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Trends in Lipids and Lipoproteins in US Adults, 1988-2010

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Context Serum total cholesterol (TC) and low-density lipoprotein cholesterol (LDL-C) contribute to atherosclerosis and its clinical consequences. Between the periods 1988-1994 and 1999-2002, mean TC and mean LDL-C declined in adults. During this time, there was an increase in the percentage of adults receiving lipid-lowering medications. Geometric mean triglyceride levels increased but mean high-density lipoprotein cholesterol (HDL-C) remained unchanged.

Objective To examine trends in serum lipids in adults between 1988 and 2010.

Design, Setting, and Participants Three distinct US cross-sectional National Health and Nutrition Examination Surveys, 1988-1994 (n=16 573), 1999-2002 (n=9471), and 2007-2010 (n=11 766).

Main Outcome Measures Mean TC, LDL-C, HDL-C, non–HDL-C, and geometric mean triglyceride levels and the prevalence of lipid-lowering medication use.

Results Mean TC declined from 206 (95% CI, 205-207) mg/dL in 1988-1994 to 196 (95% CI, 195-198) mg/dL in 2007-2010 ($P<.001$ for linear trend); mean LDL-C declined from 129 (95% CI, 127-130) mg/dL to 116 (95% CI, 114-117) mg/dL ($P<.001$ for linear trend). Mean non–HDL-C declined from 155 (95% CI, 153-157) mg/dL in 1988-1994 to 144 (95% CI, 143-145) mg/dL in 2007-2010 ($P<.001$ for linear trend). Mean HDL-C increased from 50.7 (95% CI, 50.0-51.0) mg/dL during 1988-1994 to 52.5 (95% CI, 51.8-53.2) mg/dL in 2007-2010 ($P=.001$ for linear trend). Geometric mean serum triglyceride levels increased from 118 (95% CI, 114-121) mg/dL in 1988-1994 to 123 (95% CI, 119-127) mg/dL in 1999-2002 and decreased to 110 (95% CI, 107-113) mg/dL in 2007-2010 ($P<.001$ for quadratic trend). The prevalence of lipid-lowering medication use increased from 3.4% (95% CI, 2.9%-3.9%) in 1988-1994 to 15.5% (95% CI, 14.7%-16.3%) in 2007-2010 ($P<.001$ for linear trend). Among adults not receiving lipid-lowering medications, trends in lipids were similar to those reported for adults overall. Among obese adults, mean TC, non–HDL-C, LDL-C, and geometric mean triglycerides declined between 1988 and 2010.

Conclusion Between 1988 and 2010, favorable trends in lipid levels have occurred among adults in the United States.

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Epidemiologic studies have demonstrated that high concentrations of low-density lipoprotein cholesterol (LDL-C) and total cholesterol (TC) and low levels of high-density lipoprotein cholesterol (HDL-C) are major risk factors for coronary heart disease (CHD).[1-6] Although triglyceride levels have not been shown to be an independent risk factor for CHD, there is increasing evidence of a strong association between elevated triglyceride levels and CHD risk.[7,8] Very low-density lipoprotein cholesterol combined with LDL-C form non–HDL-C, which may enhance CHD risk prediction when triglyceride levels are high (200-499 mg/dL).[9]

Among adults in the United States, there have been consistent declines in mean TC from 1960 to 1994,[10,11] with substantial decreases occurring between 1976-1980 and 1988-1991.[11] Between 1988-1994 and 1999-2002, age-adjusted mean TC and age-adjusted mean LDL-C levels continued to decline in all adults aged 20 years or older, and the decreases were substantial, in particular for men aged 60 years or older and women aged 50 years or older.[12]

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In this study, trends in serum lipids and lipoproteins among adults aged 20 years or older including TC, HDL-C, non–HDL-C, LDL-C, and triglycerides over a 22-year period spanning 1988 to 2010 were analyzed. Trends in the percentage of adults receiving lipid-lowering medications, trends in these lipid concentrations for adults not re-

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ceiving lipid-lowering medications, and trends in lipids for obese adults during this period are also presented.

