SSM - Population Health 13 (2021) 100745

Contents lists available at ScienceDirect

SSM - Population Health

journal homepage: http://www.elsevier.com/locate/ssmph

Trends of biomarkers of cardiovascular disease in the United States by income: Disparities between the richest 20% and the poorest 80%,1999–2018

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A R T I C L E I N F O

Keywords:
Obesity
Blood pressure
CVD risk Factors
Income inequality
Cardiovascular disease

A B S T R A C T

Introduction: Income inequality between the richest 20% and the poorest 80% in the United States has been increasing over the past two decades. Emerging evidence indicates widening disparities between the two groups in cardiovascular disease prevalence as well. However, the mechanisms behind this trend remains unclear. This analysis examines whether a similar trend exists in the levels of biomarkers and risk factors of cardiovascular disease in the United States.

Methods: We conducted a serial cross-sectional analysis of a nationally representative data from the National Health and Nutrition Examination Survey (NHANES) for participants age 20 or older between 1999 and 2018. We calculated trends in age-standardized means of body mass index (BMI), systolic blood pressure (SBP), and high-density lipoproteins (HDL) and the trend in prevalence of obesity, high SBP, and low HDL by income group.

Results: This analysis included 49,764 participants. Age-standardized mean BMI increased every two years by an average of 0.15 kg/m 2 among the richest 20% and by an average of 0.21 kg/m 2 among the poorest 80%. Age-standardized mean SBP decreased every two years by an average of 0.13 mm Hg among the richest 20% and by an average of 0.10 mm Hg among the poorest 80%. Age-standardized mean HDL increased every two years by an average of 0.39 mg/dL among the richest 20% and by an average of 0.19 mg/dL among the poorest 80%. When adjusted for demographic factors and time, the richest 20% had lower mean BMI (OR = −0.67, 95% CI: −0.89, -0.44), lower mean SBP (OR = −0.72, 95% CI: −1.24, −0.20), and higher mean HDL (OR = 3.04, 95% CI: 2.46, 3.62) compared to the poorest 80%

Conclusion: There are increasing disparities in cardiovascular disease biomarkers by income in the US. Between 1999 and 2018, improvement in biomarkers overwhelmingly occurred among the richest 20%

Introduction

Income inequality in the United States has increased dramatically over the past few decades, reaching levels similar to those observed during the great depression (Saez, 2019). The increasing income gap has inspired a public conversation about the causes, and potential consequences, of such inequality levels. However, the focus on the divide between the top 1% and the remainder of the population elides the growing income inequality between the richest 20% and the poorest 80% of Americans (US Census Bureau, 2016), which may be, in a number of ways, more significant to the health of the population.

Over the past two decades, the income of the richest 20%, adjusted for inflation, has increased while the income of the poorest 80% has either stayed constant or declined (Bor et al., 2017). In 2018, the average annual income for the richest 20% per household was $234,000 compared to $54,000 for the poorest 80%. The two groups also differ on a number of other demographic factors including marital status and educational attainment. About 77% of the richest 20% are married and 67% have a college degree or more. Conversely, 41% of the poorest 80% are married and only 28% have a college degree or more (Perry, 2019).

The association between income and health is well-established, with those with higher income level having lower morbidity and mortality across nearly all health outcomes (Braveman et al., 2010; Chetty et al., 2016; Cristia, 2007; Galea et al., 2011; Mackenbach et al., 2008; WHO Commission on social determinants of health, 2008). It will then not be surprising if the richest 20% accumulate more health, while the

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https://doi.org/10.1016/j.ssmph.2021.100745
Received 31 August 2020; Received in revised form 3 January 2021; Accepted 26 January 2021
Available online 30 January 2021

remainder of the population become the "health left behinds". For example, there is early evidence that life expectancy increased consistently over the past few decades among the richest 20% while the poorest 80% saw fewer, if any, gains (National Academies of Sciences and Engineering and M, 2015).

It is conceivable, therefore, that the widening in income inequality between the two groups may be an important contributor to the worsening of population-level health indictors in the United States (Woolf & Schoomaker, 2019). In other work we found a widening disparity in cardiovascular disease prevalence between the richest 20% and the poorest 80% in the United States between 1999 and 2016 (Abdalla et al., 2020). However, the mechanisms behind these differences remain unclear. An understanding of differences in biomarkers and risk factors of cardiovascular disease in the two groups may help explain these disparities. Aiming to do so, we used a nationally representative dataset to assess the trend in levels of three biomarkers and clinically significant risk factors associated with cardiovascular disease for both the richest 20% and the poorest 80% between 1999 and 2018.

