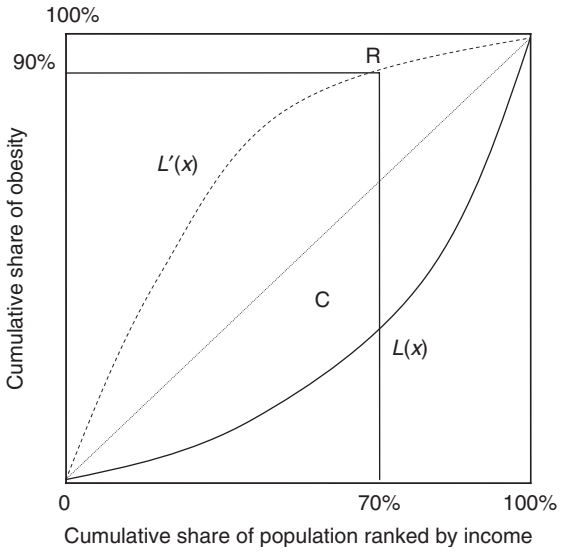

Figure 1 Concentration curve of overweight.
Notes: $L(x)$ represents progressive concentration curves; and $L'(x)$ represents regressive concentration curves. The interpretation of the overweight concentration curve is: (i) the diagonal was defined as the 'equality line', the overweight 'burden' is equally distributed across income levels; (ii) if the curve lies below the diagonal [e.g. $L(x)$], the overweight 'burden' is concentrated more heavily among the wealthy and (iii) if the curve is above the diagonal [e.g. $L'(x)$], the overweight 'burden' is concentrated more heavily in the poor.

Statistical analysis

First, we examined the socio-demographic characteristics and prevalence of overweight in boys and girls in each wave of the surveys. Subsequently, we fitted the concentration curves and calculated overall and group-specific CIs, stratified by gender and race/ethnicity. The CIs are empirically derived from sample data. To test whether these indices are different from zero, we adopted inference methods developed by Kakwani *et al*.[25] To test for changes in the CIs over time, we adopted the inference test developed by Bishop and colleagues.[33] Sampling weights were used to adjust for sample design effects to produce nationally representative estimates. Data management and data analysis were performed by using STATA Version 8 (STATA Corp., College Station, TX, USA) and Distributive Analysis/Analyse Distributive (DAD) 4.4.[34]

Results

Socio-demographic characteristics and anthropometric measures of US adolescents

As shown in Table 1, approximately half of the participants in each wave of the NHANES were female. The proportion of white adolescents dropped from 81.6% in NHANES I to 61.1% in 1999–2002, while the proportion of minority adolescents increased. These trends reflected the changes in population composition in the US during this period. The proportion of respondents from families below the poverty line increased from 15.2% to 20.8%. Black respondents had a much higher rate of poverty compared with white respondents, but this

Table 1 Socio-demographic characteristics and anthropometric measures (mean [SE] or %) of US adolescents aged 10–18 years: 1971–2002[a]