METHODS

Results are based on data from 3 National Health and Nutrition Examination Surveys (NHANES), including NHANES III (1988-1994),[13] NHANES 1999-2002, and NHANES 2007-2010.[14] Data from NHANES 2003-2006 are not presented to allow approximately equal intervals between the midpoints of the constructed survey periods and because of changes in laboratory methods during this period that most likely positively biased HDL-C values.[15]

The NHANES surveys are conducted by the National Center for Health Statistics/Centers for Disease Control and Prevention (CDC) and constitute a series of cross-sectional, nationally representative surveys of the US noninstitutionalized population. Beginning in 1999, NHANES became a continuous survey and data have been released in 2-year cycles.[14] Each of the NHANES survey designs is a complex, multistage, area probability sample. Written informed consent was obtained from participants. The survey was approved by the National Center for Health Statistics ethics review board.

Each survey includes an interview and an examination. The interview consists of health-related questions including use of lipid-lowering medications. Persons participating in the interview are invited to participate in the examination carried out in a mobile examination center including phlebotomy and body measurements.[12,13] Participants in the examination component of NHANES were randomly assigned to either a morning session (and asked to fast for at least 8 hours prior to the examination) or an afternoon/evening session. Each examined participant was eligible for TC and HDL-C measurements, whereas only participants in the morning session who fasted between 8.5 and 23 hours were eligible for triglyceride measurements.

Definition of Variables

Participants self-reported their race and ethnicity after being shown a list that included an open-ended response. Race/ethnicity was categorized as Mexican American, non-Hispanic white, and non-Hispanic black.

During the interview, adults were asked whether they had had their cholesterol checked. Those who responded affirmatively were asked whether they had been told by a physician that their cholesterol was high. Those who responded affirmatively were asked if a physician had told them to take prescribed medicine to lower their blood cholesterol. Those who responded affirmatively were then asked if they were currently taking lipid-lowering medications.

Body mass index (BMI) was defined as weight in kilograms divided by height in meters squared rounded to the nearest tenth. Adults were classified as underweight (BMI <18.5), healthy weight (BMI 18.5 to <25), overweight (BMI 25 to <30), and obese (BMI ≥ 30).

To convert TC, LDL-C, HDL-C, and non–HDL-C to millimoles per liter, multiply by 0.0259. To convert triglycerides to millimoles per liter, multiply by 0.0113.

Laboratory Methods

All lipid analyses were conducted on venous samples collected according to a standardized protocol.[15-17] There were changes in the laboratories, methods, and instruments used to measure lipid concentrations across survey periods.[12] In 2007-2010, similar to previous surveys, TC[18] and triglycerides[19] were measured using enzymatic reactions. High-density lipoprotein cholesterol was measured by the direct immunoassay method[20] during 2007-2010, whereas in 1988-1994 and 1999-2002, the heparin manganese precipitation method[21] was primarily used. The Friedewald equation[22] (LDL-C = TC – [HDL-C + triglycerides/5]) was used to calculate LDL-C for adults whose triglyceride level was less than or equal to 400 mg/dL. Non–HDL-C was calculated as TC minus HDL-C. Standardization of serum lipid measurements was performed according to the criteria of the CDC's Lipid Standardization Program.[23]

Statistical Analyses

Arithmetic means for TC, HDL-C, non–HDL-C, LDL-C, and the percentage of participants receiving lipid-lowering medications are presented. Because of the highly skewed distribution of triglycerides, the geometric mean, calculated by back-transforming the mean of the logarithm of the triglyceride values,[24] is presented. In estimating means, geometric means, and percentages, sample weights, which adjust for the unequal selection probabilities, nonresponse, and noncoverage, were incorporated. Standard errors used to construct confidence intervals were estimated using Taylor series linearization, a design-based method.[24] Confidence intervals for the percentage of adults taking lipid-lowering medications were constructed using the logit transformation[24] to avoid negative lower limits. Means, geometric means, and percentages for participants aged 20 years or older were age-adjusted by the direct method[25] to the projected 2000 Census population estimates using the age groups 20 to 39 years, 40 to 59 years, and 60 years or older.[26]

