European Journal of Preventive Cardiology

ESC European Society of Cardiology

Full research paper

European Journal of Preventive Cardiology
0(00) 1–10

DOI: 10.1177/2047487320905190
journals.sagepub.com/home/cpr

SAGE

Increased awareness, inadequate treatment, and poor control of cardiovascular risk factors in American young adults: 2005–2016

Rajat Kalra[1], Vibhu Parcha[2], Nirav Patel[3], Anirudh Bhargava[3], Katherine S Booker[4,5], Garima Arora[2] and Pankaj Arora[2,6]

Abstract

Introduction: There are little contemporary data about cardiovascular risk factors among young adults. We defined trends in diabetes mellitus (DM), hypertension, and hypercholesterolemia in American adults aged 18–44 years.

Methods: The National Health and Nutrition Examination Study serial cross-sectional surveys were used to define three time periods: 2005–2008, 2009–2012, and 2013–2016. Age-adjusted weighted trends of prevalence, awareness, treatment, and control of DM, hypertension, and hypercholesterolemia were calculated by linear regression modelling in the overall sample, males, and females. Trends were calculated after adjustment for age, race, body mass index, smoking status, education attainment, income, insurance status, and number of healthcare visits.

Results: From 2005–2008 to 2013–2016, 15,171 participants were identified. DM prevalence was stable ~3%, hypertension prevalence was stable ~11.0%, and hypercholesterolemia prevalence declined from 11.5% to 9.0% ($p_{trend} = 0.02$). DM awareness stayed stable between 61.1 and 74.1%, hypertension awareness increased from 68.7 to 77.7% ($p_{trend} = 0.05$), and hypercholesterolemia awareness was stable between 46.8 and 54.1%. DM and hypertension treatment improved markedly ($p_{trend} < 0.001$ and 0.05, respectively) but the hypercholesterolemia treatment was stable ~30%. DM control improved across survey periods (7.7–17.4%, $p_{trend} = 0.04$) but hypertension control (~50%) and hypercholesterolemia control (~13%) remained stable. Prevalence, awareness, treatment, and control trends also differed between males and females.

Conclusions: There is a stable prevalence of DM, high and stable prevalence of hypertension, and declining prevalence of hypercholesterolemia among young Americans. Despite stable or increasing awareness of diabetes and hypertension, there are inadequate treatment and control trends for DM, hypertension, and hypercholesterolemia.

Keywords
Diabetes mellitus, hypercholesterolemia, hypertension, NHANES, risk factors

Received 19 October 2019; accepted 18 January 2020

Introduction

Cardiovascular disease afflicts >90 million Americans over the age of 20.[1] Although the burden of cardiovascular risk factors and diseases is well-established in the middle-aged and elderly populations, there are fewer data about the state of cardiovascular health amongst young adults.[2]

Prior data suggest that the burden of coronary artery disease equivalents such as stroke[3] and myocardial infarction[1] is rising amongst young adults.

[1]Cardiovascular Division, University of Minnesota, USA
[2]Division of Cardiovascular Disease, University of Alabama at Birmingham, USA
[3]Department of Medicine, University of Alabama at Birmingham, USA
[4]Division of Hospital Medicine, Children's Minnesota, USA
[5]Department of Medicine, Abbott Northwestern Hospital, USA
[6]Section of Cardiology, Birmingham Veterans Affairs Medical Center, USA

Corresponding author:
Pankaj Arora, FAHA Division of Cardiovascular Disease, 1670 University Boulevard, Volker Hall B140, University of Alabama at Birmingham, Birmingham, AL 35294-0019, USA.
Email: parora@uabmc.edu

Additionally, significant proportions of young and early middle-aged adults have uncontrolled risk factors at the time of their index event.[2,4] This contrasts with suggestions that there is a declining overall prevalence in cardiovascular risk factors in the general population.[5] These disparities in the cardiovascular risk factor trends are accompanied by a suggestion that the prevalence of risk factors such as diabetes mellitus, hypertension, and hypercholesterolemia is rising and awareness is low amongst young American adults.[6] However, little is known about the treatment and control of these cardiovascular risk factors in the contemporary era.

We sought to evaluate prevalence trends for diabetes mellitus, hypertension, and hypercholesterolemia in the general American population of adults aged 18–44. We hypothesized that the prevalence of diabetes mellitus, hypertension, and hypercholesterolemia were rising and that there were differences in awareness, prevalence, and control across sex. We present the results of an investigation that employs the National Health and Nutrition Examination Study (NHANES) surveys to investigate these hypotheses.

Methods

Data source

The NHANES is a series of cross-sectional, multistage probability surveys of the non-military and non-institutionalized individuals from the US.[7] The NHANES protocols have been published previously.[7–10] The NHANES is conducted by the National Center for Health Statistics/Centers for Disease Control and Prevention once every two years.[7] During each NHANES cycle, all survey participants undergo a telephonic interview and health examination.[7] The interview involves a series of questionnaires on food intake and health conditions such as the awareness about cardiovascular disease and the use of medications.[7] Participants who agree to a mobile examination undergo the measurement of vital signs, including blood pressure, and venous blood collection for laboratory testing.[7] The study complies with the Declaration of Helsinki.

Study population

We used data from six consecutive NHANES cycles (2005–2016) to estimate trends in the prevalence of diabetes mellitus, hypertension, and hypercholesterolemia among American adults aged 18–44 years. We excluded participants who were pregnant, aged <18 or ≥45 years, or those who lacked data from the mobile examination.

