Cardiovascular Risk Factors in Young Adolescents: Results from the National Health and Nutrition Examination Survey 1988–2016

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Objectives: Lifestyle behaviors relevant to cardiovascular health are learned during childhood and continued into adulthood. Children and adolescents who participate in unhealthy behaviors have a higher lifetime risk of cardiovascular disease in adulthood. Public health institutions publish behavior and clinical recommendations designed for adolescents to reduce their lifetime cardiovascular risk. We assessed the prevalence and trends of cardiovascular-relevant behaviors and clinical tests among early adolescents using a nationally representative database.

Methods: In 2020, we compared the prevalence of cardiovascular risk factors among 1408 adolescents surveyed from 1988 to 1994 with that of 1812 adolescents surveyed from 2011 to 2016 by obtaining and comparing measures on physical activity, diet, body mass index, smoking status, cholesterol levels, hemoglobin A1c, sodium intake, and blood pressure.

Results: The prevalence of adherence to the current recommendations regarding physical activity, diet, and body weight declined over time. Conversely, the prevalence of adhering to recommendations to avoid smoking increased. Clinical indicators, including blood pressure control and normal measures of hemoglobin A1c and total serum cholesterol, showed mixed results, with more individuals showing signs of hyperglycemia, fewer showing signs of hypercholesterolemia, and the percentage of individuals with abnormal blood pressure remaining the same. The use of cardiometabolic medications also increased during the study period. Finally, the number of adolescents with all seven cardiovascular protective factors declined significantly during the study period, from 27.6% to 9.6%.

Conclusions: Modern American teenagers aged 12 to 16 years have more cardiovascular risk factors relating mostly to diet, exercise, and obesity than those of a prior generation; however, smoking rates have also declined precipitously.

Key Words: adolescence, cardiovascular health, NHANES, pediatric

Lifestyle behaviors relevant to cardiovascular health are learned during childhood and continued into adulthood. It is not unexpected, then, that young individuals who participate in unhealthy behaviors have a higher lifetime risk of cardiovascular disease in adulthood.[1] Several public health institutions publish behavior recommendations designed for adolescents to reduce their lifetime cardiovascular risk. These recommendations include at least 180 minutes of moderate-to-vigorous physical activity per week[2]; a diet that is low in sodium (<2200 mg/day for 12 and 13 year olds; <2300 mg/day for 14–16 year olds)[3] and rich in whole grains, fruits (>2 cup/day), and vegetables (>3 cup/day); a Healthy Eating Index (HEI) >50[4]; a total serum cholesterol <200 mg/dL[5]; a glycohemoglobin level <5.7%[6]; average blood pressure readings <120/80 mm/Hg[7]; the maintenance of a body mass index (BMI) <85th percentile; and the avoidance of cigarette smoking[8] (Table 1). The basis for these recommendations is epidemiological studies that have established that these behaviors and measures in adolescence reduce high blood pressure, hypercholesterolemia, obesity,[9] coronary heart disease, stroke, and diabetes mellitus[10,11] in adulthood.

Several previous studies have investigated the prevalence and trends in cardiovascular health metrics in adolescents,[12,13] but an examination of the most recent trends for these metrics has not yet been published.

Methods

The National Health and Nutrition Examination Survey (NHANES) is an ongoing cross-sectional survey of the civilian,

Key Points

- Modern American teenagers aged 12 to 16 years have more cardiovascular risk factors relating mostly to diet, exercise, and obesity than those of a prior generation.
- Clinical indicators including blood pressure control and normal measures of hemoglobin A1c and total serum cholesterol showed mixed results, with more individuals showing signs of hyperglycemia, fewer showing signs of hypercholesterolemia, and the percentage of individuals with abnormal blood pressure remaining the same.
- The number of adolescents with all seven cardiovascular protective factors declined significantly during the study period, from 27.6% to 9.6%.