Statistical hypotheses were tested using the *t* statistic and an $\alpha = .05$ based on a 2-tailed test. The Bonferroni method was used to adjust for multiple comparisons by dividing the overall α level by the number of implied comparisons. For example, in testing for trends involving all adults, men, and women, there were 3 implied comparisons and an $\alpha = .017$ was used. For trends involving the 6 sex and race/ethnicity groups, an overall $\alpha = .008$ was used. Statistical hypotheses for triglycerides were tested on the log scale. Hypotheses of no survey trends in age-adjusted means and percentages over the 22-year period 1988 to 2010 (which involved 3 survey periods, 1988-1994, 1999-2002, and 2007-2010) were tested using orthogonal contrast matrices.[27] Rejection of this null hypoth-

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esis implied the existence of a trend. Both linear (ie, consistent increases or decreases between 1988 and 2010) and quadratic (ie, an increase from 1988-1994 to 1999-2002 followed by a decrease between 1999-2002 and 2007-2010) trends were tested. To control for the possible confounding effect of BMI and lipid-lowering medications as well as race/ethnicity and age, sex-specific multiple linear regression models were constructed with survey treated as a continuous variable. Age was also treated as continuous variable. The Satterthwaite-adjusted *F* test[28] was used to test for trends. All statistical analyses were carried out using SAS version 9.2.1 (SAS Institute Inc) and SUDAAN version 10.0 (RTI International).

RESULTS

Analytic Sample

There were 16 573 adults aged 20 years or older examined in NHANES III, 9471 in NHANES 1999-2002, and 11 766 in NHANES 2007-2010. Between 5% and 7%, depending on the survey year, were excluded from analyses because of missing data for TC, HDL-C, and non–HDL-C. Some participants were missing TC but not HDL-C data and vice versa; therefore, sample sizes differ slightly for each of these outcomes. Approximately 1% to 3% of the morning sample, depending on survey year, had missing triglyceride data and were therefore excluded from these analyses. For calculation of LDL-C by the Friedewald equation, approximately 3% to 5% of participants were excluded because of triglyceride levels greater than 400 mg/dL or missing TC or HDL-C data.

Total Cholesterol

The age-adjusted mean TC level for adults declined linearly from 206 (95% CI, 205-207) mg/dL in 1988-1994 to 203 (95% CI, 201-205) mg/dL in 1999-2002 and to 196 (95% CI, 195-198) mg/dL in 2007-2010 ($P<.001$ for linear trend) (TABLE 1). Similar trends over this 22-year period were observed in age-adjusted mean TC levels for men ($P<.001$ for linear trend) and for women ($P<.001$ for linear trend).

Statistically significant declining trends in age-adjusted mean TC levels from 1988-1994 to 2007-2010 were observed in all sex and race/ethnicity subgroups except for Mexican American men ($P=.03$).

HDL Cholesterol

From 1988-1994 to 2007-2010, an increasing linear trend in age-adjusted mean HDL-C levels was observed for all adults (50.7 [95% CI, 50.0-51.0] mg/dL vs 52.5 [95% CI, 51.8-53.2] mg/dL; $P=.001$ for linear trend), for men ($P=.007$ for linear trend), and for women ($P=.001$ for linear trend) (Table 1). Age-adjusted mean HDL-C levels increased linearly in non-Hispanic whites of both sexes but not in non-Hispanic blacks or Mexican Americans.