Data measures

Standardized NHANES laboratory methods were used to assess blood glucose and cholesterol levels, as described in Supplementary Methods 1.[9–11] Diabetes mellitus was defined as a fasting plasma glucose ≥126 mg/dL (≥6.99 mmol/L) after ≥8 hours of fasting, non-fasting plasma glucose ≥200 mg/dL (≥11.1 mmol/L), plasma hemoglobin A1C (HbA1c) ≥6.5%, self-reported history of diabetes mellitus, or current use of oral hypoglycemics or insulin.[6] Borderline diabetes mellitus was defined as a fasting plasma glucose 100–125 mg/dL (5.55-6.99 mmol/L) after ≥8 hours of fasting, or plasma HbA1c 5.7–6.5% without taking medication or insulin for diabetes.[6]

Hypertension was defined as mean systolic blood pressure ≥140 mmHg, mean diastolic blood pressure ≥90 mmHg, or current use of antihypertensive medications. This was in line with the 2014 guidelines.[6,12] Prehypertension was defined as a systolic blood pressure of 120–139 mmHg or mean diastolic blood pressure of 80–89 mmHg among those without hypertension. The remaining participants were categorized as normotensive. Systolic and diastolic blood pressure measurements were performed during the mobile examination by trained personnel using a standard protocol. Antihypertensive medication usage was self-reported.

Hypercholesterolemia was defined as total cholesterol of ≥240 mg/dL (≥6.21 mmol/L). Borderline cholesterol was defined as total cholesterol of 200–239 mg/dL (5.17–6.20 mmol/L). These definitions were chosen on the basis of the American Heart Association's (AHA) Life's Simple Seven definitions for poor and intermediate health, respectively.[13] The definitions of awareness, treatment, and control of diabetes mellitus, hypertension, and hypercholesterolemia are outlined in Supplementary Methods 2.

Body mass index (BMI), smoking, physical activity, and healthy diet prevalence trends were also calculated as per the AHA Life's Simple Seven recommendations (Supplementary Methods 5). These trends were evaluated in the overall sample and in the subgroups of patients with diabetes mellitus, hypertension, and hypercholesterolemia.

Statistical analysis

NHANES data were analyzed using the survey procedures in SAS version 9.4 (SAS Institute Inc., Cary, NC) accounting for complex survey design. To estimate cardiovascular risk factor prevalence trends among US adults aged 18–44 years, NHANES cycles were merged into three groups: 1) 2005–2008, 2) 2009–2012, and 3) 2013–2016. To generate the national estimates, full sample examination weights for four years were used, as recommended by NHANES. The direct

method, utilizing the 2000 census population proportions for the age groups of 18–25, 26–34, and 35–44 years, were used to estimate the age-standardized prevalence of risk factors in the overall population and by sex. Similarly, the age-adjusted prevalence of awareness, treatment, and control was assessed among sub-groups of participants with diabetes mellitus, hypertension, and hypercholesterolemia in the overall population and by sex. Overall and sub-group weighted percentage rates with 95% confidence intervals (CIs) were estimated by linear regression models. The trend *p*-values were provided as per NHANES guidance for statistical analysis.[14] The overall and sub-group trend *p*-values adjusted for age group, race, BMI, smoking status, income, education attainment, insurance status, and number of healthcare visits per year were calculated using linear regression models for linear trends. Homogeneity of the rates across the survey cycles was tested for using multivariate-adjusted regression models with Bonferroni correction for multiple comparisons. Additionally, a sensitivity analysis was conducted using the 2017 hypertension guidelines.[15] A two-sided *p*-value of <0.05 was used to assess define statistical significance.

Results

A total of 60,936 participants were identified from the NHANES 2005–2006 to 2015–2016 cycles. Of these, 45,356 participants were excluded: 2276 participants lacked data from the mobile examination, 688 women were pregnant, and 42,392 participants were aged <18 or ≥ 45 years. A total of 409 participants with a self-reported history of heart failure, coronary artery disease, angina, myocardial infarction, stroke, or chronic kidney disease were excluded from the analyses. The final study was conducted among 15,171 American adults aged 18–44 years (Supplementary Figure 1 and Table 1).

Prevalence of diabetes mellitus, hypertension, and hypercholesterolemia in adults aged 18–44

The prevalence of diabetes mellitus, hypertension, and hypercholesterolemia in adults aged 18–44 is described in Table 1.

Diabetes mellitus prevalence rose in the overall study population from 2.6% (95% CI: 2.1–3.2%; representing ~2.5 million Americans) in 2005–2008 to 3.6% (95% CI: 2.8–4.3%; representing ~3.6 million Americans) in 2013–2016 ($p_{trend} = 0.22$; Figure 1(a)). Pre-diabetes prevalence was stable amongst the overall population. Diabetes mellitus and pre-diabetes prevalence was stable amongst the males and female sub-groups.

Hypertension prevalence was stable in the overall population at ~11.0% (representing ~11.5 million Americans) ($p_{trend} = 0.99$; Figure 1(b)). The prevalence of pre-hypertension also stayed relatively stable at around ~26% ($p_{trend} = 0.99$). The prevalence of pre-hypertension was also stable in males and females. When the 2017 hypertension guidelines were applied, hypertension prevalence was stable ~24.0% in the overall population (Supplementary Table 1).

Hypercholesterolemia prevalence declined in the overall study population from 11.5% (95% CI: 10.1–12.8%; representing ~12 million Americans) in 2005–2008 to 9.0% (95% CI: 7.7–10.3%; representing ~9.5 million) in 2013–2016 ($p_{trend} = 0.02$; Figure 1(c)). There was a significant decline in females ($p_{trend} = 0.001$), but not males. The prevalence of borderline hypercholesterolemia declined amongst all participants from 22.9% (95% CI: 21.4–24.3%; representing ~23.5 million Americans) in 2005–2008 to 19.1% (95% CI: 17.4–20.8%; representing ~20 million Americans) in 2013–2016 ($p_{trend} = 0.002$; Table 1). The prevalence declined in males and trended to decline in females.

The age-standardized weighted prevalence estimates of diabetes mellitus, pre-diabetes, pre-hypertension, hypertension, borderline hypercholesterolemia, and hypercholesterolemia were consistently higher in males than females (Table 1).

Awareness, treatment, and control of diabetes mellitus

Diabetes mellitus awareness was stable and moderately high amongst the overall population of adults, males, and females across survey periods (Table 2 and Figure 1(a)). Females had greater awareness of diabetes mellitus.