	HHANES (1982–84) ($n=2342$)	NHANES I (1971–75) ($n=2871$)	NHANES II (1976–80) ($n=2582$)	NHANES III (1988–94) ($n=3189$)	NHANES (1999–2002) ($n=4352$)
Age (years)	13.4 (0.05)	13.5 (0.05)	13.7 (0.04)	13.0 (0.05)	13.6 (0.05)
Female (%)	49.8 (0.01)	49.1 (1.05)	48.9 (0.88)	48.4 (1.75)	49.1 (0.90)
Ethnicity/Race					
White (%)	N/A[b]	81.6 (1.28)	76.7 (1.94)	65.8 (2.07)	61.1 (2.07)
Black (%)	N/A	13.7 (1.22)	14.1 (1.66)	15.5 (1.28)	15.2 (1.75)
Mexican-American (%)	59.9 (1.01)	3.7 (0.88)	4.5 (0.96)	8.6 (1.02)	11.0 (1.44)
Other (%)[c]	40.1 (1.01)	1.0 (0.20)	4.7 (0.92)	10.2 (1.71)	5.3 (0.69)
Below poverty line (%)	41.8 (1.02)	15.2 (1.12)	17.3 (1.07)	21.0 (1.51)	20.8 (0.92)
White: Below poverty line (%)	N/A	9.4 (1.06)	10.0 (1.10)	12.3 (1.55)	12.7 (1.60)
Black: Below poverty line (%)	N/A	45.5 (3.50)	46.4 (4.00)	40.7 (2.66)	37.3 (2.43)
BMI (kg/m^2)					
Both genders	20.8 (0.08)	20.0 (0.09)	20.2 (0.09)	20.9 (0.19)	22.0 (0.13)
Boys	21.1 (0.12)	19.7 (0.11)	20.1 (0.11)	20.7 (0.22)	21.8 (0.17)
Girls	20.5 (0.12)	20.2 (0.12)	20.3 (0.12)	21.1 (0.23)	22.2 (0.19)
Overweight (BMI $\geqslant$ 95 percentile), (%)					
Total sample	9.4 (0.60)	5.7 (0.46)	5.6 (0.53)	10.8 (0.95)	16.5 (0.85)
boys	9.9 (0.87)	5.3 (0.66)	5.4 (0.60)	11.5 (1.37)	17.5 (1.08)
girls	8.8 (0.83)	6.0 (0.63)	5.8 (0.72)	10.2 (1.33)	15.5 (1.28)

[a]All statistics were weight-adjusted for complex survey design.
[b]Ethnic groups not surveyed.
[c]In HHANES, Other groups mean 'other' Hispanic groups.

disparity decreased over time. HHANES population characteristics and statistical results differed from NHANES as expected because only the Hispanic population was included in HHANES. Between 1971 and 2002, the prevalence of overweight (BMI $\geqslant$95th percentile) had almost tripled, rising from 5.7% to 16.5%. Consistent with the rising prevalence of overweight, American adolescents' mean BMI also increased steadily during this period from 20.0 to 22.0. Although boys' BMI was slightly lower than that of girls, the prevalence of overweight among boys surpassed that among girls in the last two waves.

Socio-economic inequality in overweight among US adolescents over time

Prevalence of overweight

Tables 2 and 3 show differences in the prevalence of overweight by SES groups across gender and ethnic groups. Rates of overweight increased nearly 300% among black Boys—the highest increase among all groups. White Girls had the lowest increase in overweight rate, about 140%, over time. Disparities in the prevalence of overweight across SES groups existed in all gender and ethnic groups with the exception of Mexican-Americans. The widest gap was noted among girls and whites. Variations in prevalence ratios indicate some general trends in SES-related disparity across gender and ethnic groups. For white boys and girls, the prevalence ratio increased between NHANES I and III, while disparities declined between NHANES III and NHANES 1999–2002. For black girls, disparities were larger in NHANES I and II compared with the latter two waves. The protective effect of higher SES in black girls shown in NHANES III disappeared in 1999–2002. The prevalence ratios among black boys were quite striking in NHANES III, but no clear pattern emerged over the past three decades. No clear trends of SES disparities were detected among Mexican-Americans.

Concentration index for the whole sample

Because of the small sample sizes in certain subgroups (for example, medium and high income groups among blacks in NHANES I and II), standard errors were large compared with the prevalence rate. This was a limitation of using socio-economic categories based on tertiles. We presented the results of CI using respondents in the whole income distribution to overcome the small sample size limitation.

CI varied considerably across genders and over time. For boys, the CIs were 0.04, −0.09, −0.20 and −0.04 from NHANES I to NHANES 1999–2002; while for girls, they were −0.12, −0.24, −0.18 and −0.11, respectively. However, for all the CIs *P*-values were >0.05.

