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Income Disparities and Cardiovascular Risk Factors among Adolescents

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Abstract

Background and Objective: Socioeconomic disparities in cardiovascular health among adults have been documented, but disparities during adolescence are less understood. This study examined secular trends in 7 cardiovascular risk factors and disparities among US adolescents.

Methods: We analyzed National Health and Nutrition Examination Survey data from 1999-2014, including 11,557 (4,854 fasting) participants aged 12-19 years. To examine trends in cardiovascular risk factors, adolescents were stratified into 3 groups based on family income to poverty ratio (PIR): low income (PIR, <1.3), middle income (≥1.3 and <3.5), and high income (≥3.5).

Results: From 1999-2014, the prevalence of obesity increased (16.5% to 21.0%, p=0.001), but only among low and middle income adolescents, with significant disparities in prevalence by income (21.7% vs 14.6% among low vs high income adolescents, respectively, in 2011-2014). In addition, there were significant and persistent disparities in the prevalence of smoking (20.8% vs 7.4% among low vs high income adolescents, respectively, in 2011-2014), low quality diet (67.8% vs 49.0%), and physical inactivity (25.6% vs 17.0%). No significant disparities were observed in the prevalence of prediabetes/diabetes, hypertension, or hypercholesterolemia, although the prevalence of prediabetes/diabetes increased among low-income adolescents (21.4% to 28.0%, p=0.01). Overall, the prevalence of adolescents with two or more risk factors declined (48.3% to 37.1%, p<0.001), but this decline was only significant for high and middle income adolescents.

Conclusions: Recent improvements in cardiovascular health have not been equally shared by US adolescents of varying socioeconomic status.

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Contributors Statement

Dr. Jackson and Ms. Yang conceptualized and designed the study, drafted the initial manuscript, and reviewed and revised the manuscript. Dr. Zhang contributed to study design, conducted the analyses, and reviewed and revised the manuscript. All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

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This study of National Health and Nutrition Examination Survey data from 1999-2014 shows trends in cardiovascular risk factors and disparities among US adolescents.

Keywords

Adolescents; cardiovascular disease risk factors; trends; disparities

INTRODUCTION

Heart disease is the leading cause of death in the US population, with cardiovascular disease (CVD) claiming over 10 million lives in the past 18 years[1]. A substantial burden of cardiovascular risk factors exists among adolescents in the US[2] and globally,[3] and emerging evidence suggests that patterns of cardiovascular health are established early and track into adulthood.[4] There are striking disparities in risk factors and CVD across socioeconomic strata in the US,[5, 6] and lower socioeconomic status may influence CVD risk through diverse pathways including increased exposure to environmental hazards such as poor air quality; decreased educational attainment and poorer health behaviors; decreased access to healthcare; decreased family, neighborhood, and community resources such as healthy food and safe places for physical activity; and increased chronic stress associated with violence, deprivation, or discrimination.[7, 8] Few studies have examined secular trends in CVD risk factors and disparities among adolescents, despite the fact that disparities may be widening, given the increasing income inequality in the US.[9] The purpose of this study was to examine socioeconomic disparities in cardiovascular risk factor trends among US adolescents from 1999-2014.

METHODS

Study Design and Population

We used data from the National Health and Nutrition Examination Survey (NHANES), a nationally representative, cross-sectional survey of the civilian, noninstitutionalized US population. Data were collected through household interviews and physical examinations.[10] We included data from NHANES 1999-2002, 2003-2006, 2007-2010, and 2011-2014 for adolescents aged 12-19 years, excluding those pregnant (in NHANES 1999-2006, for which this information was available) or those with missing data (Supplemental Figure), yielding a total of 11,557. Of these, a random subsample of 4,854 adolescents had fasting glucose and lipid measurement; these adolescents had morning blood draws and reported fasting at least 8 hours since their last meal.

Variables

Sociodemographic variables—Demographic characteristics included age, sex, and race and Hispanic origin (classified as non-Hispanic white, non-Hispanic black, Mexican-American, and “other” for sufficient sample size). Income was categorized by family income to poverty ratio (PIR) values taken from the ratio of family income to poverty thresholds [stratified in 3 categories: low income (PIR <1.3), middle income (1.3≤ PIR <3.5), and high income (PIR ≥3.5)].[11] A PIR value of 1.3 corresponds to a family income 130% of

the poverty level for that survey year, 3.5 corresponds to 350%. Education of the head of household was categorized as <12 years, 12 years or GED, or >12 years.

Disparity Measures—To evaluate disparities in CVD prevalence trends across survey years, we used both absolute and relative measures of health disparity. We calculated the rate difference, an absolute measure, which captured the difference in risk factor prevalence between the low income group and high income group. We also calculated the Slope Index of Inequality (SII), which captured the average difference in risk factor prevalence among adolescents ranked from the lowest to the highest income group. The Relative Index of Inequality (RII) captured the mean risk factor prevalence of all weighted income groups. RII and SII are summary measures recommended for making comparisons over time.[12] These indices are regression-based, population-weighted disparity measurements, and take PIR group distribution into account. A negative SII indicates that the risk factor prevalence decreases with increasing PIR (from low to high income), a positive SII means that the prevalence increases with increasing PIR, and 0 indicates no association. Similarly, a negative rescaled RII (multiplying the results by 100) indicates the percentage decline in the risk factor's prevalence from low to high income groups, and vice versa for positive RII values. We used the Health Disparity Calculator developed by the National Cancer Institute to calculate the health disparity measures.[13]

Obesity—Adolescent weight status was classified according to age- and sex-specific reference values from the 2000 Centers for Disease Control and Prevention (CDC) growth charts.[14] Adolescents having a BMI ≥95th percentile were classified as having obesity.

Smoking—Smoking status was classified as "not current smoker", or "current smoker" [self-reported cigarettes within 30 days, *or* sex- and race-specific serum cotinine levels (≥8.78, ≥6.01, ≥1.18, and ≥8.78 ng/mL for non-Hispanic white, non-Hispanic black, Mexican American, and other males, respectively; ≥2.95, ≥2.81, ≥0.66, and ≥2.43 for corresponding females, respectively].[15] Established cutoffs for "other" race and Hispanic origin were not available, so corresponding sex-specific levels were used.

Low quality diet—The Healthy Eating Index 2010 (HEI-2010) has been validated and can reliably detect meaningful differences in diet quality.[16] It consists of 12 components representing major food groups including fruit and vegetables, whole grains, proteins, dairy, oils, sodium, and empty calories. The sum yields a total score ranging from 0-100, where a higher score indicates a more healthy diet.[17] In the present study, HEI-2010 scores ≤50 were classified as low quality diets,[18, 19] using the NHANES first 24-hour dietary recall.

Physical Inactivity—The NHANES survey questions for physical activity changed during this time period; for consistency, we only present physical activity data for NHANES 2007-2014. We classified adolescents as inactive if they reported no physical activity or <10 minutes in a typical week. Although correlations between self-reported and objectively-measured physical activity are low-to-moderate,[20] epidemiologic analyses have repeatedly demonstrated associations between cardiovascular outcomes and self-reported physical activity, and recommendations are largely based on self-reported data.[21]

Hypertension—The mean of up to three systolic and diastolic blood pressure (BP) readings were used to classify adolescents as having hypertension following age-, sex- and height-specific percentile tables provided in the 2017 American Academy of Pediatrics Clinical Practice Guideline.[22] For adolescents aged 12-17, hypertension was BP ≥95th percentile, BP ≥130/80 mm Hg, *or* anti-hypertensive medication use. For those aged 18-19, hypertension was ≥130/80 mm Hg *or* anti-hypertensive medication use. (Medication use was only available for adolescents aged 16-19 years.)

Prediabetes/diabetes—Adolescents with a self-reported diagnosis of diabetes, HbA1c ≥6.5%, or fasting plasma glucose (FPG) ≥126mg/dL were classified as having diabetes. Those without a self-reported diagnosis of diabetes, and having a HbA1c level of 5.7% to 6.4% or an FPG level of 100mg/dL to 125mg/dL, were classified as having prediabetes.[23] Forward calibration equations were used to adjust earlier NHANES cycles of data to be consistent with later years, to account for changes in glucose measurement methods over time.[24, 25] We combined diabetes and prediabetes into one category ("prediabetes/diabetes") for stable estimates, and restricted these analyses to the fasting sample.