Non-HDL Cholesterol

Between 1988 and 2010, a linear decline in age-adjusted mean non–HDL-C level was observed for all adults (from 155 [95% CI,153-157] mg/dL in 1988-1994 to 152 [95% CI, 150-154] mg/dL in 1999-2002 and to 144 [95% CI, 143-145] mg/dL in 2007-2010; $P<.001$ for linear trend), for men ($P<.001$ for linear trend), and for women ($P<.001$ for linear trend) (Table 1).

Triglycerides

The age-adjusted geometric mean triglyceride level for all adults increased from 118 (95% CI, 114-121) mg/dL in 1988-1994 to 123 (95% CI, 119-127) mg/dL in 1999-2002 and then declined in 2007-2010 to 110 (95% CI, 107-113) mg/dL ($P<.001$ for quadratic trend) (TABLE 2). Similar quadratic trends over this 22-year period were observed for men ($P=.01$ for quadratic trend) and for women ($P<.001$ for quadratic trend). Decreases in the age-adjusted geometric mean triglyceride level occurred from 1999-2002 to 2007-2010 for non-Hispanic white men ($P<.001$) and Mexican American women ($P=.001$). For non-Hispanic white women, there was a significant quadratic trend over this 22-year period ($P<.001$) (Table 2).

LDL Cholesterol

From 1988 to 2010, there was a decreasing linear trend in age-adjusted mean LDL-C levels for all adults, from 129 (95% CI, 127-130) mg/dL in 1988-1994 to 123 (95% CI, 121-125) mg/dL in 1999-2002 and to 116 (95% CI, 114-117) mg/dL during 2007-2010 ($P<.001$ for linear trend) (Table 2). Age-adjusted mean LDL-C levels for both men and women also decreased linearly ($P<.001$ for linear trend for both men and women) and converged over this 22-year period. Although men had a higher age-adjusted mean LDL-C level than women during 1988-1994 ($P<.001$) and 1999-2002 ($P<.001$), during 2007-2010 there was no longer a sex difference ($P=.37$).

Age-Specific Trends

Between 1988 and 2010, significant declining trends in mean TC, non–HDL-C, and LDL-C levels of up to 32 mg/dL were generally observed in adults of both sexes aged 50 years or older ($P<.001$ except for LDL-C in women aged 50-59 years) (eTable 1 and eTable 2; available at http://www.jama.com). For both men and women aged 50 years or older, decreasing trends in geometric mean triglyceride levels of up to 23 mg/dL were observed during this 22-year period, which were significant only for men aged 50 to 59 years and men aged 70 years or older (eTable 2). From 1988-1994 to 2007-2010, increases in mean HDL-C levels of approximately 3 mg/dL in men aged 50 years or older and ranging from 2 to 4 mg/dL in women aged 40 years or older were observed but were significant only for women aged 40 to 49 years ($P<.001$) (eTable 1).

Lipid-Lowering Medications

From 1988 to 2010, there was an increasing trend in the age-adjusted percentage of adults taking lipid-lowering medications (from 3.4% [95% CI, 2.9%-3.9%] in 1988-1994 to

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Table 1. Age-Adjusted Mean Serum Total, HDL, and Non-HDL Cholesterol Levels by Sex and Race/Ethnicity Among Adults Aged 20 Years or Older, 1988-2010[a]