The percentage of the overall population receiving diabetes mellitus treatment increased from 29.8% (95% CI: 21.3–38.3%; representing ~0.8 million Americans) in 2005–2008 to 55.9% (95% CI: 48.3–63.5%; representing ~2 million Americans) in 2013–2016 ($p_{trend} < 0.001$). The percentage of treated diabetes mellitus also rose significantly amongst males and females from 2005–2008 to 2015–2016 (p_{trend} for both sexes < 0.001). There were significantly higher proportions of females being treated for diabetes mellitus compared to males.

Controlled diabetes mellitus rose from 6.7% (95% CI: 1.5–11.8%; representing ~200,000 Americans) in 2005–2008 to 17.4% (95% CI: 11.6–23.3%; representing ~600,000 Americans) in 2013–2016 ($p_{trend} = 0.04$) in the overall population. The percentage of males with controlled diabetes mellitus rose from 4.8% (95% CI: 0.8–9.1%) in 2005–2008 to 16.3% (95% CI: 9.9–22.6%) in 2013–2016 ($p_{trend} = 0.31$). The percentage of females

Table 1. Age-standardized weighted prevalence of cardiovascular risk factors amongst adults aged 18–44: NHANES 2005–2016.

	2005–2008[a]		2009–2012[a]		2013–2016[a]		Trend *p*-value[b]
Risk factor	*N*	Percentage (95% CI)	*N*	Percentage (95% CI)	*N*	Percentage (95% CI)	Linear
Diabetes mellitus							
Overall	4861	2.6 (2.1–3.2)	5235	2.8 (2.3–3.3)	5075	3.6 (2.8–4.3)	0.22
Male	2507	2.7 (2.2–3.3)	2621	2.9 (2.1–3.7)	2473	3.6 (2.7–4.5)	0.21
Female	2354	2.5 (1.6–3.4)	2614	2.7 (2.0–3.4)	2602	3.5 (2.5–4.6)	0.45
Pre-diabetes							
Overall	4861	5.2 (4.3–6.2)	5235	5.3 (4.3–6.2)	5075	6.5 (5.1–7.8)	0.43
Male	2507	6.7 (5.4–7.9)	2621	7.3 (6.0–8.7)	2473	8.8 (6.8–10.8)	0.20
Female	2354	3.7 (2.6–4.8)	2614	3.2 (2.2–4.0)	2602	4.1 (3.0–5.2)	0.99
Hypertension							
Overall	4861	11.4 (9.8–13.1)	5235	10.3 (9.1–11.5)	5075	11.3 (10.0–12.7)	0.99
Male	2507	13.9 (11.9–15.9)	2621	11.8 (10.2–13.5)	2473	13.0 (11.0–15.0)	0.99
Female	2354	8.8 (7.1–10.5)	2614	8.8 (7.3–10.2)	2602	9.7 (8.1–11.3)	0.99
Pre-hypertension							
Overall	4861	27.1 (25.2–28.9)	5235	26.0 (24.3–27.6)	5075	25.8 (23.6–27.9)	0.93
Male	2507	36.3 (34.0–38.5)	2621	36.2 (33.7–38.8)	2473	34.7 (31.4–38.1)	0.58
Female	2354	17.3 (14.8–19.8)	2614	15.1 (13.1–17.1)	2602	16.5 (14.7–18.4)	0.77
Hypercholesterolemia							
Overall	4861	11.5 (10.1–12.8)	5235	9.0 (7.7–10.3)	5075	9.0 (8.0–9.9)	0.02
Male	2507	12.9 (10.7–15.2)	2621	10.7 (8.5–12.7)	2473	11.4 (10.2–12.7)	0.88
Female	2354	9.9 (8.4–11.5)	2614	7.2 (5.9–8.5)	2602	6.4 (5.4–7.4)	0.003
Borderline hypercholesterolemia							
Overall	4861	22.9 (21.4–24.3)	5235	22.8 (21.2–24.5)	5075	19.1 (17.4–20.8)	0.002
Male	2507	24.7 (18.1–22.6)	2621	23.7 (20.3–27.1)	2473	20.3 (18.1–22.6)	0.03
Female	2354	21.0 (18.7–23.2)	2614	22.0 (19.7–24.3)	2602	17.8 (15.7–20.0)	0.08

NHANES: national health and nutrition examination survey; CI: confidence interval.

[a]Direct method for age standardization was performed using the US census population age groups 18–19, 20–24, 25–34, and 35–44 years.

[b]Logistic regression model including age groups, race, sex, body mass index, smoking status, insurance status, education attainment, income status, number of healthcare visit in past one year, and Bonferroni correction for multiple comparisons was used to assess the linear trend in *p*-values across the survey years.

with controlled diabetes mellitus trended to increase from 8.8% (95% CI: 2.8–14.8%) in 2005–2008 to 18.6% (95% CI: 9.2–28.0%) in 2013–2016 ($p_{trend} = 0.07$). The percentage of females with controlled diabetes mellitus was consistently higher than males.

Awareness, treatment, and control of hypertension in adults aged 18–44

Hypertension awareness trended towards an increase from 68.7% (95% CI: 62.1–75.3%; representing ~8 million Americans) in 2005–2008 to 77.7% (95% CI: 74.4–81.0%; representing ~9.5 million Americans) in 2013–2016 amongst the overall population ($p_{trend} = 0.05$; Table 3 and Figure 1(b)). Amongst males, hypertension awareness improved from 57.3% (95% CI: 21.0–93.4%) in 2005–2008 to 69.9% (95% CI: 64.8–74.9%) in 2013–2016 ($p_{trend} = 0.02$). Hypertension awareness was stable amongst females across study periods, but females had substantially greater hypertension awareness across all survey periods. When the 2017 hypertension guidelines were applied, hypertension awareness was lower and stable in the overall population, males, and females (Supplementary Table 1).