Hypercholesterolemia—Serum total cholesterol (TC) levels were assessed using enzymatic reactions. Serum high-density lipoprotein cholesterol (HDL-C) was measured by direct immunoassay in 2007-2014 and by heparin manganese precipitation in 1999-2006.[26–28] Serum low-density lipoprotein cholesterol (LDL-C) was calculated using the following formula for adolescents with triglyceride level ≤400 mg/dL: LDL-C = TC - [HDL-C + (triglycerides/5)].[29, 30] Serum LDL-C levels were used to classify adolescents as having border-line high or high LDL-C. Adolescents were classified as having hypercholesterolemia if levels of LDL-C were ≥130 mg/dL or TC were ≥200mg/dL.[31] These analyses were restricted to adolescents with fasting data.

Statistical Analysis

We used multivariable logistic regression to estimate the prevalence of individual risk factors, as well as combinations of risk factors (1 or more; 2 or more) by PIR and period (1999-2002, 2003-2006, 2007-2010, and 2011-2014), adjusted for age, sex, and race and Hispanic origin. Analyses for prediabetes/diabetes, hypercholesterolemia, and combinations of risk factors used fasting sample data. Trends across survey periods, differences in prevalence between 1999-2002 vs 2011-2014, and differences in prevalence between low vs high income adolescents within each NHANES cycle, were assessed by t-test. We estimated the number of adolescents with risk factors in each PIR group by multiplying the PIR specific prevalence of risk factors by the total number of noninstitutionalized adolescents in each PIR category, derived from the Current Population Survey for each NHANES cycle (1999-2002, 2003-2006, 2007-2010, 2011-2014).[32] To estimate change in total number of adolescents with each risk factor across cycles, the estimated numbers of adolescents with each risk factor were summed across income categories, and then the summed estimates for NHANES 1999-2002 were subtracted from the summed estimates for NHANES 2011-2014. Examination weights were used for analysis of hypertension, physical inactivity, smoking and obesity, dietary weights were used for diet, and fasting subsample weights were used

for prediabetes/diabetes and hypercholesterolemia. SUDAAN, version 11, was used for analysis, taking into account the complex sampling design.

RESULTS

Among 11,557 US adolescents aged 12 to 19 years, the weighted percentage within each age, sex, and family income group remained consistent from 1999-2014 (Table 1). The proportion of adolescents under a household head who attained more than 12 years of education increased from 54.4% to 66.5% (P<0.001).

Obesity

Although the prevalence of obesity increased (16.5% to 21.0%, p=0.001), with an estimated increase of 1.8 million adolescents with obesity in 2011-2014 compared to 1999-2002 (Table 2; Fig 1A), increases were only observed among the low income (18.1% to 21.7%, p=0.002) and middle income (17.1% to 26.0%, p=0.01) groups. Among high income adolescents, obesity prevalence remained stable (14.3% to 14.6%, p=0.91). There were statistically significant disparities (RII and SII) in obesity prevalence in the most recent NHANES cycles (2007-2010 and 2011-2014).

Smoking

The prevalence of smoking as defined in this study declined among all adolescents (24.1% to 13.2%, p<0.001), with an estimated 3.3 million fewer current smokers in 2011-2014 compared to 1999-2002 (Table 2; Fig 1B). While declines were significant across all income strata, significant disparities persisted (both RII and SII), with low income adolescents having the highest prevalence of smoking throughout the survey period.

Low quality diet

The percentage of US adolescents consuming a low quality diet decreased (81.1% to 59.4%, p<0.001), with an estimated 6 million fewer adolescents with low quality diet in 2011-2014 compared to 1999-2002 (Table 2; Fig 1C). Improvements were significant across all income groups (all p<0.001). However, diet improved the most among high income adolescents, and significantly fewer high income adolescents had low quality diet compared to low income adolescents in 2011-2014. There was little disparity in the prevalence of low quality diet between income groups throughout the first three survey periods, but the disparity was statistically significant in 2011-2014.

Physical Inactivity

Overall, approximately 20% of US adolescents were physically inactive, which remained stable between 2007-2010 and 2011-2014 (Table 2; Fig 1D). The prevalence of physical inactivity differed among income groups, with low income adolescents (25.6%) more likely to be inactive than high (17.0%) income adolescents in 2011-2014. Disparities were statistically significant.

Hypertension

Overall, the prevalence of hypertension among US adolescents decreased from 1999-2014 (8.6% to 4.2%, p<0.001), with an estimated 1.3 million fewer adolescents having hypertension in 2011-2014 compared to 1999-2002 (Table 2; Fig 1E). Patterns were fairly consistent across income strata, and all income groups had statistically significant declines.

Prediabetes and diabetes

The prevalence of prediabetes and diabetes among US adolescents did not increase significantly from 1999-2014 (21.9% to 23.1%, p=0.33; Table 2; Fig 1F). There was a significant increase among low-income adolescents (21.4% to 28.0%, p=0.01), and a total of approximately 7.8 million adolescents had prediabetes and diabetes in 2011-2014.

Hypercholesterolemia

Hypercholesterolemia prevalence did not change significantly from 1999-2014 (11.1% to 8.5%, p=0.11) among US adolescents overall, or stratified by income (Table 2; Fig 1G).

Multiple risk factors

Most adolescents had at least 1 CVD risk factor (Supplemental Table). Overall, the proportion of adolescents with 1 or more CVD risk factors decreased across survey years (90.4% to 80.1%, p<0.001; Table 3). Throughout the first three survey periods, there was little disparity in prevalence of at least one CVD risk factor between income groups, but the disparity became significant in 2011-2014. The prevalence of having at least two risk factors declined overall (48.3% to 37.1%, p<0.001), but this decline was only significant among high and middle income adolescents.

DISCUSSION

This study provides a comprehensive analysis of secular trends in CVD risk factors and disparities among US adolescents from 1999-2014. During this time, the prevalence of obesity increased, but only among low and middle income adolescents. There were also significant and persistent disparities in the prevalence of smoking, low quality diet, and physical inactivity. No significant disparities were observed in the prevalence of prediabetes and diabetes, hypertension, or hypercholesterolemia for the most recent period (2011-2014), although the prevalence of prediabetes/diabetes increased among low income adolescents from 1999 to 2014. Overall, the prevalence of adolescents with two or more CVD risk factors declined during this period (primarily due to declines in smoking, low quality diet, and hypertension), but this decline was only significant for high and middle income adolescents.

Our findings are consistent with prior surveillance of adolescent obesity, which has increased across recent decades.[33] However, the most recent data from NHANES suggest a plateau in obesity prevalence, with a nonsignificant increase from 18.1% in 2007-2008 to 20.6% in 2015-2016 among those aged 12-19.[34] Our study indicates obesity has risen only among adolescents belonging to low and middle income groups, while remaining stable among high income adolescents. Disparities in adolescent obesity prevalence have

been previously reported,[35] and there are numerous pathways through which socioeconomic status may impact obesity and other cardiovascular risk factors.[7, 8]

For example, socioeconomic status may affect obesity and other cardiovascular risk factors by influencing both diet and physical activity.[36–40] Poverty is associated with food insecurity (which is paradoxically associated with obesity in the US),[41] reduced ability to afford healthy food such as fruits and vegetables, or neighborhood factors such as having fewer supermarkets and more fast food outlets.[38] We observed modest improvements in diet among all adolescents, which is consistent with prior work.[42, 43] However, high income adolescents improved the most, and disparities worsened over time. The prevalence of physical inactivity remained fairly stable between 2007-2014, but was significantly higher among low income adolescents compared to high income adolescents. Socioeconomic and racial/ethnic disparities in physical activity exist,[44] and may be related to factors such as difficulty affording equipment for organized sports, reduced access to parks and other places to exercise, and high crime rates or lack of perceived safety for outdoor physical activity.[45] Public health initiatives such as the US Surgeon General's "*Step It Up!"* call to action highlight the importance of community and environmental factors in improving physical activity.[46]

Increasing obesity prevalence, and high prevalence of both poor diet and physical inactivity, may have contributed to the observed increase in prediabetes and diabetes among low income adolescents.[47] Obesity, particularly abdominal obesity, is strongly associated with the development of insulin resistance and type 2 diabetes, and the period of pubertal insulin resistance may mean that adolescent development is a particularly vulnerable time if multiple risk factors for diabetes occur together.[48] Autonomic dysfunction and chronic inflammation may contribute to the link between obesity and diabetes.[49] The increase in prediabetes and diabetes among low income youth, combined with existing socioeconomic disparities and a growing burden of cardiometabolic disease among adults,[5, 44] is cause for concern. Increasing CVD risk factors such as obesity and diabetes among youth and young adults may be contributing to observed increases in burden of stroke among younger adults.[50] However, the present study could not distinguish between type 1 and type 2 diabetes, and underlying risk factors and trends of these conditions differ. If current trends continue, one study projected that the prevalence of type 1 diabetes may triple and type 2 diabetes may quadruple by 2050 among youth <20 years of age in the United States.[51]

The prevalences of smoking and hypertension decreased significantly and the prevalence of hypercholesterolemia remained stable. The observed decline in adolescent smoking is consistent with prior reports, and may reflect tobacco control efforts.[52, 53] However, this study could not examine use of other inhaled nicotine products (such as e-cigarettes) or marijuana, which may have increased during this time period.[54, 55] Moderate declines in hypercholesterolemia and in hypertension among adolescents have been previously shown.[56, 57] While largely unexplained, these trends may be related to improved diet or improved screening and earlier clinical intervention.[43, 58] Further research could explore the contrast observed between rising obesity and decreasing hypertension among US adolescents.