	1988-1994		1999-2002		2007-2010			
	No. of Participants	Mean (95% CI), mg/dL	No. of Participants	Mean (95% CI), mg/dL	No. of Participants	Mean (95% CI), mg/dL	*P* Value for Linear Trend, 1988-1994 to 2007-2010[b]	*P* Value for Comparison of 1999-2002 and 2007-2010[c]
Total Cholesterol								
All race/ethnicity groups[d]								
Both sexes	15 719	206 (205-207)	8809	203 (201-205)	11 028	196 (195-198)	<.001	<.001
Men	7392	204 (202-206)	4165	202 (200-205)	5376	194 (192-196)	<.001	<.001
Women	8327	207 (206-209)	4644	204 (202-205)	5652	198 (196-200)	<.001	<.001
Mexican American								
Both sexes	4304	205 (203-208)	2122	202 (199-204)	1988	199 (197-201)	<.001	.08
Men	2157	205 (202-208)	998	204 (200-207)	951	200 (197-203)	.03	.11
Women	2147	205 (202-208)	1124	199 (196-202)	1937	197 (195-199)	<.001	.22
Non-Hispanic white								
Both sexes	6545	206 (205-208)	4338	204 (202-206)	5321	197 (195-198)	<.001	<.001
Men	3051	204 (202-206)	2091	202 (199-205)	2663	193 (191-195)	<.001	<.001
Women	3494	208 (206-210)	2247	205 (203-207)	2658	200 (198-202)	<.001	.001
Non-Hispanic black								
Both sexes	4243	204 (203-206)	1602	199 (196-201)	1989	192 (190-194)	<.001	<.001
Men	1914	202 (199-204)	749	195 (191-199)	965	191 (188-193)	<.001	.08
Women	2329	206 (204-207)	853	201 (198-205)	1024	192 (188-196)	<.001	.001
HDL Cholesterol								
All race/ethnicity groups[d]								
Both sexes	15 610	50.7 (50.0-51.0)	8808	51.3 (51.0-52.0)	11 028	52.5 (51.8-53.2)	.001	.02
Men	7335	45.6 (44.9-46.0)	4164	45.9 (45.0-47.0)	5376	47.0 (46.4-47.7)	.007	.02
Women	8275	55.4 (54.5-56.0)	4644	56.2 (55.0-57.0)	5652	57.6 (56.7-58.5)	.001	.04
Mexican American								
Both sexes	4272	48.7 (47.9-50.0)	2122	48.9 (48.0-49.0)	1988	49.4 (48.3-50.5)	.32	.40
Men	2134	45.2 (44.3-46.0)	998	45.0 (44.0-46.0)	951	45.4 (44.3-46.5)	.71	.57
Women	2138	52.3 (51.3-53.0)	1124	52.9 (52.0-54.0)	1037	53.7 (52.2-55.1)	.13	.39
Non-Hispanic white								
Both sexes	6493	50.4 (49.6-51.0)	4337	51.2 (50.0-52.0)	5321	52.5 (51.5-53.5)	.003	.06
Men	3028	44.8 (43.9-46.0)	2090	45.5 (45.0-46.0)	2663	46.7 (45.8-47.5)	.005	.06
Women	3465	55.7 (54.6-57.0)	2247	56.6 (55.0-58.0)	2658	58.1 (56.8-59.4)	.007	.12
Non-Hispanic black								
Both sexes	4224	55.2 (54.3-56.0)	1602	54.5 (54.0-56.0)	1989	56.1 (55.1-57.0)	.16	.03
Men	1907	52.4 (51.2-54.0)	749	51.0 (50.0-52.0)	965	52.6 (51.6-53.6)	.76	.06
Women	2317	57.3 (56.4-58.0)	853	57.3 (56.0-58.0)	1024	58.7 (57.2-60.2)	.12	.12
Non-HDL Cholesterol								
All race/ethnicity groups[d]								
Both sexes	15 605	155 (153-157)	8807	152 (150-154)	11 028	144 (143-145)	<.001	<.001
Men	7334	158 (156-160)	4164	156 (154-159)	5376	147 (145-148)	<.001	<.001
Women	8271	152 (150-154)	4643	147 (146-149)	5652	140 (139-142)	<.001	<.001
Mexican American								
Both sexes	4272	156 (154-158)	2122	153 (150-155)	1988	149 (147-152)	<.001	.07
Men	2134	159 (156-162)	998	159 (155-163)	951	155 (151-158)	.04	.11
Women	2138	153 (150-155)	1124	146 (143-149)	1037	143 (140-145)	<.001	.15
Non-Hispanic white								
Both sexes	6491	156 (154-158)	4337	152 (150-155)	5321	144 (143-145)	<.001	<.001
Men	3028	160 (157-162)	2090	156 (153-159)	2663	146 (145-148)	<.001	<.001
Women	3463	152 (149-154)	2247	148 (146-151)	2658	142 (140-143)	<.001	<.001
Non-Hispanic black								
Both sexes	4221	149 (147-150)	1601	144 (141-147)	1989	136 (133-138)	<.001	<.001
Men	1906	149 (146-152)	749	144 (140-148)	965	138 (135-141)	<.001	.03
Women	2315	148 (146-150)	852	144 (140-148)	1024	133 (130-137)	<.001	<.001