Table 1. Public health recommendations for American adolescents to reduce cardiometabolic risk

CV risk factor	Recommendation	Variable definition	Institution, y
Diet			
Daily fruit servings	>2 cups	>2 cups	USDA, 2015
Daily vegetable servings	>3 cups	>3 cups	USDA, 2015
Daily sodium intake	<2200 mg (12- and 13-year-olds); <2300 mg (14- to 16-year-olds)	<2200 mg (12- and 13-year-olds); <2300 mg (14- to 16-year-olds)	USDA, 2015
Total Healthy Eating Index	>50 (out of 100)	>50 (out of 100)	USDA, 2015
Physical activity	>180 min/wk of moderate activity	>180 min/wk of moderate activity	CDC, 2018
Cardiometabolic factors			
Total cholesterol	<200 mg/dL	<200 mg/dL or taking a cholesterol-lowering medication	AHA, 2013
HbA1c	<5.7%	<5.7% or taking an antidiabetic medication	ADA, 2020
BMI	<85th percentile (18.5-24.9 kg/m)	85th–95th percentile = overweight; >95th percentile = obese	CDC, 2020
Blood pressure, mm Hg			
Systolic blood pressure	<120	<120 or taking a high blood pressure medication	AHA, 2013
Diastolic blood pressure	<80	<80 or taking a high blood pressure medication	AHA, 2013
Smoking	No smoking or use of tobacco products	Cotinine level of <2.99 ng/mL	HHS, 2010

ADA, American Diabetes Association; AHA, American Heart Association; CDC, Centers for Disease Control and Prevention; Hb, hemoglobin; HHS, US Department of Health and Human Services; USDA, US Department of Agriculture.

noninstitutionalized US population. NHANES surveys are conducted annually using a complex, stratified, multistage cluster probability sampling of a representative US sample. NHANES consists of three parts: a health interview survey, a health examination survey, and a nutrition survey. The current study (2020) examined the prevalence of cardiometabolic behaviors for two distinct groups of nationally representative adolescents totaling 3220 adolescents aged 12 to 16 years who participated in the NHANES of either the 1988–1994 cycle or the 2011–2016 cycle.

Demographic data, including self-reported information on age, sex, race/ethnicity, household income, and education as presented were collected. Sex was described as either male or female. Race was grouped as either White, Black, Hispanic, or Other. Household income was defined by the poverty income ratio (PIR), in which a PIR of 1 denotes a family income at the federal poverty line and a PIR of 5 denotes a family income of 5 times the federal poverty line. Education status grouped subjects as either currently in school or not.

Health behavior data included answers to key survey questions regarding physical activity and diet. We calculated the percentage of adolescents who met physical activity recommendations by the US Department of Health and Human Services of >180 minutes/week of moderate-to-vigorous-intensity aerobic physical activity, or an equivalent combination of moderate- and vigorous-intensity aerobic activity. Dietary data were obtained from a 24-hour dietary recall questionnaire. These data were then merged with the HEI database developed by the US Department of Agriculture (USDA). The HEI is a measure of diet quality that assesses conformity to US dietary guidelines. Scores range from 0 to 100, with 100 points referring to perfect diet quality and lower results indicating larger deviations from the recommended intakes.[4] The HEI has several components representing all of the major

Table 2. Comparison of demographic characteristics between adolescent sample from NHANES III (1988–1994) and NHANES 2011–2016

Characteristics	NHANES III 1988–1994, n = 1408 % (95% CI)	NHANES 2011–2016, n = 1812 % (95% CI)
Age, y		
12–14	60.73 (56.63–64.83)	59.05 (55.90–62.20)
15–16	39.27 (35.17–43.37)	40.95 (37.80–44.10)
Sex		
Male	51.17 (45.91–56.42)	51.04 (48.17–53.91)
Female	48.83 (43.57–54.09)	48.96 (46.09–51.83)
Race		
White	81.30 (77.67–84.93)	57.40 (50.69–64.11)
Black	14.46 (11.49–17.43)	13.22 (9.45–16.99)
Hispanic or Other	4.24 (1.89–6.60)	29.39 (22.77–36.00)
Currently attending school		
Yes	99.97 (99.93–100.00)	97.23 (96.30–98.17)
No	0.03 (0.00–0.07)	2.77 (1.83–3.70)
Poverty income ratio		
<1	20.95 (17.19–24.71)	20.51 (16.46–24.56)
1–1.99	25.13 (21.34–28.92)	24.08 (20.92–27.24)
2–2.99	23.48 (18.96–27.99)	17.88 (14.83–20.94)
3–3.99	20.54 (14.81–26.26)	13.60 (9.95–17.25)
4–4.99	5.14 (2.37–7.92)	7.45 (5.20–9.69)
≥5	4.77 (2.52–7.02)	16.47 (12.42–20.53)