This study had several limitations. First, we could not exclude pregnant adolescents from NHANES 2007-2014 as pregnancy data became confidential; the number of pregnant teens in these cycles was likely to be small as NHANES stopped oversampling this subpopulation. Second, we only examined physical inactivity among adolescents for NHANES 2007-2014 to maintain consistency after NHANES questions were reformatted. Third, the HEI-2010 cutoff for low quality diet (≤50) was somewhat arbitrary, consistent with a previous study.[18] Fourth, HEI scores were based on a single 24-hour dietary recall and do not reflect usual intake for individuals. Fifth, up to three blood pressure measurements were taken during a single NHANES visit, rather than spread over multiple days as would be required for clinical diagnosis of hypertension.[22] Sixth, if any adolescents were not truly fasting, the prevalence of prediabetes/diabetes may have been over-estimated. However, among the fasting sample included in this study, all blood draws were taken in the morning and followed NHANES protocols to ensure fasting status. Seventh, the choice between forward-calibration (adjusting early years of glucose data to be comparable with later years) and backward-calibration (adjusting later years of glucose data to be comparable with earlier years) can influence estimates of prediabetes and diabetes prevalence in NHANES, and neither form of calibration accounts for variability in the calibration sample.[24, 25]

CONCLUSION

There is a disproportionate burden of CVD risk factors across socioeconomic strata among US adolescents, and some disparities appear to be worsening. This supports the need for further surveillance and public health action to address CVD risk factors and disparities among youth. Establishing healthy behaviors early in life can help maintain those behaviors into adulthood,[59] and addressing risk factors such as hypertension during adolescence may reduce cardiovascular risk later in life.[60] While individual-level behavior change and health education programs may be the least effective type of public health intervention,[8] broader strategies to improve adolescent health and reduce disparities include addressing the social determinants of health such as economic stability of families and communities; neighborhood and environmental factors such as housing, transportation, safety, and walkability; access to high-quality education from early childhood through K-12 schooling; social support systems; and access to quality healthcare.[61, 62] Within healthcare, related efforts include the Center for Medicare and Medicaid Innovation's State Innovation Models Initiative, which emphasizes population health; certain Medicaid delivery and payment reforms, such as patient centered medical homes (which coordinate care for persons with chronic conditions and can include care management, patient and family support, and referrals to social support services); and programs that support community health centers and community health workers.[62] Efforts to improve cardiovascular health and reduce disparities among adolescents may help to slow the rising tide of cardiovascular disease among middle aged adults,[50] and may help alleviate health inequalities.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Abbreviations

BP	blood pressure
CVD	cardiovascular disease
FPG	fasting plasma glucose
HEI-2010	Healthy Eating Index 2010
HDL-C	high-density lipoprotein cholesterol
LDL-C	low-density lipoprotein cholesterol
NHANES	National Health and Nutrition Examination Survey
PIR	income to poverty ratio
RII	Relative Index of Inequality
SII	Slope Index of Inequality
TC	total cholesterol
US	United States

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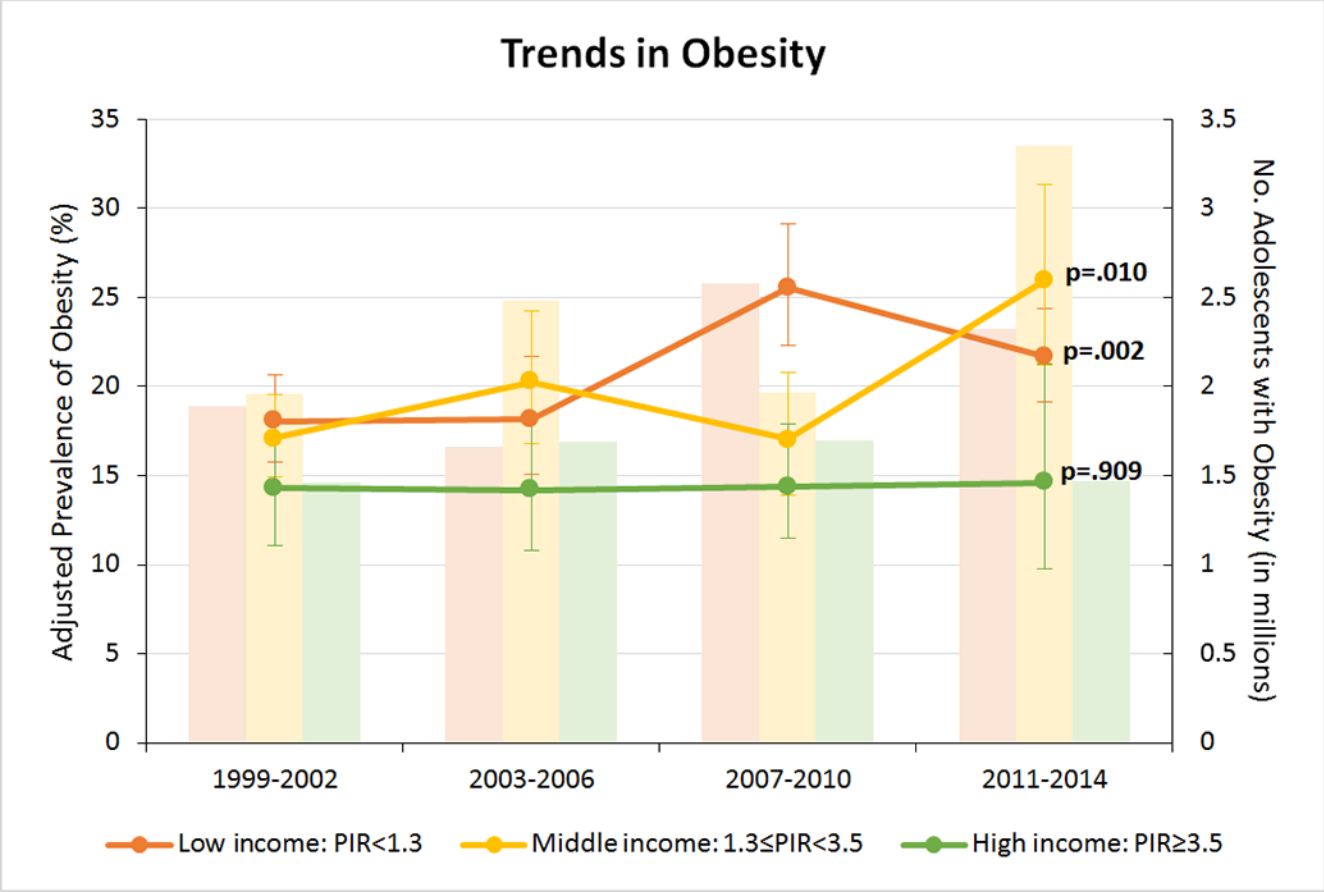
What's Known on this Subject:

There are socioeconomic disparities in cardiovascular disease among adults, but disparities during adolescence are less understood. Cardiovascular risk factors in adolescents are important because they can track into adulthood, and cardiovascular disease is a leading cause of morbidity and mortality.

What this Study Adds:

This study examined secular trends and socioeconomic disparities in cardiovascular risk factors among US adolescents from 1999-2014. Obesity increased, while other risk factors improved. Significant disparities persisted, and improvements were not shared equally across income strata.