Abbreviation: HDL, high-density lipoprotein.
SI conversions: To convert total, HDL, and non-HDL cholesterol to mmol/L, multiply by 0.0259.
[a] All estimates are based on weighted data. Age-adjusted by direct method to the year 2000 population using the age groups 20 to 39 years, 40 to 59 years, and 60 years or older.
[b] Applying the Bonferroni method for adjusting for multiple comparisons for all adults, for men, and for women, there were 3 implied comparisons and an $\alpha = .017$ ($\alpha = .05/3$) was used. For the 6 sex and race/ethnicity groups, an $\alpha = .008$ ($\alpha = .05/6$) was used.
[c] The α levels given in footnote "b" were used to adjust for multiple comparisons.
[d] Includes data for race/ethnicity groups not shown separately.

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9.3% [95% CI, 8.7%-10.0%] in 1999-2002 and to 15.5% [95% CI, 14.7%-16.3%] in 2007-2010; $P<.001$ for linear trend) (TABLE 3). The increase in lipid medication use was significant for all sex and race/ethnicity subgroups. Among men and women aged 50 years or older, increases in lipid-lowering medications of up to 35% were observed.

Adults Not Taking Lipid-Lowering Medications

Declining trends in age-adjusted mean TC and non–HDL-C levels and increasing trends in age-adjusted mean HDL-C levels similar to those observed in adults aged 20 years or older in the US population between 1988 and 2010 were also seen in adults not receiving lipid-lowering medications (TABLE 4). For example, the age-adjusted mean TC level for adults not taking lipid-lowering medications decreased from 206 (95% CI, 204-207) mg/dL in 1988-1994 to 204 (95% CI, 202-205) mg/dL in 1999-2002 and to 199 (95% CI, 198-201) mg/dL in 2007-2010 ($P<.001$ for linear trend) (Table 4). Quadratic trends in age-adjusted geometric mean triglyceride levels and declining linear trends in age-adjusted

Table 2. Age-Adjusted Geometric Mean Triglyceride and Mean LDL Cholesterol Levels by Sex and Race/Ethnicity Among Adults Aged 20 Years or Older, 1988-2010[a]