Methods

Data source and study population

We used data from the National Health and Nutrition Examination Survey (NHANES) to report on trends in biomarkers and clinically significant cardiovascular disease risk factors (National Center for Health Statistics, 2014). We included data from 10 waves (surveyed every two years) of NHANES from 1999 to 2018 among adults 20 years and older, as some of the demographic variables we used in the analysis were only collected with these age restrictions. To increase estimate precision and reduce sampling error, we developed weight variables for the dataset. Following NHANES guidelines, we used a 4-year weight for the first two survey cycles (1999–2002) and a 2-year weight for survey cycles 3 to 10 (2003–2018) to create a 20-year weight variable that represents the 10 survey cycles in our study population (NHANES, 2020). The demographic variables we included in this analysis were age, gender, race and ethnicity, marital status, education, and citizenship status (STROBE, 2020). This study did not require institutional approval as we used de-identified publicly available data for the analysis. NHANES data collection process is approved by the National Center for Health Statistics (NCHS) Research Ethics Review Board and requires document consent from all participants (CDC. NHANES - NCHS Research, 2020).

Income variable

We used the income-to-poverty ratio index developed by NHANES to stratify the population into two income groups. The income-to-poverty ratio index accounts for annual family income, adjusted for geographic location, family size, and inflation (NHANES, 2015). For our analysis, income-to-poverty ratio index was reported as missing when a participant's income data were missing, or if a participant reported their annual income as "<$20,000" or ">$20,000", without providing their specific annual family income. These participants were excluded from our analysis.

We created a binary variable of either an index equal to or greater than 5 (richest 20% group) or less than 5 (poorest 80% group). Because of the structure of NHANES reporting on income—in which participants with very high income are grouped in one category to avoid disclosure concerns—the analysis distribution did not fully align with the richest 20% and poorest 80% of participants cutoff. The "richest 20%" income group represented between 22 and 26% (weighted) of the sample in each survey cycle, i.e. every two years.

Outcome variables

We included data from participants who received medical examinations through NHANES to obtain body mass index (BMI), systolic blood pressure (SBP), and high-density lipoproteins (HDL). BMI was calculated by NHANES using weight in kilograms divided by height in meters squared. In addition, we calculated the mean SBP for each participant as the NHANES medical examination includes the collection of three consecutive measurements of SBP, with a fourth measurement taken if a previous reading was incomplete.

We then dichotomized these biomarkers into binary variables for a sub-analysis to obtain the prevalence of clinically significant risk factors for cardiovascular disease. We used the following cutoff values: BMI equal to or greater than 30 kg/m^2 for obesity; SBP equal to or greater than 130 mm Hg for high systolic blood pressure; and HDL lower than or equal to 40 mg/dL for low HDL.

Statistical analysis

We first performed descriptive analysis to compare basic demographic characteristics among richest 20% and poorest 80% group using Chi-square and SAS Surveyfreq procedure, which allowed us to obtain nationally representative estimates by accounting for the complex survey design and incorporating NHANES sampling weights, using the 2010 census population (NHANES, 2020). To assess the trends in biomarker levels between 1999 and 2018, we calculated the age-standardized mean of each biomarker by using linear regression, with survey cycle as a continuous variable. We then applied the DOMAIN statement to estimate the trend within the richest 20% and poorest 80% income groups. We used the same process to calculate age-standardized prevalence of obesity, high SBP, and low HDL. We used point estimates of the survey cycle variable to assess the magnitude of the trend.

We applied multivariable linear regression models to study the effects of income group on mean BMI, SBP, and HDL from 1999 to 2018, controlling for survey cycle and the following demographic variables: age, gender, race/ethnicity, marital status, education, and citizenship. We used a test significance was at 0.05 level for all calculations, and the hypothesis tests were two-sided.