A



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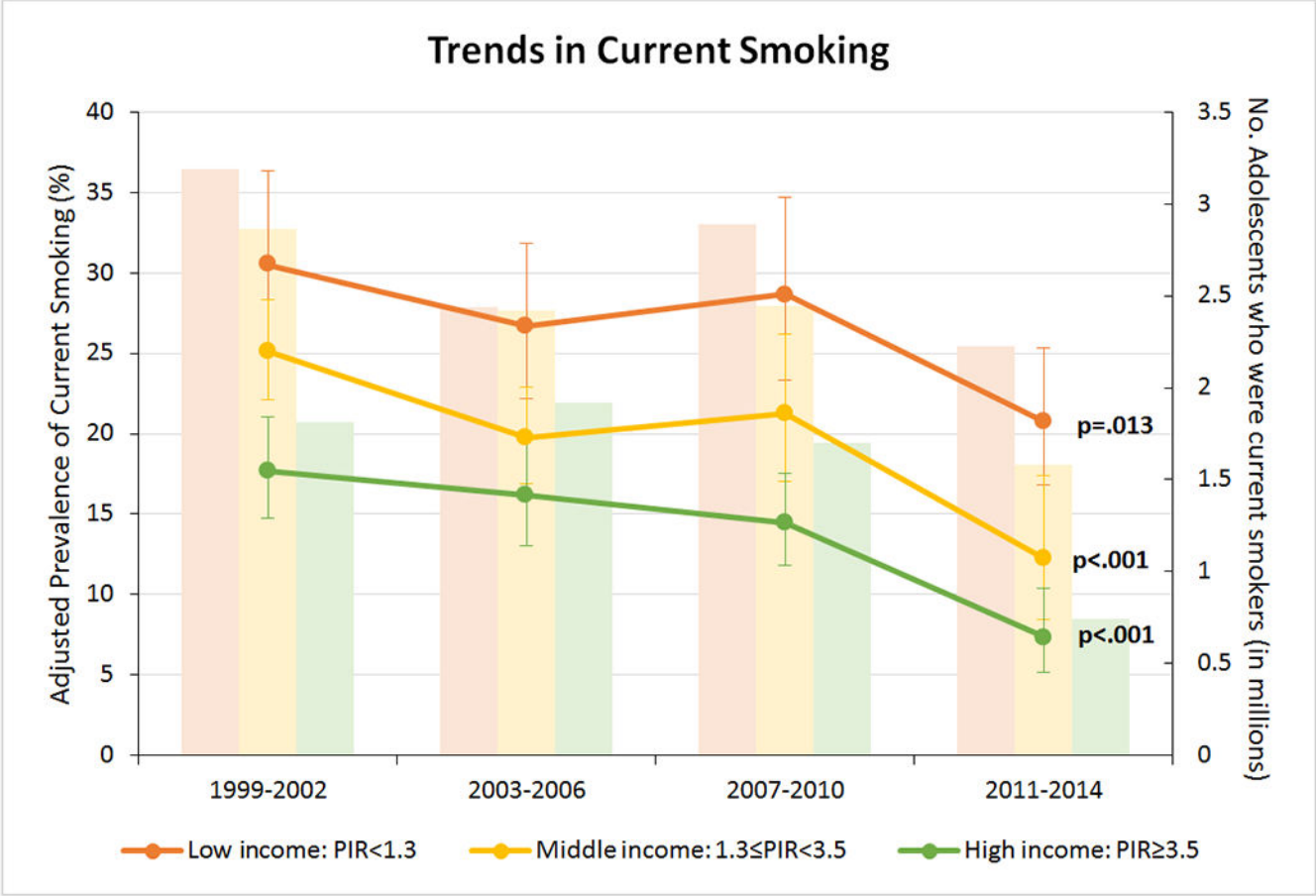

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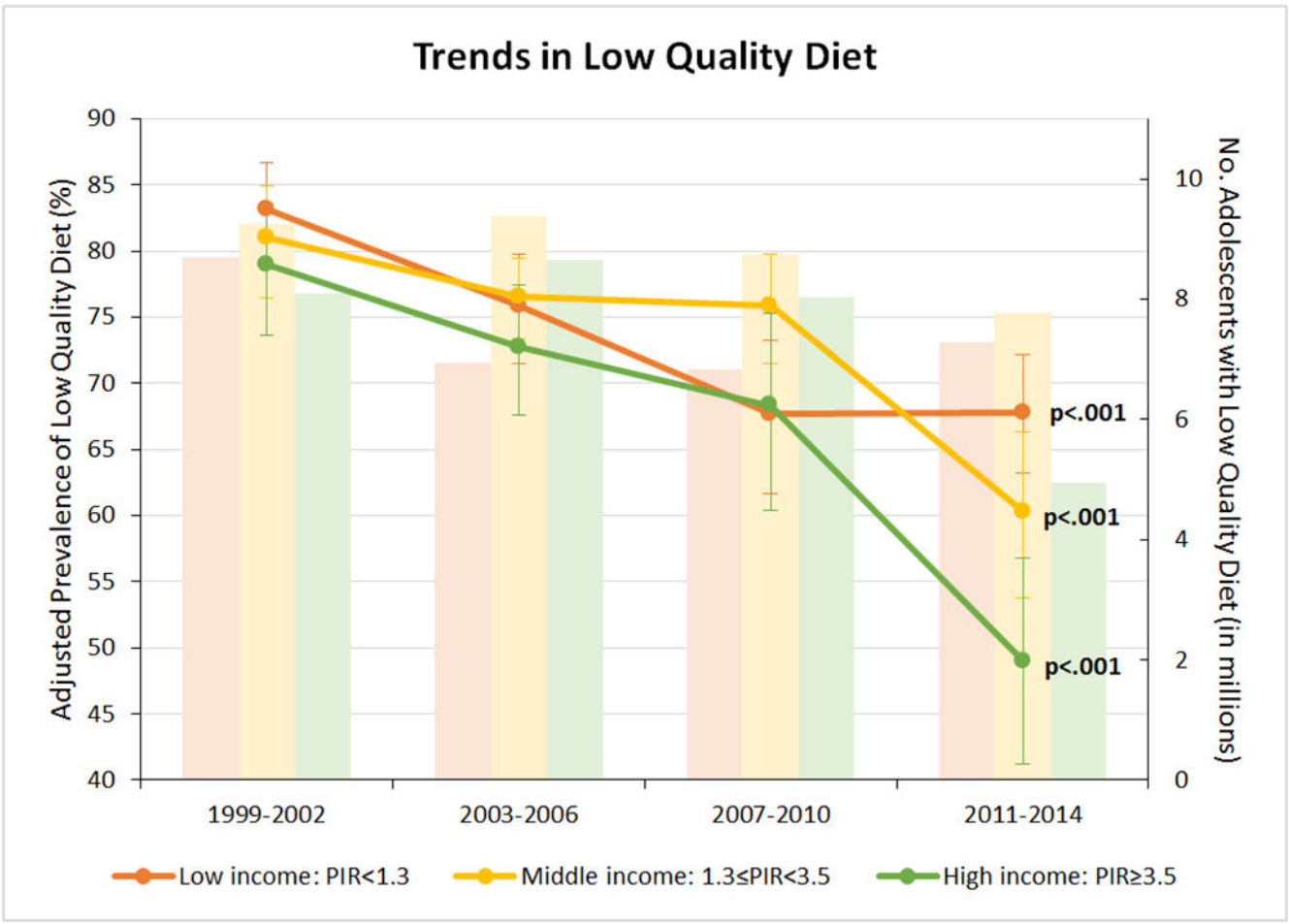