	1988-1994		1999-2002		2007-2010		*P* Value for Linear Trend, 1988-1994 to 2007-2010[b]	*P* Value for Comparison of 1999-2002 and 2007-2010[c]
	No. of Participants	Mean (95% CI), mg/dL	No. of Participants	Mean (95% CI), mg/dL	No. of Participants	Mean (95% CI), mg/dL		
Triglycerides								
All race/ethnicity groups[d]								
Both sexes	6945	118 (114-121)[e]	3982	123 (119-127)[e]	4942	110 (107-113)[e]	.003	<.001
Men	3245	127 (122-132)[f]	1893	132 (125-138)[f]	2353	119 (115-123)[f]	.03	.001
Women	3700	110 (106-114)[e]	2089	115 (112-119)[e]	2589	102 (99-105)[e]	.006	<.001
Mexican American								
Both sexes	1914	134 (129-139)	994	139 (132-146)	921	127 (121-133)	.1	.02
Men	954	136 (129-143)	467	142 (130-154)	431	136 (127-144)	.87	.42
Women	960	132 (127-138)	527	135 (126-143)	490	117 (112-123)	<.001	.001
Non-Hispanic white								
Both sexes	2925	120 (116-125)	1997	125 (121-130)	2354	111 (108-114)	.004	<.001
Men	1356	130 (124-137)	965	134 (126-142)	1146	119 (114-123)	.01	<.001
Women	1569	111 (107-116)[e]	1032	117 (114-121)[e]	1208	104 (100-108)[e]	.03	<.001
Non-Hispanic black								
Both sexes	1832	93 (90-96)	674	94 (89-99)	867	88 (83-93)	.11	.08
Men	812	100 (95-105)	312	99 (91-106)	409	94 (87-101)	.16	.36
Women	1020	88 (84-92)	362	90 (85-96)	458	83 (79-88)	.1	.03
LDL Cholesterol								
All race/ethnicity groups[d]								
Both sexes	6795	129 (127-130)	3867	123 (121-125)	4846	116 (114-117)	<.001	<.001
Men	3154	131 (129-133)[g]	1815	126 (123-128)[g]	2287	116 (115-118)	<.001	<.001
Women	3641	126 (123-128)	2052	120 (118-123)	2559	115 (113-117)	<.001	<.001
Mexican American								
Both sexes	1856	125 (123-127)	950	121 (119-124)	898	118 (115-121)	<.001	.08
Men	913	127 (125-130)	439	125 (121-129)	416	120 (116-124)	.001	.05
Women	943	123 (120-126)	511	117 (114-120)	482	115 (111-119)	<.001	.34
Non-Hispanic white								
Both sexes	2856	129 (127-131)	1938	124 (121-126)	2305	116 (114-118)	<.001	<.001
Men	1317	132 (130-134)[f]	924	126 (123-129)[f]	1114	115 (113-117)	<.001	<.001
Women	1539	126 (123-129)	1014	121 (119-124)	1191	116 (113-118)	<.001	.001
Non-Hispanic black								
Both sexes	1814	128 (125-131)	670	121 (118-124)	858	115 (112-118)	<.001	.005
Men	802	129 (125-133)	309	121 (117-124)	403	116 (112-120)	<.001	.07
Women	1012	127 (124-129)	361	121 (116-126)	455	114 (111-118)	<.001	.02

Abbreviation: LDL, low-density lipoprotein.
SI conversions: To convert triglycerides to mmol/L, multiply by 0.0113. To convert LDL cholesterol to mmol/L, multiply by 0.0259.
[a] Age-adjusted by direct method to the year 2000 population using the age groups 20 to 39 years, 40 to 59 years, and 60 years or older.
[b] Applying the Bonferroni method for adjusting for multiple comparisons for all adults, for men, and for women, there were 3 implied comparisons and an $\alpha=.017$ ($\alpha=.05/3$) was used. For the 6 sex and race/ethnicity groups, an $\alpha=.008$ ($\alpha=.05/6$) was used.
[c] The α levels given in footnote "b" were used to adjust for multiple comparisons.
[d] Includes data for race/ethnicity groups not shown separately.
[e] Significant quadratic trend: $P<.001$ for all adults, for women, and for non-Hispanic white women, adjusted for multiple comparisons.
[f] Significant quadratic trend for men: $P<.02$, adjusted for multiple comparisons.
[g] Significantly different from women of the same race/ethnicity and survey period.

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mean LDL-C levels similar to those observed in the US population over this 22-year period were also observed in adults not taking lipid-lowering medications. For example, the age-adjusted mean LDL-C level for adults not receiving lipid-lowering medications declined from 128 (95% CI, 127-130) mg/dL in 1988-1994 to 124 (95% CI, 122-126) mg/dL in 1999-2002 and to 119 (95% CI, 117-121) mg/dL in 2007-2010 ($P<.001$ for linear trend) (TABLE 5).