Concentration indices for whites, blacks and Mexican-Americans

Figures 2, 3 and 4 show CIs by gender and ethnicity, respectively, and over time. If the bar is below the horizontal axis, this means overweight status is more concentrated in the low-SES groups; if the bar is above the horizontal axis, then overweight status is more concentrated in the high-SES groups. The height of the bar corresponds to the severity

Table 2 Prevalence of overweight across socio-economic groups among white and black adolescents, 1971–2002

	NHANES I (1971–75)	NHANES II (1976–80)	NHANES III (1988–94)	NHANES (1999–2002)
White boys	5.2 (0.71)	4.7 (0.67)	10.2 (1.80)	14.3 (1.53)
Prevalence by SES (%) (SE)				
Low income	3.9 (1.40)	4.9 (1.55)	18.2 (6.34)	14.4 (3.06)
Medium income	5.8 (1.22)	6.2 (1.47)	11.5 (3.01)	14.8 (2.32)
High income	5.1 (1.09)	2.8 (0.96)	6.3 (2.53)* [b]	14.2 (2.48)
Relative difference in prevalence				
(Low-medium)/low (%)	−48.7	−26.5	36.8	−2.8
(Medium-high)/medium (%)	12.1	54.8	45.2	4.1
(Low-high)/low (%)	−30.8	42.9	65.4	1.4
White girls	5.5 (0.71)	4.9 (0.72)	9.7 (1.88)	12.1 (1.87)
Prevalence by SES (%) (SE)				
Low income	7.1 (1.76)	7.1 (1.82)	17.4 (4.12)	17.9 (5.06)
Medium income	6.3 (1.39)	5.1 (1.18)	12.6 (3.39)	10.6 (2.44)
High income	3.8 (1.00)	3.1 (0.77)	3.1 (1.35)* [b]	10.6 (2.24)
Relative difference in prevalence				
(Low-medium)/low (%)	11.3	28.2	27.6	40.8
(Medium-high)/medium (%)	39.7	39.2	75.4	0.0
(Low-high)/low (%)	46.5	56.3	82.2	40.8
Black boys	4.8 (1.63)	4.9 (2.08)	12.6 (1.30)	19.6 (1.62)
Prevalence by SES (%) (SE)				
Low income	3.8 (1.68)	4.7 (2.47)	12.6 (1.87)	18.8 (2.46)
Medium income	6.7 (5.22)	0 (0.00)	14.2 (3.22)	18.4 (2.51)
High income	10.4 (6.37)	15.9 (9.64)	6.9 (2.57)	22.2 (3.99)
Relative difference in prevalence				
(Low-medium)/low (%)	−76.3	N/A[a]	−12.7	2.1
(Medium-high)/medium (%)	−55.2	N/A[a]	51.4	−20.7
(Low-high)/low (%)	−173.7	−238.3	45.2	−18.1
Black girls	9.0 (1.68)	12.1 (2.55)	15.9 (1.73)	25.0 (1.52)
Prevalence by SES (%) (SE)				
Low income	8.2 (2.09)	14.5 (3.55)	13.7 (2.17)	24.5 (2.54)
Medium income	14.8 (7.15)	8.2 (5.04)	15.0 (3.82)	18.7 (2.28)
High income	1.9 (1.97)	6.5 (5.90)	26.1 (6.66)* [b]	38.0 (3.83)* [b]
Relative difference in prevalence				
(Low-medium)/low (%)	−80.5	43.4	−9.5	23.7
(Medium-high)/medium (%)	87.2	20.7	−74.0	−103.2
(Low-high)/low (%)	76.8	55.2	−90.5	−55.1

[a]No overweight adolescent was in the reference group.
[b]Chi-square tests, *P-value <0.05.

of socio-economic inequality. Arrows illustrate the statistical tests for time trends.