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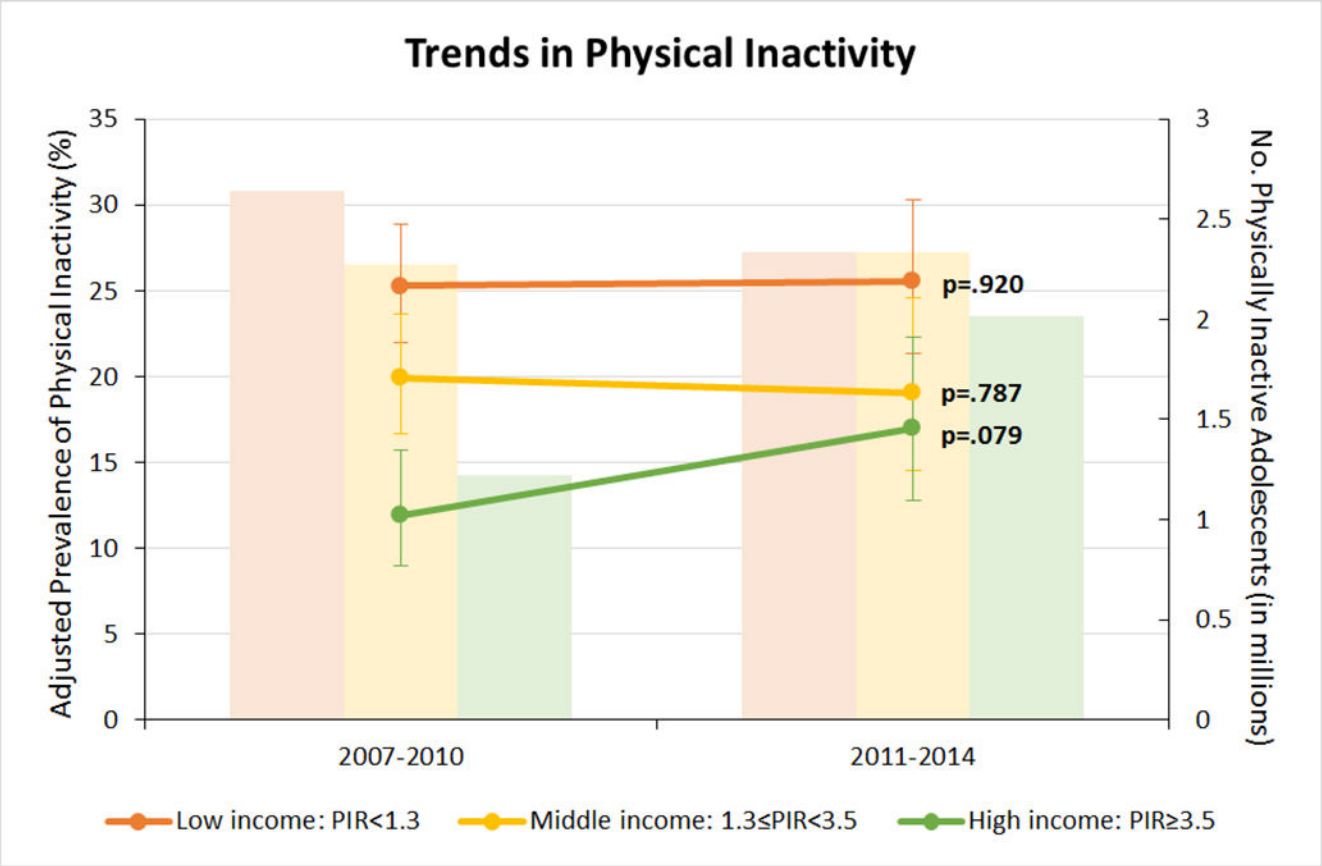

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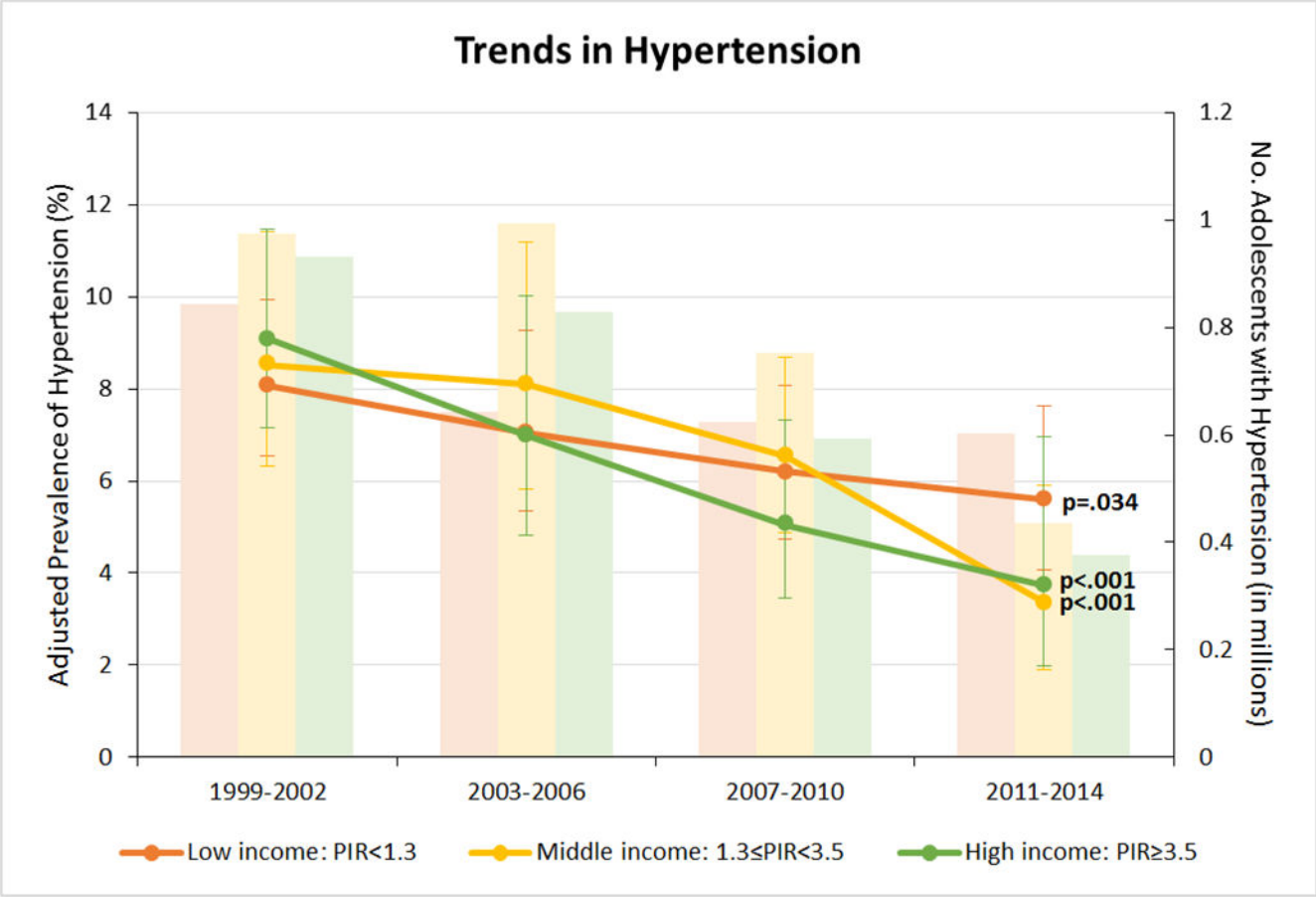

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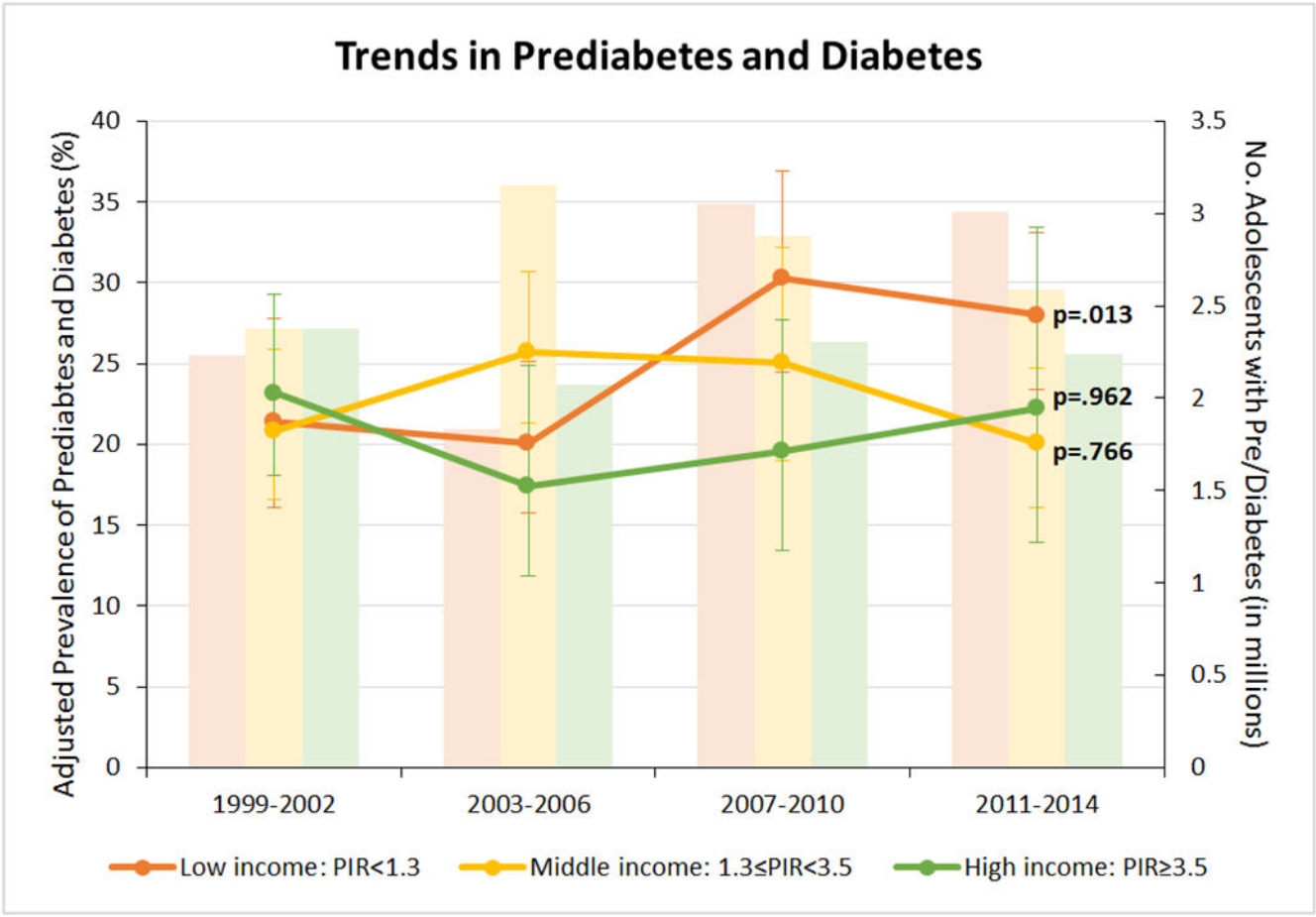