Results

Our final sample included 49,764 adults who were 20 years or older, excluding participants with missing data on income, which constituted 9.6% of the overall sample during the analysis period. Among participants included in the analysis, 489 had missing data on marital status, 60 on education, 70 on citizenship status, 3066 on BMI, 6926 on SBP, and 4896 on HDL. The two income groups had different distribution of all demographic variables examined. The two demographic variables with the most pronounced differences between the two groups included marital status and educational attainment; 72.3% of the richest 20% were married compared to 50.5% among the poorest 80%. In addition, 55.8% of the richest 20% had a college degree or more compared to only 18.7% in the poorest 80% (Table 1).

Unadjusted trend in the means of biomarkers

Age-standardized mean BMI increased by an average of 0.15 kg/m^2 (p-value = 0.0003) per survey cycle (every two years) among the richest 20% group and by an average of 0.21 kg/m^2 (p-value<0.0001) per survey cycle among the poorest 80% group. Age-standardized mean SBP decreased by an average of 0.13 mm Hg (p-value = 0.18) per survey cycle among the richest 20% group and by an average of 0.10 mm Hg (p-value = 0.09) per survey cycle among the poorest 80% group. Age-standardized mean HDL increased by an average of 0.39 mg/dL (p-value = 0.0002) per survey cycle among the richest 20% group and by an average of 0.19 mg/dL (p-value = 0.0008) per survey cycle among the poorest 80% group (Fig. 1a–c).

Table 1
Demographic characteristics of study participants stratified by income group, 1999–2018.

Participants	Richest 20% (n = 8764)	Poorest 80% (n = 41,000)	*p*-value
Age			<.0001
20–39 y	2512 (28.2%)	14,742 (41.0%)	
40–59 y	3611 (49.1%)	12,011 (33.9%)	
≥60 y	2641 (22.7%)	14,247 (25.1%)	
Gender			<.0001
Men	4526 (51.8%)	19,481 (46.9%)	
Women	4238 (48.2%)	21,519 (53.1%)	
Race/ethnicity			<.0001
Non-Hispanic White	5340 (83.3%)	17,238 (64.0%)	
Non-Hispanic Black	1327 (5.6%)	8997 (12.9%)	
Hispanic and Mexican	999 (4.6%)	11,314 (16.2%)	
Other	1098 (6.5%)	3451 (6.9%)	
Marital status*			<.0001
Not married	2608 (27.7%)	20,808 (49.5%)	
Married	6068 (72.3%)	19,791 (50.5%)	
Education*			<.0001
No high school diploma	446 (3.6%)	12,802 (21.5%)	
High school graduate/GED or equivalent	1170 (13.9%)	10,332 (27.4%)	
Some college or AA degree	2400 (26.7%)	11,719 (32.4%)	
College graduate or above	4746 (55.8%)	6089 (18.7%)	
Citizenship*			<.0001
US citizen	8270 (96.5%)	34,689 (89.8%)	
Non-US citizen	491 (3.5%)	6244 (10.2%)	

Data are from the National Health and Nutrition Examination Survey (NHANES) between 1999 and 2018 (n = 49,764). Results are shown as n (weighted %). *Marital status missing from 489 participants, education missing from 60 participants, and citizenship status missing from 70 participants. The Richest 20% cut-off was defined by income-to-poverty > 5 in NHANES dataset.

Unadjusted change in the prevalence of clinically significant risk factors between 1999-2000 and 2017–2018

Fig. 2 shows that both income groups saw an increase in obesity prevalence between the 1999–2000 and 2017–2018 survey cycles. However, the richest 20% had a sharper increase in obesity prevalence, from 23.5% (95% CI:17.07, 30.00) in 1999–2000 to 40.3% (95% CI:33.23, 47.44) in 2017–2018, compared to the poorest 80% group. Conversely, the richest 20% saw a sharper decrease in the prevalence of high SBP and low HDL. For high SBP, the prevalence among the richest 20% decreased from 27.3% (95% CI:22.90, 31.79) in 1999–2000 to 23.2% (95% CI:19.00, 27.46) in 2017–2018 while the prevalence among the poorest 80% went from 31.4% (95% CI:28.52, 34.23) in 1999–2000 to 30.1% (95% CI:27.47, 32.73) in 2017–2018. For low HDL, the prevalence among the richest 20% decreased from 21.1% (95% CI:15.40, 26.87) in 1999–2000 to 11.6% (95% CI:7.88, 15.41) in 2017–2018 while the prevalence among the poorest 80% went from 25.8% (95% CI:22.63, 28.97) in 1999–2000 to 17.1% (95% CI:14.70, 19.58) in 2017–2018.