The percentage of the overall population receiving hypertension treatment increased from 58.7% (95% CI: 52.7–64.7%; representing ~7 million Americans) in 2005–2008 to 70.4% (95% CI: 65.6–75.2%; representing ~8.5 million Americans) in 2013–2016 ($p_{trend} = 0.02$). The percentages of males receiving hypertension treatment rose significantly from 45.9% (95% CI: 39.2–53.6%) in 2005–2008 to 59.6% (95% CI: 52.1–67.1%) in 2013–2016 ($p_{trend} = 0.03$). The trend was stable for females across study periods.

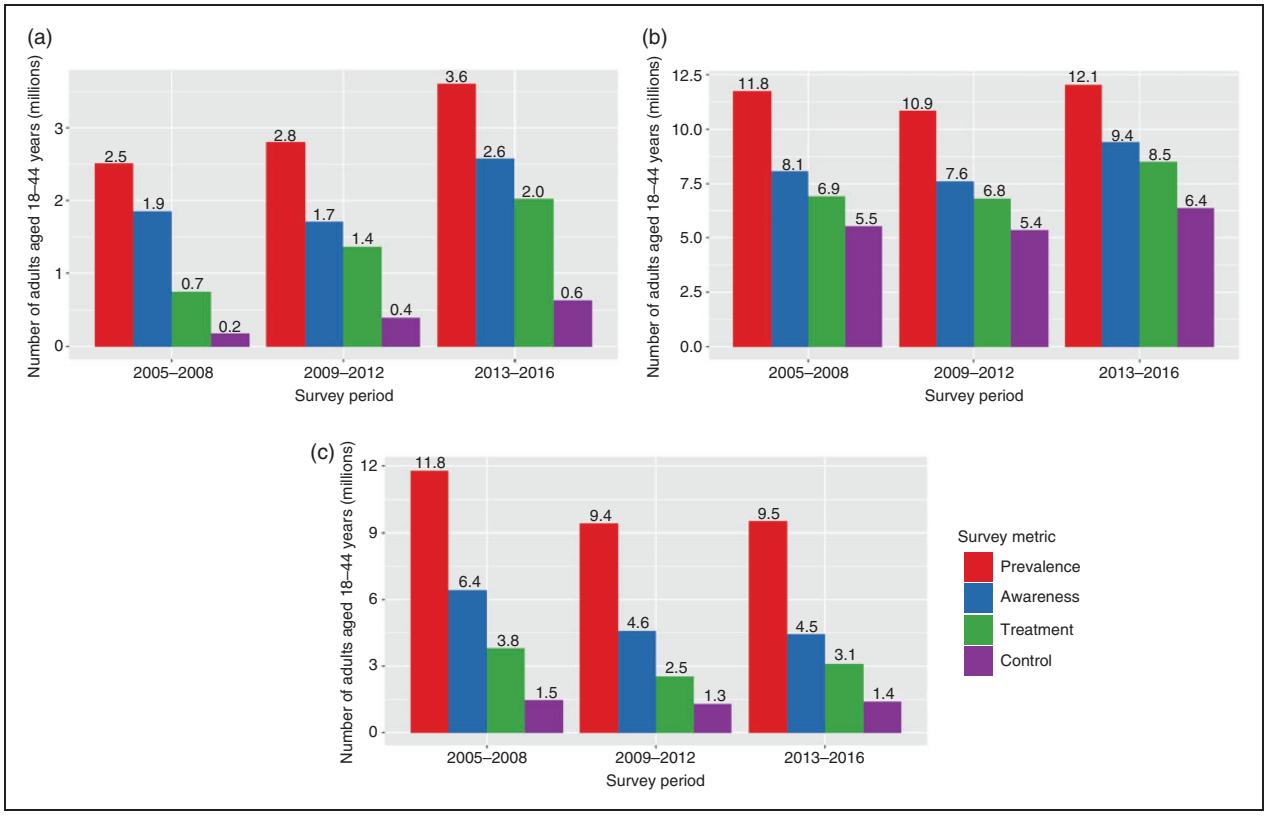

Figure 1. Trends in prevalence, awareness, treatment, and control of diabetes mellitus, hypertension, and hypercholesterolemia amongst adults aged 18–44 years: NHANES 2005–2016.
Bars represent the prevalence (red), awareness (blue), treatment (green), and control (purple) of diabetes mellitus (Panel A), hypertension (Panel B), and hypercholesterolemia (Panel C) among young adults (in millions).

Table 2. Age-standardized weighted awareness, treatment, and control of diabetes mellitus amongst adults aged 18–44: NHANES 2005–2016.

	2005–2008[a]		2009–2012[a]		2013–2016[a]		Trend p-value[b]
	N	Percentage (95% CI)	N	Percentage (95% CI)	N	Percentage (95% CI)	Linear
Awareness							
Overall	128	74.1 (66.7–81.5)	191	61.1 (50.9–71.3)	192	71.3 (64.0–78.4)	0.99
Male	76	66.6 (57.2–76.0)	95	63.3 (49.0–77.6)	92	63.6 (54.9–72.3)	0.13
Female	52	82.6 (72.8–92.4)	96	58.6 (45.9–71.4)	100	79.2 (70.6–87.8)	0.90
Treatment							
Overall	128	29.8 (21.3–38.3)	191	49.0 (37.4–60.5)	192	55.9 (48.3–63.5)	<0.001
Male	76	30.5 (21.1–39.9)	95	48.0 (35.2–60.7)	92	53.6 (44.7–62.6)	<0.001
Female	52	29.0 (18.5–39.4)	96	50.1 (36.1–64.2)	100	58.2 (45.9–70.6)	<0.001
Control							
Overall	128	6.7 (1.5–11.8)	191	14.0 (8.8–19.2)	192	17.4 (11.6–23.3)	0.04
Male	76	4.8 (0.8–9.1)	95	11.3 (5.8–16.8)	92	16.3 (9.9–22.6)	0.31
Female	52	8.8 (2.8–14.8)	96	17.0 (10.6–23.3)	100	18.6 (9.2–28.0)	0.07

NHANES: national health and nutrition examination survey; CI: confidence interval.
[a]Direct method for age standardization was performed using the US census population age groups 18–19, 20–24, 25–34, and 35–44 years.
[b]Logistic regression model including age groups, race, sex, body mass index, smoking status, insurance status, education attainment, income status, number of healthcare visit in past one year, and Bonferroni correction for multiple comparisons was used to assess the linear trend in *p*-values across the survey years.
Note: the numbers are depicted in the population with prevalent diabetes mellitus.