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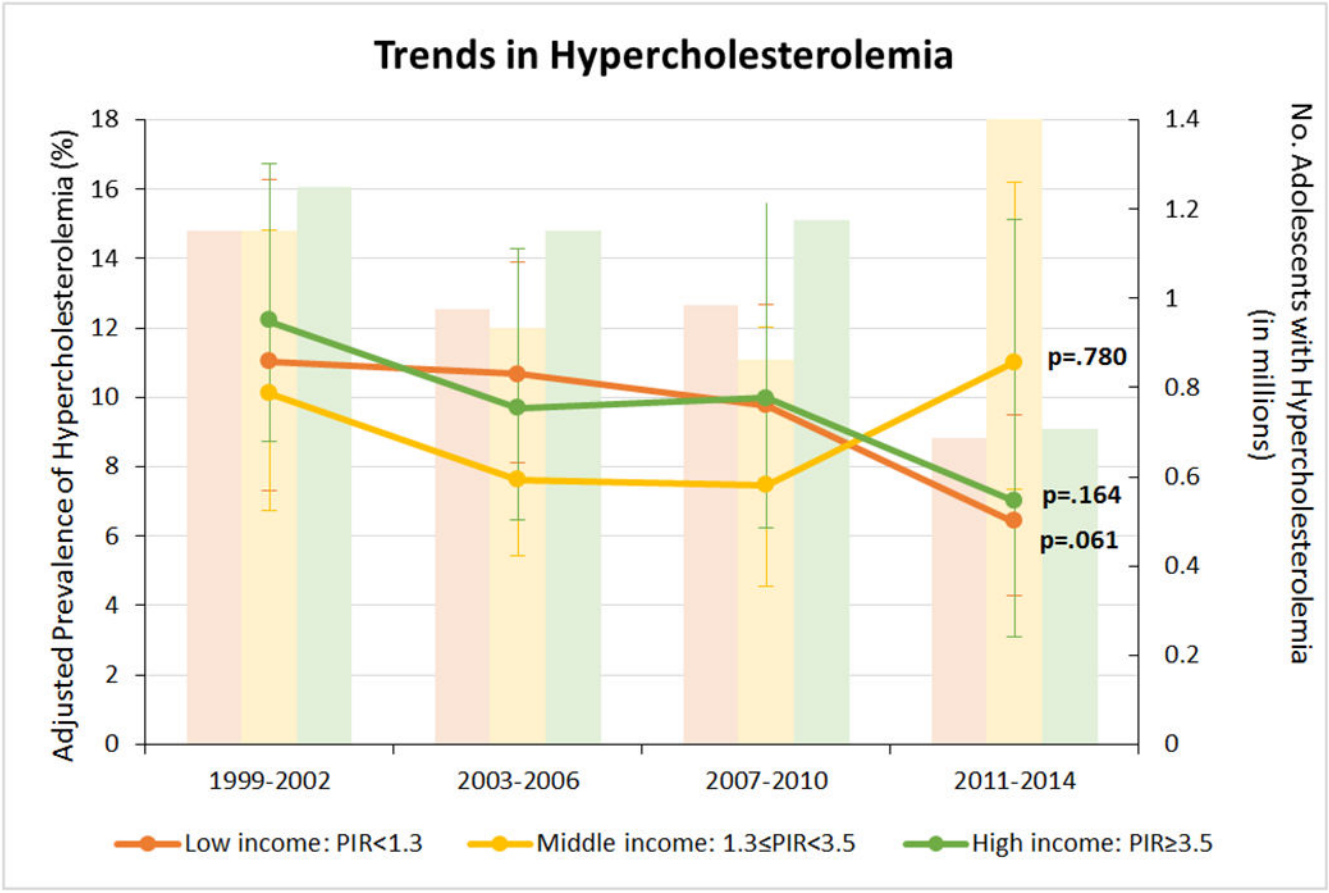

Figure 1:

Adjusted prevalence and trends of CVD risk factors and number of estimated adolescents by PIR among adolescents aged 12 to 19 years, NHANES 1999–2014. Adolescents having a BMI percentile ⩾95th percentile were classified as having obesity. Smoking status was classified as “current smoker” on the basis of self-reported smoking data or sex- and race-specific serum cotinine level. HEI-2010 scores ⩽50 were classified as low-quality diets. Physical inactivity was classified as no physical activity or <10 minutes of physical activity in a typical week in NHANES 2007 – 2014. Hypertension was classified according to 2017 AAP guidelines. Adolescents with a self reported diagnosis of diabetes, HbA1c ⩾6.5%, or FPG ⩾126 mg/dL were classified as having diabetes. Those without a self-reported diagnosis of diabetes but who had an HbA1c level of 5.7% to 6.4% or an FPG level of 100 to 125 mg/dL were classified as having prediabetes. Diabetes and prediabetes were combined into 1 category (prediabetes and diabetes). Adolescents were classified as having hypercholesterolemia if levels of LDL-C were ⩾130 mg/dL or TC were ⩾200 mg/dL.

Table 1.

Characteristics of Adolescents Aged 12-19 Years—NHANES 1999-2014

Characteristics	NHANES 1999-2002 N = 3792	NHANES 2003-2006 N = 3719	NHANES 2007-2010 N = 2040	NHANES 2011-2014 N = 2006	
	% (95% CI)	% (95% CI)	% (95% CI)	% (95% CI)	P-value for trend [a]
Age group					
12-15 year	51.4 (49.0-53.7)	52.2 (49.4-54.9)	51.8 (49.4-54.3)	52.4 (49.2-55.7)	0.659
16-19 year	48.6 (46.3-51.0)	47.8 (45.1-50.6)	48.2 (45.7-50.6)	47.6 (44.3-50.8)	
Sex					
Male	51.8 (49.8-53.7)	51.3 (49.2-53.4)	51.7 (49.1-54.3)	51.3 (48.4-54.2)	0.865
Female	48.2 (46.3-50.2)	48.7 (46.6-50.8)	48.3 (45.7-50.9)	48.7 (45.8-51.6)	
Race and Hispanic Origin					
Non-Hispanic white	60.3 (56.3-64.2)	64.6 (58.8-70.0)	61.4 (55.8-66.8)	56.8 (50.3-63.0)	0.259
Non-Hispanic black	13.2 (10.3-16.7)	14.5 (11.2-18.4)	14.0 (11.6-16.9)	14.1 (10.3-19.2)	0.772
Mexican American	10.3 (7.96-13.3)	10.9 (8.34-14.2)	12.3 (9.19-16.3)	14.1 (11.0-18.0)	0.073
Other	16.2 (12.5-20.8)	10.1 (8.06-12.5)	12.2 (9.43-15.7)	15.0 (12.4-17.9)	0.847
Education attainment of household head	n=3702	n=3622	n=2016	n=1983	
<12 years	21.2 (19.1-23.5)	14.7 (12.5-17.3)	15.5 (13.2-18.2)	16.1 (13.3-19.4)	0.017
12 years	24.4 (21.5-27.4)	22.4 (19.2-25.9)	18.8 (16.3-21.6)	17.4 (14.3-21.1)	<0.001
>12 years	54.4 (50.7-58.1)	62.9 (59.1-66.5)	65.6 (61.7-69.4)	66.5 (61.9-70.8)	<0.001
Poverty Income Ratio					
<1.3 (low income)	32.6 (29.8-35.5)	27.5 (23.7-31.6)	30.2 (26.6-34.1)	31.9 (25.7-38.7)	0.955
≥1.3-<3.5 (middle income)	35.5 (32.6-38.6)	36.8 (33.7-40.0)	34.5 (30.6-38.7)	38.3 (33.4-43.3)	0.524
≥3.5 (high income)	31.9 (28.9-35.0)	35.7 (31.2-40.5)	35.3 (30.4-40.5)	29.9 (24.6-35.8)	0.531

Abbreviations: CI, confidence interval; NHANES, National Health and Nutrition Examination Survey.