Adjusted association between income group and mean of biomarkers

There was a significant difference in the mean value of all three biomarkers between the two income groups when accounting for time passing (through controlling for survey cycle) and other demographic covariates listed in Table 2. Compared to participants in the poorest 80% group, those in the richest 20% group had lower mean BMI (OR = −0.67, 95% CI: −0.89, −0.44), lower mean SBP (OR = −0.72, 95% CI: −1.24, −0.20), and higher mean HDL (OR = 3.04, 95% CI: 2.46, 3.62).

Adjusted association between other demographic variables and mean of biomarkers

Table 2 summarizes the association between demographic variables and the means of biomarkers. Overall, older age, higher educational attainment, and being a non-US citizen were associated with better outcomes. The direction of the association between gender, race/ethnicity, and marital status and biomarker levels differed depending on the biomarker.

The association between race/ethnicity and biomarkers level was particularly strong. Compared to Black participants, white participants had healthier mean levels of biomarkers; they had lower mean BMI (OR = −1.95, 95% CI: −2.18, −1.71) and lower mean SBP (OR = −4.65, 95% CI: −5.22, −4.08). Conversely, white participants had a lower mean HDL (OR = −3.18, 95% CI: −3.68, −2.67) compared to Black participants.

Discussion

In a nationally representative analysis of 49,764 adults in the United States between 1999 and 2018, we found that the richest 20% had healthier levels of BMI, SBP, and HDL compared to the poorest 80%. Both groups saw an improvement in the mean of SBP and HDL. In 1999–2000, mean SBP was 121.8 mm Hg and 124.0 mm Hg among the richest 20% and the poorest 80%, respectively. In 2017–2018, mean SBP was 121.9 mm Hg and 123.7 mm Hg among the richest 20% and the poorest 80%, respectively. In 1999–2000, mean HDL was 52.4 mg/dL and 49.9 mg/dL among the richest 20% and the poorest 80%, respectively. In 2017–2018, mean HDL was 55.8 mg/dL and 52.6 mg/dL among the richest 20% and the poorest 80%, respectively. Conversely, both groups had worse BMI levels between 1999 and 2018. In 1999–2000, mean BMI was 27.3 kg/m^2 and 28.3 kg/m^2 among the richest 20% and the poorest 80%, respectively. In 2017–2018, mean BMI was 29.2 kg/m^2 and 30.1 kg/m^2 among the richest 20% and the poorest 80%, respectively.

Our results build on the evidence for income-based disparities in cardiovascular disease biomarkers in the United States (Caleyachetty et al., 2015; Havranek et al., 2015; Kanjilal et al., 2006). However, our analysis focuses on the architecture of these differences, illustrating that the 20% versus the 80% differences are among the drivers of growing health gaps in the country. There are echoes of these findings in the available literature. For example, Odutayo et al. found that, between 1999 and 2014, mean SBP among the low-income group (below the poverty line) decreased from 127.6 mm Hg in 1999–2004 to 126.8 mm Hg in 2011–2014. During the same period, mean SBP in the high-income group decreased from 126.0 mm Hg in 1999–2004 to 122.3 mm Hg in 2011–2014 (Odutayo et al., 2017). Another study by Ogden et al. reported that the prevalence of obesity among those in the lowest income groups (≤130% the federal poverty line) was 39% while the prevalence among the highest income group (>350% the federal poverty line) was 31.2% during 2011–2014. They also found that from 1999 to 2002 to 2011–2014 the obesity prevalence increased among all women except those in the highest income group and among men for all income groups (Ogden et al., 2017). We show that many of these disparities may be driven by differences between the richest 20% and entire poorest 80% cohorts rather than just the those who are below the poverty line, and the gap is deepening over time.

An exception to the general trend we observe is in obesity. We found that both mean BMI and obesity prevalence increased for both groups during the analysis period. However, the rate of increase in obesity prevalence among the richest 20% led to a comparable obesity prevalence between the two income groups in 2017–2018. The increase in both mean BMI and obesity in both groups supports emerging evidence that ubiquitous structural and environmental factors, which are part of the United States national infrastructure, may play a key role in the rising obesity epidemic (Maddock, 2004; Sallis et al., 2020; Wen et al., 2018). This highlights the importance of further examining other social, structural, and environmental factors that may be driving the obesity epidemic in the United States.