Except for the CI in NHANES I for white boys, the CIs in all periods for whites were negative, indicating overweight was more concentrated in the low-SES groups all the time. P-values of CIs in NHANES II and III among white boys and girls were 0.021 and 0.023, respectively. For black boys, three out of the four CIs were positive, but all the P-values were >0.05. This suggests overweight tended to concentrate in the high-SES groups. For black girls, the CIs in NHANES I and II were negative, but they became positive in NHANES III and 1999–2002, indicating overweight tended to concentrate in high-SES black girls. This is in contrast to white girls where overweight concentrated in low-SES groups. For Mexican-American adolescents, all the CIs were positive (P-value >0.05), except the CI for girls in the last wave of NHANES.

There was no strong socio-economic inequality in overweight in NHANES I in any gender–ethnic groups, but inequality increased in NHANES II and NHANES III. Among white adolescents, CIs in NHANES III were greater than those in NHANES I. However, in the most recent NHANES wave (1999–2002), socio-economic inequality decreased in all

Table 3 Prevalence of overweight across socioeconomic groups among Mexican-American adolescents, 1982–2002[a]

	HHANES (1982–84)	NHANES III (1988–94)	NHANES (1999–2002)
Mexican American boys	9.6 (1.12)	16.7 (1.97)	28.6 (1.81)
Prevalence in SES groups (%) (SE)			
Low income	9.7 (2.05)	16.5 (2.51)	25.8 (2.68)
Medium income	9.9 (1.89)	16.7 (5.03)	35.2 (3.57)
High income	9.4 (1.91)	22.3 (8.23)	22.7 (5.30)
Relative difference in prevalence			
(Low-medium)/low (%)	−2.1	−1.2	−36.4
(Medium-high)/medium (%)	5.1	−33.5	35.5
(Low-high)/low (%)	3.1	−35.2	12.0
Mexican American girls	9.8 (1.11)	13.6 (3.16)	20.3 (2.02)
Prevalence in SES groups (%) (SE)			
Low income	9.5 (1.88)	9.8 (3.48)	24.0 (2.72)
Medium income	8.6 (1.79)	23.1 (5.34)	18.9 (2.69)
High income	10.7 (2.11)	11.8 (4.55)	18.3 (4.52)
Relative difference in prevalence			
(Low-medium)/low (%)	9.5	−135.7	21.3
(Medium-high)/medium (%)	−24.4	48.9	3.2
(Low-high)/low (%)	−12.6	−20.4	23.8

[a]All statistics were weight-adjusted for complex survey design.