[a] *P*-values for trends across the NHANES surveys were based on t-tests; all tests 2-tailed.

Table 2.

Adjusted Prevalence of CVD Risk Factors by PIR in Adolescents Aged 12-19 Years, NHANES 1999-2014

Poverty-Income Ratio	NHANES 1999-2002	NHANES 2003-2006	NHANES 2007-2010	NHANES 2011-2014	P for Trend[a]	Difference 1999-2002 vs 2011-2014 (SE)
Obesity						
Overall	16.5 (14.9-18.2)	17.7 (15.2-20.5)	18.9 (16.8-21.1)	21.0 (18.8-23.4)	0.001	−4.55 (1.40)*
<1.3 (Low income)	18.1 (15.7-20.6)	18.2 (15.1-21.7)	25.6 (22.3-29.1)	21.7 (19.2-24.4)	0.002	−3.61 (1.74)*
1.3-<3.5 (Middle income)	17.1 (15.0-19.6)	20.3 (16.8-24.3)	17.1 (13.9-20.8)	26.0 (21.2-31.3)	0.010	−8.81 (2.82)*
≥3.5 (High income)	14.3 (11.1-18.2)	14.2 (10.8-18.4)	14.4 (11.5-17.9)	14.6 (9.75-21.3)	0.909	−0.33 (3.39)
Diff in prevalence between Low and High Income (SE)[b]	3.77 (1.84)*	3.96 (1.84)*	11.1 (2.33)**	7.05 (3.09)*	---	3.28 (3.56)
RII	−33.6 (−72.6-5.46)	−37.7 (−80.9-5.47)	−86.7 (−125--48.8)	−46.3 (−91.3--1.27)	---	---
SII	−5.55 (−11.8-0.72)	−6.60 (−14.0-0.77)	−16.2 (−23.1--9.33)	−9.81 (−18.7--0.90)	---	---
Current Smoking						
Overall	24.1 (21.6-26.8)	20.6 (18.8-22.6)	21.1 (18.9-23.5)	13.2 (11.3-15.4)	<0.001	10.9 (1.64)**
<1.3 (Low income)	30.5 (25.2-36.3)	26.7 (22.2-31.8)	28.7 (23.3-34.7)	20.8 (16.8-25.3)	0.013	9.74 (3.40)*
1.3-<3.5 (Middle income)	25.1 (22.1-28.3)	19.8 (16.9-22.9)	21.3 (17.1-26.2)	12.3 (8.47-17.4)	<0.001	12.8 (2.73)**
≥3.5 (High income)	17.7 (14.8-21.1)	16.2 (13.0-19.9)	14.4 (11.8-17.6)	7.35 (5.15-10.4)	<0.001	10.3 (2.01)**
Diff in prevalence between Low and High Income (SE)[b]	12.8 (2.88)**	10.6 (3.22)*	14.3 (3.31)**	13.4 (2.63)**	---	0.60 (3.76)
RII	−77.0 (−113--41.4)	−73.6 (−114--32.9)	−100 (−140--60.4)	−144 (−195--93.4)	---	---
SII	−18.9 (−28.3--9.45)	−15.0 (−23.4--6.61)	−21.1 (−30.3--11.9)	−19.5 (−26.6--12.3)	---	---
Healthy Eating Index Score ≤50						
Overall	81.1 (78.7-83.2)	75.2 (73.2-77.2)	70.8 (66.9-74.5)	59.4 (55.6-63.1)	<0.001	21.7 (2.18)**
<1.3 (Low income)	83.1 (78.9-86.7)	75.9 (71.5-79.8)	67.7 (61.6-73.3)	67.8 (63.2-72.2)	<0.001	15.3 (2.89)**
1.3-<3.5 (Middle income)	81.1 (76.4-85.0)	76.6 (73.3-79.5)	75.9 (71.5-79.8)	60.3 (53.8-66.4)	<0.001	20.8 (3.87)**
≥3.5 (High income)	79.0 (73.6-83.6)	72.8 (67.6-77.5)	68.3 (60.4-75.3)	49.0 (41.2-56.8)	<0.001	30.0 (4.71)**
Diff in prevalence between Low and High Income (SE)[b]	4.10 (3.32)	3.07 (3.31)	−0.60 (4.68)	18.8 (4.85)**	---	14.7 (5.79)*

Poverty-Income Ratio	NHANES 1999-2002	NHANES 2003-2006	NHANES 2007-2010	NHANES 2011-2014	P for Trend[a]	Difference 1999-2002 vs 2011-2014 (SE)
RII	−7.44 (−18.9-3.97)	−6.57 (−19.3-6.13)	−0.05 (−20.0-19.9)	−45.8 (−68.6--22.9)	---	---
SII	−6.04 (−15.3-3.18)	−4.93 (−14.4-4.55)	−0.04 (−14.1-14.1)	−27.1 (−40.0--14.3)	---	---
Physical Inactivity						
Overall	---	---	19.1 (17.1-21.3)	20.4 (18.1-23.0)	0.424	−1.34 (1.67)
<1.3 (Low income)	---	---	25.3 (22.0-28.9)	25.6 (21.4-30.3)	0.920	−0.27 (2.68)
1.3-<3.5 (Middle income)	---	---	19.9 (16.7-23.6)	19.1 (14.5-24.6)	0.787	0.85 (3.15)
≥3.5 (High income)	---	---	11.9 (8.94-15.7)	17.0 (12.8-22.3)	0.079	−5.09 (2.87)
Diff in prevalence between Low and High Income (SE)[b]	---	---	13.4 (2.40)**	8.57 (3.62)*	---	−4.82 (4.08)
RII	---	---	−107 (−147--67.1)	−61.0 (−107--14.5)	---	---
SII	---	---	−20.0 (−27.1--12.9)	−12.5 (−21.9--3.17)	---	---
Hypertension						
Overall	8.55 (7.37-9.89)	7.43 (5.84-9.40)	5.93 (4.81-7.27)	4.22 (3.37-5.27)	<0.001	4.33 (0.79)**
<1.3 (Low income)	8.07 (6.54-9.93)	7.05 (5.34-9.26)	6.20 (4.74-8.07)	5.60 (4.08-7.62)	0.034	2.47 (1.21)*
1.3-<3.5 (Middle income)	8.53 (6.32-11.4)	8.11 (5.82-11.2)	6.54 (4.88-8.70)	3.37 (1.90-5.89)	<0.001	5.16 (1.59)*
≥3.5 (High income)	9.09 (7.16-11.5)	6.98 (4.81-10.0)	5.05 (3.46-7.31)	3.74 (1.98-6.97)[c]	<0.001	5.34 (1.65)*
Diff in prevalence between Low and High Income (SE)[b]	−1.02 (1.13)	0.08 (1.48)	1.15 (1.25)	1.85 (1.46)	—	2.87 (1.87)
RII	17.6 (−28.5-63.6)	−4.42 (−68.7-59.9)	−30.7 (−94.6-33.2)	−65.8(−171-39.0)	—	—
SII	1.50 (−2.47-5.47)	−0.33 (−5.08-4.42)	−1.82 (−5.53-1.90)	−2.76 (−6.93-1.42)	—	—
Prediabetes and Diabetes[d]						
Overall	21.9 (19.0-25.1)	21.4 (17.8-25.6)	24.7 (21.3-28.5)	23.1 (20.2-26.3)	0.325	−1.19 (2.16)
<1.3 (Low income)	21.4 (16.1-27.8)	20.1 (15.8-25.1)	30.3 (24.4-36.9)	28.0 (23.4-33.1)	0.013	−6.63 (3.77)
1.3-<3.5 (Middle income)	20.9 (16.6-25.9)	25.7 (21.3-30.7)	25.0 (19.0-32.2)	20.0 (16.1-24.7)	0.766	0.81 (3.22)
≥3.5 (High income)	23.2 (18.1-29.3)	17.4 (11.9-24.9)	19.6 (13.4-27.7)	22.2 (14.0-33.4)	0.962	1.00 (5.69)
Diff in prevalence between Low and High Income (SE)[b]	−1.84 (4.11)	2.64 (3.71)	10.7 (4.91)*	5.80 (6.05)	---	7.63 (7.28)