Being in richest 20% is likely associated with a range of positive

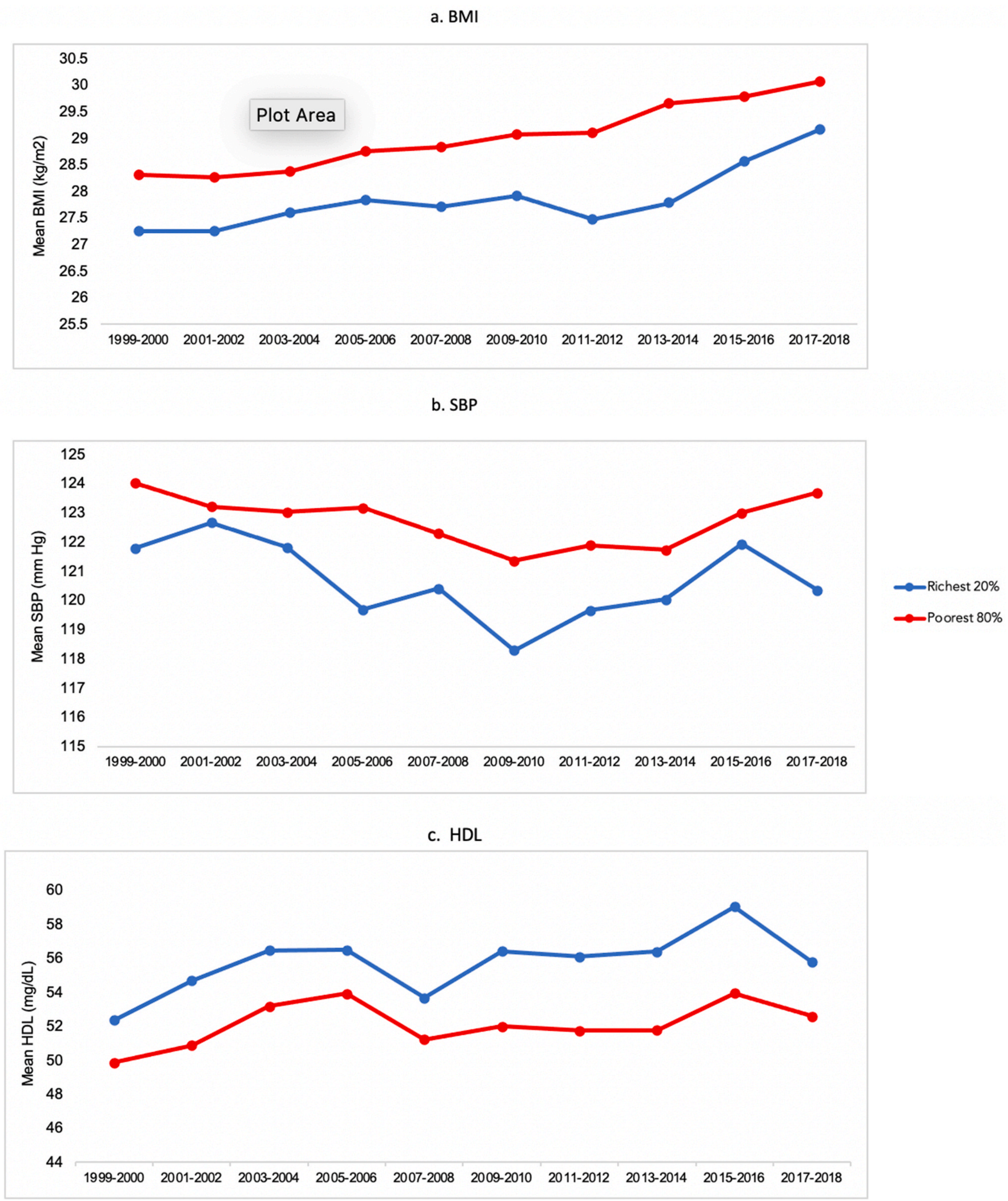

Fig. 1. a–c: Age-standardized mean BMI, mean SBP, and mean HDL by survey cycle, stratified by income group, 1999–2018.
Data are from 49,764 participants in the National Health and Nutrition Examination Survey (NHANES) between 1999 and 2018. The Richest 20% cut-off was defined by income-to-poverty > 5 in NHANES dataset.