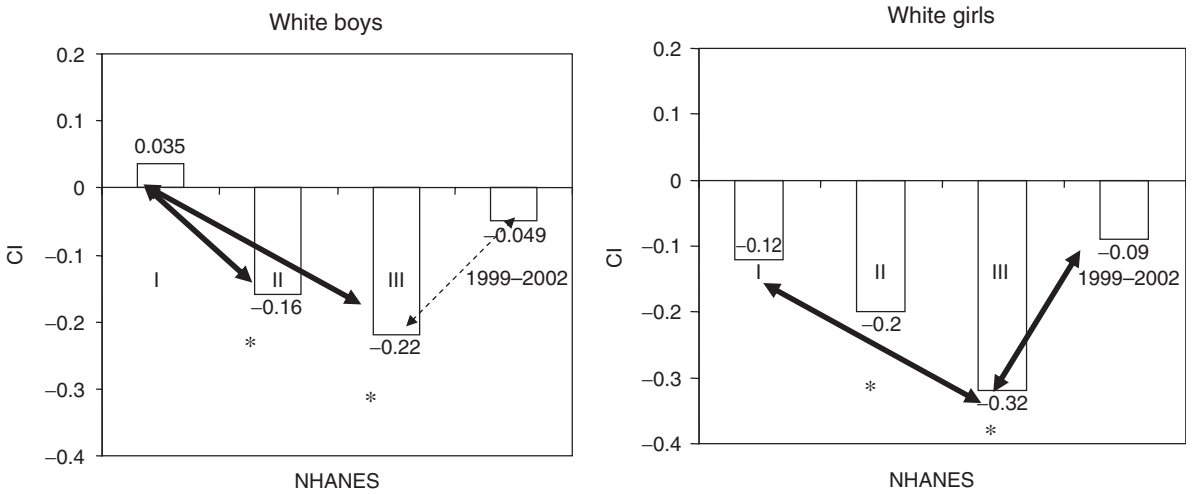

Figure 2 Trends in the concentration indices of overweight among white adolescents aged 10–18 years old (1971–2002). ◂⟶▸ *P*-value <0.05; ◂- - -▸ *P*-value >0.05 and *P*-value <0.10; **P*-value <0.05.

gender–ethnic groups, particularly among white adolescents. For white boys, the *P*-value of differences between CIs in NHANES I and II was 0.047, while the *P*-value of the differences between CIs in NHANES II and III was 0.034. For black adolescents, there was no strong socio-economic inequality in any waves; however, the direction of socio-economic inequality became more positive, or more concentrated in high SES groups, compared with those in previous waves. For black girls, the *P*-value of the differences between CIs in NHANES II and III was 0.040. Mexican-American boys showed similar trends. The CI increased between HHANES and NHANES III, but decreased to almost zero in NHANES 1999–2002, with *P*-values of the differences >0.05. Among Mexican-American girls, there was a reduction of socio-economic inequality in NHANES III, but the prevalence of overweight was more concentrated in the high SES in NHANES 1999–2002 (*P*-value of 0.04).

Discussion

Using the CI approach, which we recently introduced to the obesity field[12], we examined trends in the socio-economic inequality of overweight among US adolescents over the past three decades. Compared with traditional regression analysis,

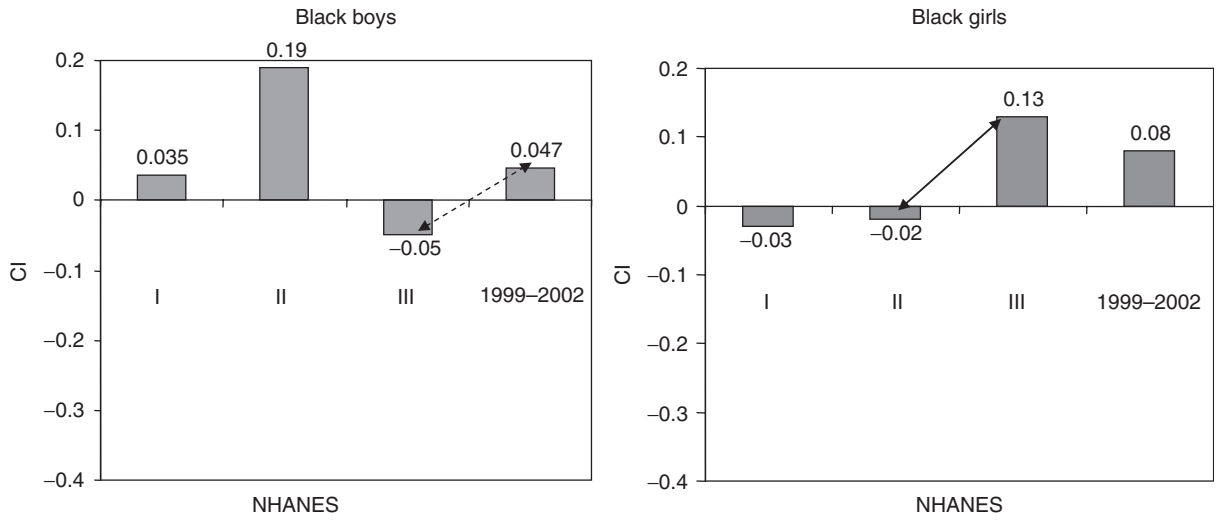

Figure 3 Trends in the concentration indices of overweight among black adolescents aged 10–18 years old (1971–2002). ⟷ *P*-value <0.05; ◂----▸ *P*-value >0.05 and *P*-value <0.10; **P*-value <0.05.