Poverty-Income Ratio	NHANES 1999-2002	NHANES 2003-2006	NHANES 2007-2010	NHANES 2011-2014	P for Trend[a]	Difference 1999-2002 vs 2011-2014 (SE)
RII	12.4 (−42.3-67.1)	−25.0 (−82.2-32.2)	−64.5 (−124--5.03)	−37.2 (−107-32.6)	---	---
SII	2.69 (−9.20-14.6)	−5.30 (−17.1-6.53)	−15.9 (−30.0--1.86)	−8.65 (−24.1-6.82)	---	---
Hypercholesterolemia [d]						
Overall	11.1 (9.00-13.6)	9.19 (7.41-11.3)	9.01 (6.91-11.7)	8.45 (6.55-10.9)	0.110	2.63 (1.58)
<1.3 (Low income)	11.0 (7.31-16.3)	10.7 (8.12-13.9)	9.77 (7.46-12.7)	6.40 (4.28-9.49)	0.061	4.62 (2.52)
1.3-<3.5 (Middle income)	10.1 (6.75-14.8)	7.63 (5.44-10.6)	7.48 (4.57-12.0)	11.0 (7.34-16.2)	0.780	−0.91 (2.99)
≥3.5 (High income)	12.2 (8.74-16.8)	9.70 (6.47-14.3)	9.98 (6.23-15.6)	7.01 (3.08-15.1)[e]	0.164	5.18 (3.49)
Diff in prevalence between Low and High Income (SE) *b*	−1.17 (3.25)	0.97 (2.54)	−0.22 (2.86)	−0.60 (3.05)	---	0.57 (4.41)
RII	15.4 (−63.7-94.5)	−9.62 (−87.5-68.3)	6.56 (−80.6-93.7)	13.2 (−89.7-116)	---	---
SII	1.70 (−7.01-10.4)	−0.89 (−7.99-6.22)	0.59 (−7.36-8.55)	1.10 (−7.64-9.84)	---	---

Prevalences are adjusted for age, sex, and race and Hispanic origin. Adolescents having a BMI percentile ≥95th percentile were classified as having obesity. Smoking status was classified as “current smoker” based on self-reported smoking data or sex- and race-specific serum cotinine level. HEI-2010 scores ≤50 were classified as low quality diets. Physical inactivity was classified as no physical activity or <10 minutes of physical activity in a typical week in NHANES 2007-2014. Hypertension was classified according to 2017 AAP guidelines. Adolescents with a self-reported diagnosis of diabetes, HbA1c ≥6.5%, or fasting plasma glucose (FPG) ≥126mg/dL were classified as having diabetes. Those without a self-reported diagnosis of diabetes, and having an HbA1c level of 5.7% to 6.4% or an FPG level of 100mg/dL to 125mg/dL, were classified as having prediabetes. Diabetes and prediabetes were combined into one category (prediabetes/diabetes). Adolescents were classified as having hypercholesterolemia if levels of LDL-C were ≥130 mg/dL or TC were ≥200mg/dL. Abbreviations: PIR, poverty income ratio; RII, relative inequality index, and RII has been rescaled by multiplying the results by 100; SII, slope index of inequality; NHANES, National Health and Nutrition Examination Survey.

*indicates p-value <0.05;

**indicates p-value <0.001.

*a.*P-value for testing trend across NHANES cycles based on t-test, all tests 2-tailed

*b.*P-value for interaction between PIR and survey years based on Wald χ^2 test: Obesity p=0.008; Current smoking p=0.586; HEI-2010 p= 0.019; Physical activity p=0.319; Hypertension p=0.330; Prediabetes/diabetes p=0.003, and Hypercholesterolemia p=0.348.

*c.*Relative standard error (RSE) >30% (31.8%)

*d.*Fasting samples were used to estimate the prevalence and disparity measures for hypercholesterolemia and prediabetes and diabetes.

Table 3.

Adjusted Prevalence[a] and Disparity of Number of CVD Risk Factors[b] by Poverty-Income Ratio in Adolescents Aged 12-19 Years –NHANES, 1999-2014

Poverty-Income Ratio	NHANES 1999-2002	NHANES 2003-2006	NHANES 2007-2010	NHANES 2011-2014	P-value for Trend[a]	Prev. Diff 1999-2002 vs 2011-2014
One or more Risk Factors [b]						
Overall	90.4 (87.8-92.6)	89.3 (86.7-91.4)	87.1 (84.2-89.6)	80.1 (75.3-84.1)	<0.001	10.4 (2.53)**
<1.3 (Low income)	92.4 (87.8-95.4)	89.4 (85.0-92.6)	88.5 (84.3-91.6)	86.2 (80.1-90.7)	0.049	6.19 (3.16)
1.3-<3.5 (Middle income)	89.1 (83.7-92.9)	90.9 (87.2-93.6)	86.8 (80.7-91.2)	81.5 (73.9-87.3)	0.036	7.59 (4.09)
≥3.5 (High income)	90.0 (86.2-92.9)	87.2 (81.4-91.3)	86.0 (80.1-90.3)	71.0 (60.1-79.8)	<0.001	19.1 (5.34)**
Diff in prevalence between Low and High Income[c]	2.38 (2.31)	2.21 (3.08)	2.52 (3.03)	15.3 (5.75)*	---	12.9 (6.12)*
RII	−3.92 (−11.9-4.09)	−4.22 (−14.5-6.02)	−4.23 (−15.0-6.50)	−27.5 (−48.2--6.76)	---	---
SII	−3.55 (−10.8-3.71)	−3.76 (−12.8-5.33)	−3.68 (−13.0-5.62)	−21.9 (−38.0--5.94)	---	---
Two or more Risk Factors [b]						
Overall	48.3 (44.6-52.1)	48.5 (43.5-53.4)	43.2 (40.0-46.4)	37.1 (33.4-40.8)	<0.001	11.3 (2.62)**
<1.3 (Low income)	53.5 (45.8-60.9)	53.2 (45.0-61.2)	51.5 (44.9-58.0)	47.3 (41.8-52.9)	0.178	6.14 (4.64)
1.3-<3.5 (Middle income)	42.3 (36.4-48.4)	50.5 (44.9-56.1)	43.2 (37.0-49.6)	34.7 (27.8-42.3)	0.046	7.61 (4.77)
≥3.5 (High income)	49.7 (42.7-56.7)	41.8 (34.1-49.9)	35.9 (29.0-43.5)	29.1 (19.6-40.8)	<0.001	20.6 (6.38)*
Diff in prevalence between Low and High Income[c]	3.77 (5.18)	11.4 (5.07)*	15.6 (4.88)*	18.3 (6.79)*	---	14.5 (8.39)
RII	−11.8 (−43.1-19.5)	−35.7 (−70.5--0.94)	−53.7 (−88.5--18.9)	−71.8 (−122--21.1)	---	---
SII	−5.71 (−20.9-9.44)	−17.2 (−33.7--0.68)	−23.1 (−37.7--8.60)	−26.6 (−43.7--9.49)	---	---

Prevalences are adjusted for age, sex, and race and Hispanic origin. Adolescents having a BMI percentile ≥95th percentile were classified as having obesity. Smoking status was classified as “current smoker” based on self-reported smoking data or sex- and race-specific serum cotinine level. HEI-2010 scores ≤50 were classified as low quality diets. Hypertension was classified according to 2017 AAP guidelines. Adolescents with a self-reported diagnosis of diabetes, HbA1c ≥6.5%, or fasting plasma glucose (FPG) ≥126mg/dL were classified as having diabetes. Those without a self-reported diagnosis of diabetes, and having an HbA1c level of 5.7% to 6.4% or an FPG level of 100mg/dL to 125mg/dL, were classified as having prediabetes. Diabetes and prediabetes were combined into one category (prediabetes/diabetes). Adolescents were classified as having hypercholesterolemia if levels of LDL-C were ≥130 mg/dL or TC were ≥200mg/dL. Abbreviations: PIR, poverty income ratio; RII, relative inequality index, and RII had been rescaled by multiplying the results by 100; SII, slope index of inequality; NHANES, National Health and Nutrition Examination Survey.

* indicates p-value <0.05

a. P-value for testing trends across NHANES cycles based on t-test.

[b] Fasting samples were used to estimate the prevalence of number of CVD risk factors. Number of risk factors is calculated out of 6 total (obesity, smoking, low quality diet, hypertension, prediabetes/diabetes, hypercholesterolemia). Physical inactivity was not included, as consistent data were not available across all 4 time intervals examined.

[c] P-value for interaction between PIR and survey years: One or more risk factors p=0.40; Two or more risk factors p=0.07.