Using the 2014 guidelines, hypertension control was stable from 47.1–52.7% of the population exhibiting controlled hypertension in 2013–2016 ($p_{trend} = 0.50$; Table 3). Using the 2017 guidelines, the percentage of participants with controlled hypertension was stable from 13.3–16.8% ($p_{trend} = 0.22$). The percentage of females with controlled hypertension was consistently higher than males (Supplementary Table 1).

Awareness, treatment, and control of hypercholesterolemia in adults aged 18–44

Hypercholesterolemia awareness was stable ($p_{trend} = 0.30$; Table 4 and Figure 1(c)) amongst the overall population and was consistently lower than that for diabetes mellitus. Females' awareness of hypercholesterolemia was greater than males in the 2005–2008 and 2009-2012 survey periods, but then declined to lower than that of males by 2015–2016 ($p_{trend} = 0.02$).

In the overall population, 32.0–32.6% (95% CI: 26.9–38.2%) of Americans received treatment for hypercholesterolemia ($p_{trend} = 0.99$). The percentage of the overall population, males, and females receiving treatment for hypercholesterolemia remained stable at ~3 million Americans across the study periods. The percentage of females receiving treatment for hypercholesterolemia was higher than males in the 2005–2008 survey period but then declined below the percentage of males receiving treatment for hypercholesterolemia by 2013–2016.

The percentage of participants who had controlled hypercholesterolemia (~1 million Americans) remained stable across study periods among the overall population, males, and females.

BMI, smoking, and physical activity prevalence trends in adults aged 18–44

The percentage of overall participants who were obese increased from 29.7% (95% CI: 26.9–32.6%) in 2005–2008 to 35.2% (95% CI: 32.9–37.4%) in 2013–2016 ($p_{trend} = 0.002$) (Supplementary Table 2). The rising prevalence of obesity was seen in both males and females ($p_{trend} = 0.01$ for both males and females).

The percentage of overall participants who were described as current smokers decreased from 28.6% (95% CI: 26.1–31.0%) in 2005–2008 to 21.5% (95% CI: 19.7–23.4%) in 2013–2016 ($p_{trend} = 0.003$) (Supplementary Table 2). There was a significant decline in the prevalence of current smoking amongst men ($p_{trend} = 0.006$) but not in women ($p_{trend} = 0.27$).

The prevalence of ideal physical activity amongst all participants was stable at around 57.6–59.0% ($p_{trend} = 0.99$) (Supplementary Table 2). The prevalence of males with ideal physical activity was

Table 3. Age-standardized weighted awareness, treatment, and control of hypertension amongst adults aged 18–44: NHANES 2005–2016 (using the 2014 hypertension guidelines).

	2005–2008[a]		2009–2012[a]		2013–2016[a]		Trend p-value[b]
	N	Percentage (95% CI)	N	Percentage (95% CI)	N	Percentage (95% CI)	Linear
Awareness							
Overall	528	68.7 (62.1–75.3)	547	70.1 (63.9–76.3)	585	77.7 (74.4–81.0)	0.05
Male	325	57.3 (21.0–93.4)	316	63.5 (55.5–71.5)	318	69.9 (64.8–74.9)	0.02
Female	203	87.8 (82.0–93.6)	231	79.4 (72.2–86.7)	267	88.6 (85.5–91.7)	0.99
Treatment							
Overall	528	58.7 (52.7–64.7)	547	62.6 (56.0–69.2)	585	70.4 (65.6–75.2)	0.02
Male	325	45.9 (39.2–52.6)	316	54.4 (46.3–62.4)	318	59.6 (52.1–67.1)	0.03
Female	203	80.1 (73.6–86.5)	231	74.1 (66.1–82.1)	267	85.4 (82.3–88.4)	0.59
Control							
Overall	528	47.1 (41.3–52.9)	547	49.3 (42.3–56.4)	585	52.7 (47.9–57.4)	0.50
Male	325	35.1 (29.0–41.1)	316	40.2 (32.6–47.9)	318	40.4 (34.3–46.5)	0.51
Female	203	67.1 (58.7–75.5)	231	62.2 (52.5–71.9)	267	69.6 (63.9–75.3)	0.99

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

[a]Direct method for age standardization was performed using the following US census population age groups 18–19, 20–24, 25–34, and 35–44 years.

[b]Logistic regression model including age groups, race, sex, body mass index, smoking status, insurance status, education attainment, income status, number of healthcare visit in past one year, and Bonferroni correction for multiple comparisons was used to assess the linear trend in *p*-values across the survey years.

Note: the numbers for awareness, treatment, and control are depicted in the population with prevalent hypertension.

Table 4. Age-standardized weighted awareness, treatment, and control of hypercholesterolemia amongst adults aged 18–44: NHANES 2005–2016.