Figure 4 Trends in the concentration indices of overweight among Mexican-American adolescents aged 10–18 years old (1982–2002). ⟷ *P*-value <0.05; ◂----▸ *P*-value >0.05 and *P*-value <0.10; **P*-value <0.05.

CI has its advantages and limitations. One advantage is that because all respondents were included in the calculation of CI, results are not likely to be biased by the small sample sizes present in some gender–SES subgroups. Another advantage is that CI is more sensitive to changes in the socio-economic distribution. The primary limitation of CI is that it can only be applied if a strict ranking socio-economic variable, like income, is available. Although missing income can bias the value of CI, we estimated the effects of bias to be minimal in the present study because the percentage of subjects with missing income was small (Appendix 2) and randomized.

Our analysis shows that socio-economic inequality in overweight among adolescents varied across ethnic groups and over time. These findings suggest several characteristics in the trends of socio-economic inequality in adolescent overweight.

First, an inverse relationship between overweight and SES among US adolescents does not always exist—low-SES groups were not always at increased risk of overweight. Among black boys, only in NHANES III was overweight more concentrated in the low-SES group. Among black girls, overweight became more concentrated in high-SES groups after 1980. Only before 1980, overweight was slightly more concentrated among black girls in relatively low-SES groups. Similar patterns existed in Mexican-American groups, but the trends were less obvious. The study period for Mexican-American groups was shorter (1982–2002) and the study populations were different between HHANES and NHANES, which influenced the results. Among white adolescents, although low-SES groups experienced higher prevalence over time, the severity of overweight suggested an inverted U-shaped pattern. The evolving inequality of overweight among adolescents should alert researchers to approach the study of inequality within a dynamic framework, rather than a static study framework. Our findings also help explain inconsistent findings generated in previous studies regarding the socio-economic inequality of overweight among US young

people, i.e. pattern variation by age-, gender- and ethnic groups and time of data collection.

Second, socio-economic inequalities in adolescent overweight tended to diminish over time as the obesity epidemic progressed. In the 1970s, when the prevalence of overweight was relatively low among adolescents, socio-economic inequality was also quite negligible compared with later periods. However, in 1999–2002, when the prevalence of overweight had increased, socio-economic inequality was reduced relative to NHANES III. Among white girls, socio-economic inequality in overweight was less severe in 1999–2002 than in the earlier period of 1971–75.

One explanation is the unparalleled increase in the prevalence of overweight in American adolescents over time in the low- and high-SES groups. As shown in Table 2, a rapid increase in the prevalence of overweight in the low-income group occurred between NHANES II and III, while the rise in prevalence in the high-income group occurred primarily between NHANES III and NHANES 1999–2002. The longer gap between NHANES II and III (8 years) may partially account for the larger increase in adolescent overweight. Other possible accounts were given in our previous study.[36] We suspect that several factors might help explain the patterns we observed. In general, it has been argued that increased TV-viewing time and energy intake accompanied by decreased physical activity over time have contributed to the growing childhood overweight epidemic in the US.[37–39] One previous study showed that children with low SES were more likely to watch TV over 2 h/day.[40] During NHANES II and III, TV-watching may have been the primary type of inactivity among poor adolescents.

However, during NHANES III and 1999–2002, greater access to computers and computer games may have increased patterns of sedentary activity across all adolescents regardless of SES, thus diminishing inequalities in overweight. More studies are necessary to examine the trends in children's media usage.