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

food groups, including fruits, vegetables, grains, milk, meat and beans, oils, saturated fats, sodium, calories from solid fats, and alcoholic beverages. Food components are given maximum and minimum points per 1000 calories, giving each participant a corresponding HEI score.[12] Participants' diets can be categorized as "poor" ($\leq$50), "needs improvement" (51–80), and "good" (>80) score.[5] We defined a score $\geq$51 as adhering to USDA recommendations. In addition, we assessed participants' intake of the recommended amount of fruit (>2 cup/day), and vegetables (>3 cup/day). We further defined and assessed the total dietary sodium intake using 2200 mg for 12- to 13-year-olds and 2300 mg for 14- to 16-year-olds, as recommended by the USDA.[14]

BMI, cotinine levels, cholesterol levels, glycohemoglobin, sodium intake, medication usage, systolic blood pressure, and diastolic blood pressure were obtained from the NHANES examination and laboratory data. BMI was calculated as weight (kg)/height (m^2). Overweight adolescents were defined as those within the 85th and 95th percentiles for weight, and obese adolescents were defined as those above the 95th percentile.[15] The ascertainment of smoking status occurred through the measurement of serum cotinine levels because smoking status classification by questionnaire among adolescents is considered unreliable and invalid.[16] Cotinine is a metabolite of nicotine and a valid biomarker of tobacco exposure,[17] and serum levels <3 ng/mL among adolescents suggest no exposure to tobacco smoke.[18] Three systolic and diastolic blood pressure readings were averaged to arrive at a measure of blood pressure. Diastolic levels <80 mm/Hg and systolic levels

<120 mm/Hg were defined as normal and adherent to American Heart Association guidelines.[7] We defined a glycohemoglobin level <5.7% as normal based upon guidelines from the American Diabetes Association.[6] We defined a total cholesterol level of <200 mg/dL as normal based upon guidelines from the American Heart Association[19] (Table 1).

For each reported healthy behavior, 1 point was assigned to a total behavior score, with the maximum score being 7. We compared the percentage of individuals from the 1988–1994 cohort with the group of individuals surveyed from 2011–2016 regarding adherence to all seven cardiovascular protective factors.

Statistical analyses were performed using SAS version 9.4 (SAS Institute, Cary, NC). Survey sample weights were used in all of the analyses to produce estimates representative of the US population.

Results

From the NHANES III (1988–1994) to the NHANES continuous cycles of 2011–2016, demographic data were significantly different for race, with the White population declining from 81% to 57% and the Hispanic population increasing from 4% to 29% (Table 2). In addition, adherence to current physical activity recommendations decreased from 79.8% to 59.6% ($P < 0.0001$) as did the average HEI score, which decreased from 59 to 47 ($P < 0.0001$). The prevalence of recommended vegetable intake also decreased from 12.6% to 5.6% ($P < 0.0001$), and the prevalence of excess sodium intake increased from 23.4% to 27.8%

Table 3. Comparison of cardiovascular risk factors between adolescent samples from NHANES III (1988–1994) and NHANES 2011–2016