	2005–2008[a]		2009–2012[a]		2013–2016[a]		Trend p-value[b]
	N	Percentage (95% CI)	N	Percentage (95% CI)	N	Percentage (95% CI)	Linear
Awareness							
Overall	480	54.1 (47.7–60.6)	476	48.6 (42.5–54.7)	422	46.8 (41.4–52.2)	0.30
Male	285	47.1 (38.8–55.4)	279	46.6 (38.4–54.8)	271	48.1 (41.6–54.5)	0.99
Female	195	63.9 (55.1–72.7)	197	51.7 (42.2–61.2)	151	44.5 (34.7–54.3)	0.02
Treatment							
Overall	480	32.0 (26.1–37.8)	476	26.7 (21.6–31.8)	422	32.6 (26.9–38.2)	0.99
Male	285	28.8 (21.7–35.8)	279	24.4 (18.7–30.1)	271	34.9 (28.7–41.1)	0.38
Female	195	36.4 (28.6–44.2)	197	30.3 (21.7–39.0)	151	28.4 (16.0–40.8)	0.68
Control							
Overall	480	12.3 (8.1–16.6)	476	13.5 (8.9–18.2)	422	14.6 (10.2–18.9)	0.99
Male	285	13.9 (8.5–19.4)	279	13.4 (6.5–20.2)	271	13.6 (8.0–19.2)	0.99
Female	195	10.1 (4.1–16.0)	197	13.8 (9.3–18.4)	151	16.3 (6.4–26.3)	0.39

NHANES: national health and nutrition examination survey; CI: confidence interval.

[a]Direct method for age standardization was performed using the US census population age groups 18–19, 20–24, 25–34, and 35–44 years.

[b]Logistic regression model including age groups, race, sex, body mass index, smoking status, insurance status, education attainment, income status, number of healthcare visit in past one year, and Bonferroni correction for multiple comparisons was used to assess the linear trend in *p*-values across the survey years.

Note: the numbers are depicted in the population with prevalent hypercholesterolemia.

higher than the prevalence of females across all study periods.

Dietary trends

The prevalence of subjects that achieved an intermediate or healthy diet was stable across the study period at 22.3–23.7% ($p_{trend} = 0.72$) (Supplementary Table 3 and Figure 2). This score was also stable but poor among the sub-groups of patients with hypertension, hypercholesterolemia, and diabetes mellitus at similar levels (Supplementary Figure 2).

Discussion

In summary, we describe a stable prevalence of diabetes mellitus and hypertension, with a declining prevalence of hypercholesterolemia amongst adults aged 18–44 in the general American population. The trend for increasing awareness of hypertension is coupled with the rising prevalence of obesity and inadequate treatment and control trends for diabetes mellitus, hypertension, and hypercholesterolemia. Additionally, we described a higher prevalence of hypertension, pre-hypertension, pre-diabetes, borderline hypercholesterolemia, and hypercholesterolemia amongst males compared to females across all three study periods. However, percentages for diabetes mellitus and hypertension treatment and control were higher amongst females. We also assessed the impact of the 2017 high blood pressure guidelines on the prevalence, awareness, treatment, and control of hypertension and observed a substantial prevalence of hypertension of nearly one in four young adults, which remained stable across the study periods. There were higher percentages of males receiving treatment for hypercholesterolemia but females exhibited better control. The declining prevalence of current smoking was also noted across the study periods. Finally, there was a relatively low prevalence of healthy diet across study periods in the overall sample.

There may be multiple mechanistic explanations for our findings. The childhood obesity burden has been acknowledged as an epidemic for >20 years in America.[16] We also witnessed rising obesity prevalence among young adults. It is possible that the potent metabolic dysregulation induced by childhood obesity is now manifesting in young adulthood as a higher prevalence of pre-diabetes and diabetes mellitus. Similarly, Kit et al. previously noted that ~20% of adolescents had dyslipidemia and ~10% were hypertensive.[17] Our data may suggest that there are adult sequelae of these childhood cardiovascular pathologies. Changes in risk factor prevalence due to immigration patterns may also play a role. The declining prevalence of hypercholesterolemia has also been previously noted in the wider American population. This has partly been attributed to the reduction in dietary trans-fat consumption.[17]

However, we found that there were relatively low levels of healthy diet throughout the survey periods. Multiple widely publicized health campaigns[13] and the release of two lipid-related consensus guidelines since 2013 may have also publicized broader lifestyle changes for the general population.[18,19] Increasing statin usage was reported from 2002 to 2013 amongst Americans, but select high-risk groups (such as diabetics) still were underrepresented.[20] These changes may have led to a disproportionately low level of hyperlipidemia despite rising obesity levels among children and young adults. However, hypercholesterolemia treatment levels remain low overall. This may, in part, be due to the reluctance of clinicians to start young adults with a potentially lifelong pharmacologic therapy early in life. There was also comparatively lower prevalence and better awareness, treatment, and control of diabetes mellitus and hypertension amongst females compared to males. Zhang et al. previously linked more frequent preventive visits for females to improvements in awareness, treatment, and control of hypertension.[12] Females have been noted to more accurately and consistently report nutritious food intake patterns.[21] This combination of frequent healthcare visits with a perceptive approach to preventive healthcare overall may be yielding significant benefits for females in cardiovascular risk factor prevention.

Our findings offer comparisons to existing literature. George et al. previously described the high prevalence of key cardiovascular risk factors in adults aged 18–44 who presented with stroke in the National Inpatient Sample,[2] and Bucholz et al. demonstrated poor awareness of hypertension, dyslipidemia, and diabetes amongst male and female participants in NHANES aged 18–39.[6] We confirm the findings of both investigations and build upon them by highlighting the concomitant trends in risk factor treatment and control. We also reiterate that all of these trends sharply contrast between males and females over a longer study period. Vanhecke et al. demonstrated that adolescents aged 15–18 at American schools generally perceived themselves to have an inappropriately low lifetime risk of cardiovascular diseases.[22] Our findings suggest that this persists and manifests as poor awareness, treatment, and control of cardiovascular risk factors. This may represent an important niche population where health promotion should be targeted to break a chain of poor generational health outcomes. The prevalence of diabetes could be related to the persistently high rates of physical inactivity amongst youth and adults combined with a rising prevalence of overweight and obesity nationwide, based on recent NHANES data.[1] We noted that there were modest improvements in diabetes control. This could partly be due to previously described trends suggesting increasing diabetes medication usage during the study periods we examined.[23] Our data also offer an opportunity to compare cardiovascular risk factor trends to other populations. Importantly, the treatment and control of hypertension, diabetes, hypercholesterolemia among adults aged 18–44 in our study population fell far below those of the >65 years American population from NHANES data.[24] Our findings also contrasted with the rising prevalence of diabetes mellitus, obesity, and hypertension amongst young Canadian adults aged ≤55 years.[25]