assets that contribute to better health. In an earlier analysis, we reported a widening disparity in cardiovascular disease prevalence between the richest 20% and the poorest 80% in the United States (Abdalla et al., 2020). Our observation that being part of the richest 20% is associated with a better biomarker profile is a confirmation of the many pathways through which having more resources can result in better health outcomes. Importantly, our analysis adds to the growing evidence that income inequality undermines population health, either on its own or as an effect modifier that worsens the effects of established determinantal factors to the health of populations (Babones, 2008; Backlund et al., 2007; Hill et al., 2019; Jorgenson et al., 2020; Kaplan et al., 1996; Thombs et al., 2020). For example, a recent analysis by Hill and

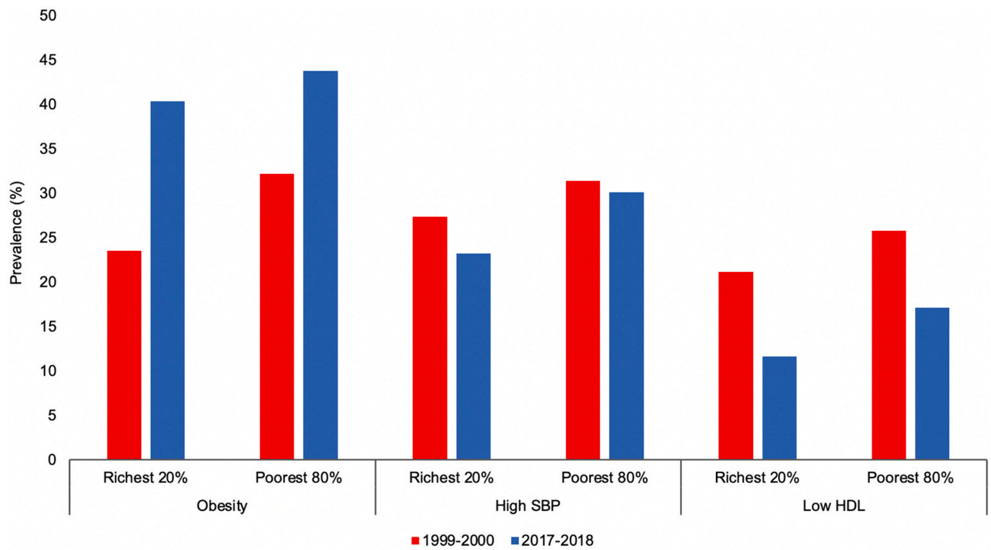

Fig. 2. Age-standardized prevalence of clinically significant thresholds of biomarkers (risk factors) stratified by income group, 1999–2000 and 2017–2018.
Data are from 49,764 participants in the National Health and Nutrition Examination Survey (NHANES) between 1999 and 2018. Obesity was defined as BMI of greater than or equal to 30 kg/m^2. High SBP was defined as SBP greater than or equal to 130 mm Hg. The Richest 20% cut-off was defined by income-to-poverty > 5 in NHANES dataset.

Table 2
Multivariable regression of mean biomarker levels for BMI, SBP, and HDL among participants aged ≥ 20, adjusted for demographic covariates, 1999–2018.