	NHANES 1988–1994, n = 1408	NHANES 2011–2016, n = 1812	P
BMI			
<85th percentile	70.77 (63.12–78.41)	59.46 (53.80–65.13)	**<0.0001**
85th–95th percentile	17.88 (14.60–21.16)	18.34 (15.72–20.96)	
>95th percentile	11.36 (8.12–14.59)	22.19 (19.18–25.21)	
Smokers	17.01 (13.86–20.15)	6.55 (4.89–8.22)	**<0.0001**
Physically active	79.84 (76.02–83.65)	59.61 (56.44–62.77)	**<0.0001**
Diet			
Excess sodium intake	23.36 (18.96–27.77)	27.75 (24.59–30.92)	0.05
Fruit intake >2 cups/d	10.85 (8.10–13.60)	16.60 (13.67–19.52)	**<0.0001**
Vegetable intake >3 cups/d	12.57 (9.68–15.45)	5.59 (4.36–6.82)	**<0.0001**
Average HEI score	59.00 (16.00–90.10)	47.28 (0.00–91.06)	**<0.0001**
Cardiometabolic factors			
Hypercholesterolemia	9.19 (6.97–11.40)	6.90 (5.41–8.39)	**<0.0001**
Elevated HbA1c	3.71 (2.01–5.40)	6.51 (5.13–7.89)	**0.001**
High diastolic blood pressure	2.75 (1.04–4.46)	1.79 (1.06–2.53)	0.31
High systolic blood pressure	10.94 (8.01–13.87)	10.63 (8.54–12.71)	0.60
Taking cardiovascular medications[a]	0.59 (0.00–1.46)	2.05 (1.04–3.06)	**<0.0001**

BMI, body mass index; CI, confidence interval; Hb, hemoglobin; HEI, Healthy Eating Index; NHANES, National Health and Nutrition Examination Survey.
[a]*Includes hypoglycemic, cholesterol lowering, and antihypertensive agents. Boldface type indicates statistical significance (P < 0.05).*

($P = 0.05$). Conversely, the prevalence of several healthy behaviors increased including the decline in active smoking, which decreased from 17.0% to 6.6% ($P < 0.0001$), and the increase in fruit intake from 10.9% to 16.6% ($P < 0.0001$). The prevalence of hyperglycemia increased from 3.7% to 6.5% ($P < 0.0001$). Finally, 2.1% of adolescents take medications for either hypercholesterolemia, hyperglycemia, or high blood pressure as compared with 0.6% of adolescents from the NHANES III (Table 3). Finally, the number of adolescents who were compliant with all seven cardiovascular protective factors declined from 27.6% in 1988 to 9.6% in 2016 equally across all races.

Discussion

We found that the prevalence of obesity, poor diet, physical inactivity, hyperglycemia, and medication use increased over the time frame of 1988 to 2016, but smoking, hypercholesterolemia, and high blood pressure declined over the same period. We also found that only 9.6% of American adolescents participate in all healthy cardiovascular behaviors and have optimal cardiovascular metrics, as compared with 27.6% from 1988 to 1994. Our data are consistent with several other studies that have analyzed trends in cardiovascular risk among children and adolescents over time.[12,13]

The strengths of these analyses are that NHANES data are collected using extensive quality control measures, these findings are likely to be the representative of the US population, and the large NHANES sample size provides more precise estimates of effect. The limitations of these data include self-reported data, which could lead to a misclassification error for each of the estimated parameters.[20] Of the seven estimated parameters, however, five were based on objective measures, and self-reported adolescent data regarding vegetable intake was previously found to be valid.[21]

Nonadherence to the cardiovascular behavior recommendations during adolescence is common and in part stems from both the child's and the parents' insufficient knowledge or awareness of the consequences of unhealthy behaviors and the lack of perceived immediate health benefits.[22] Societal factors also play a role, with less emphasis on physical activity and insufficient access and offering of healthy food options both at school and at home. The average HEI score decline of >10 points among adolescents aged 12 to 16 means that fewer adolescents are obtaining optimal nutrients through a well-rounded diet of fruits and vegetables and suggests that this age group is likely consuming higher amounts of processed and ultra-processed foods that are high in added sodium, refined sugars, and poor-quality fats. Dietary behavior often continues unchanged from adolescence into adulthood,[23] and poor food choices are associated with the development of type 2 diabetes mellitus and heart disease.[24] Other factors that are attributable to the observed decline in cardiovascular risk profile in adolescence include socioeconomic factors, insufficient public health messaging, and industrial advertising, all of which favor poor food choices and inactivity. In addition, the percentage of adolescents who met activity guidelines declined 20% on an absolute basis. Increased screen time and reduced recreational activity at school are likely contributors to this concerning trend.[25]

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