There may be several public health implications of our findings. The majority of primary care patients with one cardiovascular risk factor have multiple additional coexisting risk factors.[26] Our data suggest that aggressive screening and treatment of key cardiovascular risk factors such as diabetes mellitus, hypertension, and hypercholesterolemia are of paramount importance to reduce the burden of cardiovascular disease amongst young adults.[1] The hypertension prevalence seen when utilizing the 2017 high blood pressure guidelines suggests that a vast number of young adults are eligible for hypertension treatment and, if treated, could improve their cardiovascular risk profile.[15] Approximately 30% of those diagnosed will be immediately eligible for medication while others must be started on lifestyle modification and reassessed in 3–6 months. Prior data have suggested that the occurrence of adolescent hypertension doubles the hazard of developing end-stage renal disease in later life.[27] An unmitigated rising prevalence in any of these cardiovascular risk factors, particularly diabetes mellitus, combined with sub-optimal rates of treatment and control, may manifest as other end-organ cardiovascular diseases in a similar manner. The rising awareness of hypertension and hypercholesterolemia was contrasted with a decline in treatment. This may partly be due to differing uptake of guidelines by different physician societies creating discordant treatment thresholds.[28] In view of the rising prevalence of diabetes mellitus, clinicians should consider treatment of diabetes mellitus amongst young adults with the sodium-glucose cotransporter-2 inhibitor or other classes of medications, according to recent guideline recommendations,[29] as they have been shown to improve long-term cardiovascular outcomes.[30] Aggressive diabetes mellitus preventive care and treatment should also be pursued on a broader level. Recent evidence indicates that an increase in physical activity is associated with a lower risk for incident hypertension and diabetes mellitus.[31] Our results suggest that obesity, physical activity, and dietary habits should also be targeted to address the burden of hypertension and diabetes. We also noted that the deterioration in risk factor trends occurred amidst an unstable climate for health policy. Improvement in the

low levels of treatment and control of cardiovascular risk factors is contingent upon consistent access to primary care for preventive care and health education. Additionally, the current trend towards high deductible insurance plans for primary care visits may be associated with delayed presentation to primary care.[32] The urgency of addressing primary care access is reiterated by the fact that we found that 10–30% of adults aged 18–44 had pre-hypertension, borderline hypercholesteremia, and pre-diabetes that may progress to full-scale disease. Improvements in healthcare access were noted with the introduction of the Affordable Care Act.[33] Increasing diabetic medication usage and the declining smoking prevalence may be an example of a positive result of this legislation. Finally, many cardiovascular diseases have been demonstrated to have strong links to social determinants of health. Social determinants of health and changes in health service provision may have played a role in the observed changes in risk factor prevalence and awareness. Addressing racial disparities in healthcare access should be another social priority for policymakers that accompanies targeted screening to address the health outcomes that we have demonstrated.

Our investigation also has important limitations. The NHANES is a series of cross-sectional surveys. Hence, incident measures of frequency and inferences regarding causality and temporality cannot be obtained from this design. However, our aim was to provide a broad overview of cardiovascular health amongst adults aged 18–44 and the NHANES data is well-suited to this. Data regarding medication are self-reported, but prior NHANES data show good validity of self-report.[34] Additionally, the raw prevalence trends themselves are suggestive of an urgent need to aggressively address these important risk factors.

Conclusion

In summary, American adults aged 18–44 have a stable prevalence of diabetes mellitus, pre-diabetes, and hypertension, with a declining prevalence of hypercholesterolemia. These trends are coupled with inadequate treatment and control of diabetes mellitus, hypertension, and hypercholesterolemia, despite stable or increasing awareness of these risk factors. Clinicians should intensify efforts to address screening and treatment of these key cardiovascular risk factors to foster improvement in these trends.

Author contribution

RK, VP, NP, and PA contributed to the conception, design, acquisition, analysis, interpretation, and critical revision of the manuscript. GA contributed to the conception, design, acquisition, interpretation, and critical revision of the manuscript. AB and KSB contributed to the design, interpretation, and drafting of the manuscript.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: Dr Pankaj Arora is supported by the National Institutes of Health Mentored Patient-Oriented Research Award (1K23HL146887-01).

References

1. Benjamin EJ, Muntner P, Alonso A, et al. Heart disease and stroke statistics — 2019 update: a report from the American Heart Association. *Circulation* 2019; 139: e56–e528.
2. George MG, Tong X and Bowman BA. Prevalence of cardiovascular risk factors and strokes in younger adults. *JAMA Neurol* 2017; 74: 695–703.
3. Swerdel JN, Rhoads GG, Cheng JQ, et al. Ischemic stroke rate increases in young adults: evidence for a generational effect? *J Am Heart Assoc* 2016; 5: e004245.
4. Yandrapalli S, Nabors C, Goyal A, et al. Modifiable risk factors in young adults with first myocardial infarction. *J Am Coll Cardiol* 2019; 73: 573–584.
5. Sun X and Du T. Trends in cardiovascular risk factors among U.S. men and women with and without diabetes, 1988-2014. *BMC Public Health* 2017; 17: 893.
6. Bucholz EM, Gooding HC and de Ferranti SD. Awareness of cardiovascular risk factors in U.S. young adults aged 18-39 years. *Am J Prev Med* 2018; 54: e67–e77.
7. Zipf G, Chiappa M, Porter KS, et al. National health and nutrition examination survey: plan and operations, 1999-2010. *Vital Health Stat 1* 2013: 1–37.
8. Centers for Disease Control and Prevention. *NHANES questionnaires, datasets, and related documentation*. Hyattsville, MD: US Department of Health & Human Services, 2019.
9. Kalra R, Patel N, Arora P, et al. Cardiovascular health and disease among Asian-Americans (from the National Health and Nutrition Examination Survey). *Am J Cardiol* 2019; 124: 270–277.
10. Patel N, Kalra R, Bhargava A, et al. Ideal cardiovascular health among American adults after the economic recession of 2008-2009: insights from NHANES. *Am J Med* 2019; 132: 1182–1190.e5.
11. Centers for Disease Control and Prevention. *National health and nutrition examination survey (NHANES) MEC laboratory procedures manual*. Hyattsville, MD: US Department of Health & Human Services, 2016.