Variables	Mean BMI* (kg/m^2)		Mean SBP* (mm Hg)		mean HDL* (mg/dL)	
	Estimate (95% CI)	*p*-value	Estimate (95% CI)	*p*-value	Estimate (95% CI)	*p*-value
Age						
40-59 vs. 20-39	1.27 (1.07, 1.47)	<.0001	7.87 (7.42, 8.32)	<.0001	1.09 (0.67, 1.51)	<.0001
60+ vs. 20-39	0.68 (0.43, 0.92)	<.0001	19.00 (18.42, 19.59)	<.0001	3.14 (2.60, 3.68)	<.0001
Gender						
female vs. male	0.22 (0.06, 0.37)	0.01	−3.63 (−4.02, −3.25)	<.0001	10.86 (10.45, 11.28)	<.0001
Race/Ethnicity						
White vs. Black	−1.95 (−2.18, −1.71)	<.0001	−4.65 (−5.22, −4.08)	<.0001	−3.18 (−3.68, −2.67)	<.0001
Hispanic/Mexican vs. Black	−0.63 (−0.91, −0.36)	<.0001	−4.23 (−4.87, −3.59)	<.0001	−4.82 (−5.46, −4.18)	<.0001
Other vs. Black	−3.35 (−3.72, −2.97)	<.0001	−3.62 (−4.44, −2.80)	<.0001	−4.25 (−5.03, −3.47)	<.0001
Survey trend						
Survey cycle vs previous survey cycle	0.22 (0.17, 0.26)	<.0001	−0.09 (−0.19, 0.01)	0.08	0.18 (0.09, 0.28)	0.0003
Marital status*						
married vs. not married	0.68 (0.51, 0.85)	<.0001	−1.04 (−1.46, −0.62)	<.0001	−0.97 (−1.35, −0.60)	<.0001
Education*						
High school graduate vs. no high school diploma	0.32 (0.05, 0.58)	0.02	−1.12 (−1.65, −0.60)	<.0001	0.54 (0.00, 1.08)	0.05
Some college vs. no high school diploma	0.34 (0.08, 0.60)	0.01	−2.02 (−2.61, −1.44)	<.0001	1.45 (0.87, 2.03)	<.0001
College graduate or above vs. no high school diploma	−1.06 (−1.35, −0.78)	<.0001	−4.26 (−4.85, −3.67)	<.0001	4.59 (3.93, 5.26)	<.0001
Citizen status*						
Non-US citizen vs. US citizen	−1.80 (−2.06, −1.54)	<.0001	−1.60 (−2.23, −0.97)	<.0001	0.44 (−0.20, 1.07)	0.17
Income to poverty ratio						
Richest 20% vs. Poorest 80%	−0.67 (−0.89, −0.44)	<.0001	−0.72 (−1.24, −0.20)	0.01	3.04 (2.46, 3.62)	<.0001

Data are from 49,764 participants in the National Health and Nutrition Examination Survey (NHANES) between 1999 and 2018.
*BMI data missing for 3066 participants, SBP data missing for 6926 participants, and HDL data missing for 4896 participants, marital status data missing from 489 participants, education data missing from 60 participants, and citizenship status data missing from 70 participants. The Richest 20% cut-off was defined by income-to-poverty > 5 in NHANES dataset.

Jorgenson found that state-level income inequality undermines the life expectancy of both women and men in the Unites States (Hill & Jorgenson, 2018).

Limitations

This study should be considered with several limitations in mind. First, the NHANES data structure limited our ability to create a clear income cut-off that divides the study participants into two income groups, the richest 20% versus the poorest 80%. However, the central purpose in our stratification is to identify general groups that can explain health divides and we suggest that a 20:80 divided is more meaningful to population health than is the typical consideration of the richest 1% or comparison between the highest income group and the lowest income group. Second, the small sample size when stratifying income groups by racial ethnic groups sub-groups reduced our ability to investigate whether the overall trends by income group observed in this analysis may differ for different racial/ethnic groups. Third, the sample analyzed excluded any participants with missing data on income, primarily due to the nature of how the income-to-poverty index is presented in NHANES. Participants included in the analysis also had missing data on a number of variables, including biomarkers. Our results can embed biases if the reasons for missing data were systematic, although there was no evidence, empiric or theoretical, to suspect this was the case. Fourth, this study uses serial cross-sectional data, suggesting the need for further research to fully describe causal pathways between income group and levels of biomarkers in the United States.

Conclusion

In an analysis comparing biomarkers levels and risk factors—which ultimately lead to cardiovascular disease—we found that gains in establishing healthier biomarker levels between 1998 and 2018 were concentrated among the richest 20%. These results show that the ever-greater concentration of resources among the richest 20% stand then to embed disparities and widen gaps in cardiovascular disease in the United States over time.

Author statement

Salma Abdalla: Conceptualization, Methodology, Visualization, and Writing- Original draft preparation. Shui Yu: Data curation, Software, Formal analysis, and Writing - Review & Editing. Sandro Galea: Conceptualization, Methodology, Supervision, and Writing- Reviewing and Editing.

Ethical statement

Salma M Abdalla: Conceptualization, Methodology, Formal analysis, Writing - original draft, Writing - review & editing. Shui Yu: Methodology, Formal analysis, Writing - review & editing. Sandro Galea: Conceptualization, Methodology, Writing - review & editing.

Declaration of competing interest

Sandro Galea receives consulting fees from Sharecare and activity. Salma M Abdalla and Shui Yu declare no competing interest.

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