Third, trends among US adolescents are quite different from trends among adults. Literature has suggested similar trends in the prevalence of overweight among US adults and adolescents.[1,2] However, few studies have examined differences in changes of the severity of disparity between adults and adolescents. Our previous study found that there was an almost monotonically diminishing inequality across SES groups among adults during the last three decades.[39] Socio-economic inequality was more severe in early years (e.g. before the 1990s). However, the current study showed the socio-economic inequality of overweight among adolescents was not obvious in the 1970s across gender–ethnic groups. The largest socio-economic inequality was observed in the late 1980s and early 1990s when the prevalence of overweight dramatically increased among adolescents. NHANES 1999–2002 revealed that SES-inequality has diminished, which is similar to what we observed in US adults.[39]

Unlike the social environment of adults, the relatively standardized school environment can mitigate the impact of SES on health-related behaviours. Adolescents are in a more adaptive stage compared with adults. They are more sensitive to social–environmental influences on body weight beyond the scope of their families. School curriculum, peer influence and the media could have a greater impact on adolescents than that of their parental characteristics, such as household income. These factors may help explain why the socio-economic inequality of overweight among adolescents is smaller than that among adults in most survey periods.

Childhood overweight epidemic is a complex public health problem related to people's dietary intake, physical activity, culture and built environment.[40,41] Societal changes in the US, and the shift of American adults and children's eating and physical activity patterns, combined with the between-population groups' differences in these shifts[42–46] are likely to help explain the changes we observed in the present study in adolescents and adults. To understand the underlying factors causing the changes in the socio-economic inequalities in adolescent overweight, more multidisciplinary research in trend analysis is needed. Knowledge from such undertaking will help enhance our understanding of the aetiology of the growing obesity epidemic and facilitate the elimination of health disparities.

In summary, using the CI approach, we expanded the research on the relation between SES and overweight beyond simple categorization (e.g. low, medium and high) of SES to exploit a full SES spectrum. In general, our findings are consistent with those based on classic statistical methods of analysis approaches.[16,17,23] Our findings suggest that obesity prevention-related policies and programmes should not focus only on disadvantaged groups of adolescents, e.g. minority and low-SES groups, but should adopt population-based interventions targeting all groups.

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KEY MESSAGES

- Socio-economic inequalities in adolescent overweight tended to diminish over time as the obesity epidemic progressed in US
- Trends in socio-economic inequality of adolescent overweight were different from those in adult obesity.
- CI is a useful tool to measure the changes in socio-economic inequality in adolescent overweight.

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Appendix 1 Sample sizes across socio-economic groups among white and black adolescents, 1971–2002

	HHANES (1982–84)	NHANES I (1971–75)	NHANES II (1976–80)	NHANES III (1988–94)	NHANES (1999–2002)
White boys					
Low income	N/A[a]	263	238	73	93
Medium income	N/A	362	354	140	165
High income	N/A	367	388	150	269
White girls					
Low income	N/A	270	227	92	100
Medium income	N/A	360	321	148	165
High income	N/A	346	327	175	255
Black boys					
Low income	N/A	235	143	297	294
Medium income	N/A	55	40	145	205
High income	N/A	21	22	78	101
Black girls					
Low income	N/A	271	134	321	308
Medium income	N/A	49	43	133	190
High income	N/A	22	15	75	97
Mexican American boys					
Low income	207	43	41	305	372
Medium income	252	7	19	111	228
High income	234	8	7	54	78
Mexican American girls					
Low income	243	33	32	298	363
Medium income	245	10	13	131	258
High income	215	4	3	66	105
Other American boys					
Low income	221[b]	3	32	33	17
Medium income	133[b]	4	20	23	12
High income	125[b]	5	12	9	17
Other American girls					
Low income	225[b]	4	31	37	22
Medium income	129[b]	3	10	27	19
High income	104[b]	2	8	9	17

[a]Ethnic groups not surveyed.
[b]Other Hispanic groups.

Appendix 2 Number of respondents who did not have income information: NHANES 1971–2002

	HHANES (1982–84)	NHANES I	NHANES II	NHANES III	NHANES (1999–2002)
Total sample size included	2342	2871	2582	3189	4352
Respondents missing income	9	104	102	259	416
Absolute percentage of missing income	0.38	3.62	3.95	8.12	9.56
Weighted percentage of missing income	0.38	4.22	3.94	5.54	7.53