12. Zhang Y and Moran AE. Trends in the prevalence, awareness, treatment, and control of hypertension among young adults in the United States, 1999 to 2014. *Hypertension* 2017; 70: 736–742.
13. Lloyd-Jones DM, Hong Y, Labarthe D, et al. Defining and setting national goals for cardiovascular health promotion and disease reduction: the American Heart Association's strategic impact goal through 2020 and beyond. *Circulation* 2010; 121: 586–613.
14. Ingram DD, Malec DJ, Makuc DM, et al. National Center for Health Statistics guidelines for analysis of trends. *Vital Health Stat 2* 2018: 1–71.
15. Whelton PK, Carey RM, Aronow WS, et al. 2017 ACC/AHA/AAPA/ABC/ACPM/AGS/APhA/ASH/ASPC/NMA/PCNA guideline for the prevention, detection, evaluation, and management of high blood pressure in adults: executive summary: a report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. *J Am Coll Cardiol* 2018; 71: 2199–2269.
16. Hedley AA, Ogden CL, Johnson CL, et al. Prevalence of overweight and obesity among US children, adolescents, and adults, 1999-2002. *JAMA* 2004; 291: 2847–2850.
17. Kit BK, Kuklina E, Carroll MD, et al. Prevalence of and trends in dyslipidemia and blood pressure among US children and adolescents, 1999-2012. *JAMA Pediatrics* 2015; 169: 272–279.
18. Grundy SM, Stone NJ, Bailey AL, et al. 2018 AHA/ACC/AACVPR/AAPA/ABC/ACPM/ADA/AGS/APhA/ASPC/NLA/PCNA guideline on the management of blood cholesterol. *Circulation*. 2018; 73(24): e285–e350.
19. Stone NJ, Robinson JG, Lichtenstein AH, et al. 2013 ACC/AHA guideline on the treatment of blood cholesterol to reduce atherosclerotic cardiovascular risk in adults: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines. *J Am Coll Cardiol* 2014; 63: 2889–2934.
20. Patel N, Bhargava A, Kalra R, et al. Trends in lipid, lipoproteins, and statin use among U.S. adults: Impact of 2013 cholesterol guidelines. *J Am Coll Cardiol* 2019; 74: 2525–2528.
21. Wardle J, Haase AM, Steptoe A, et al. Gender differences in food choice: the contribution of health beliefs and dieting. *Ann Behav Med* 2004; 27: 107–116.
22. Vanhecke TE, Miller WM, Franklin BA, et al. Awareness, knowledge, and perception of heart disease among adolescents. *Eur J Cardiovasc Prev Rehabil* 2006; 13: 718–723.
23. Selvin E, Parrinello CM, Sacks DB, et al. Trends in prevalence and control of diabetes in the United States, 1988-1994 and 1999-2010. *Ann Intern Med* 2014; 160: 517–525.
24. Unger AN, McDonald M, Hertz RP, et al. Prevalence, awareness, and management of hypertension, dyslipidemia, and diabetes among United States adults aged 65 and older. *J Gerontol A* 2009; 64A: 256–263.
25. Vikulova DN, Grubisic M, Zhao Y, et al. Premature atherosclerotic cardiovascular disease: trends in incidence, risk factors, and sex-related differences, 2000 to 2016. *J Am Heart Assoc* 2019; 8: e012178.
26. Handschin A, Brighenti-Zogg S, Mundwiler J, et al. Cardiovascular risk stratification in primary care patients with arterial hypertension: results from the Swiss Hypertension Cohort Study (HccH). *Eur J Prev Cardiol* 2019; 26: 1843–1851.
27. Leiba A, Fishman B, Twig G, et al. Association of adolescent hypertension with future end-stage renal disease. *JAMA Intern Med* 2019; 179: 517–523.
28. American Academy of Family Practice. *AAFP decides to not endorse AHA/ACC hypertension guideline*. Leawood, KS: American Academy of Family Practice, 2017.
29. Buse JB, Wexler DJ, Tsapas A, et al. 2019 Update to: management of hyperglycemia in type 2 diabetes, 2018. A consensus report by the American Diabetes Association (ADA) and the European Association for the Study of Diabetes (EASD). *Diabetes Care* 2019; 43: dci190066.
30. Neal B, Perkovic V, Mahaffey KW, et al. Canagliflozin and cardiovascular and renal events in type 2 diabetes. *N Engl J Med* 2017; 377: 644–657.
31. Lee JY, Ryu S and Sung KC. Association of baseline level of physical activity and its temporal changes with incident hypertension and diabetes mellitus. *Eur J Prev Cardiol* 2018; 25: 1065–1073.
32. Wharam JF, Lu CY, Zhang F, et al. High-deductible insurance and delay in care for the macrovascular complications of diabetes. *Ann Intern Med* 2018; 169: 845–854.
33. Patel N, Kalra R, Bhargava A, et al. Ideal cardiovascular health among American adults after the economic recession of 2008-2009: insights from the National Health And Nutrition Examination Survey. *Am J Med* 2019; 132: 1182–1190.
34. Vargas CM, Burt VL, Gillum RF, et al. Validity of self-reported hypertension in the National Health and Nutrition Examination Survey III, 1988–1991. *Preventive Medicine* 1997; 26: 678–685.