Obese Adults Aged 20 Years or Older

Statistically significant declines in age-adjusted mean TC, non–HDL-C, and LDL-C levels between 1988 and 2010, similar to those observed for US adults and adults not taking lipid-lowering medications, were seen in obese adults, obese men, and obese women ($P<.001$ for linear trend). In contrast to adults in the US population and to adults not taking lipid-lowering medications, there was a significant linear decrease in age-adjusted geometric mean triglyceride levels between 1988-1994 and 2007-2010 for obese adults, obese men, and obese women ($P<.001$ for linear trend) but not a significant quadratic trend. Also, the age-adjusted mean HDL-C level for all obese adults and for obese men did not change significantly, but there was an increasing linear trend in age-adjusted mean HDL-C level for obese women ($P=.008$ for linear trend) (eTable 3).

Sex-Specific Multiple Linear Regression Models

After controlling for the possible confounding effects of race/ethnicity, age, BMI, and lipid-lowering medications, a significant decrease in TC of approximately 4 mg/dL per year was observed in both men and women between 1988 and 2010 ($P<.001$ by Satterthwaite-adjusted F test for trend). Decreases in LDL-C of approximately 6 mg/dL per year for men and 5 mg/dL per year for

Table 3. Age-Adjusted Use of Lipid-Lowering Medications by Sex, Age, and Race/Ethnicity Among Adults Aged 20 Years or Older, 1988-2010[a]

	1988-1994		1999-2002		2007-2010			
	No. of Participants	Use of Lipid-Lowering Medications, % (95% CI)	No. of Participants	Use of Lipid-Lowering Medications, % (95% CI)	No. of Participants	Use of Lipid-Lowering Medications, % (95% CI)	*P* Value for Linear Trend, 1988-1994 to 2007-2010[b]	*P* Value for Comparison of 1999-2002 and 2007-2010[c]
All race/ethnicity groups[d]								
Both sexes	16 019	3.4 (2.9-3.9)	9062	9.3 (8.7-10.0)	11 355	15.5 (14.7-16.3)	<.001	<.001
Men, age group, y								
≥20	7494	3.1 (2.5-3.8)	4269	10.7 (9.6-11.8)	5510	16.8 (15.7-17.9)	<.001	<.001
20-39	3038	0.4 (0.1-1.0)	1405	1.5 (0.9-2.5)	1765	1.8 (1.0-3.2)	.009	.66
40-49	1187	3.0 (1.8-5.0)	767	8.4 (5.9-11.8)	927	13.5 (11.2-16.2)	<.001	.008
50-59	826	5.0 (3.6-6.8)	586	16.7 (13.5-20.5)	914	21.5 (17.8-25.8)	<.001	.07
60-69	1119	6.9 (4.9-9.6)	683	24.9 (20.6-29.8)	919	41.2 (36.6-45.9)	<.001	<.001
≥70	1324	6.7 (4.5-9.8)	828	23.6 (20.7-26.8)	985	42.0 (39.6-44.4)	<.001	<.001
Women, age group, y								
≥20	8525	3.5 (2.9-4.3)	4793	8.1 (7.3-8.9)	5845	14.4 (13.3-15.6)	<.001	<.001
20-39	3624	0.2 (0.1-0.9)	1859	0.5 (0.2-1.1)	1915	2.0 (1.4-2.7)	<.001	<.001
40-49	1333	2.3 (1.3-4.1)	784	4.0 (2.4-6.6)	1052	6.9 (5.1-9.2)	<.001	.041
50-59	976	6.1 (4.4-8.5)	593	12.8 (9.6-16.7)	866	22.4 (19.5-25.5)	<.001	<.001
60-69	1106	8.7 (6.4-11.7)	716	20.1 (16.8-23.8)	953	33.7 (29.6-38.2)	<.001	<.001
≥70	1486	8.7 (6.7-11.1)	841	22.8 (19.1-27.1)	1059	38.3 (35.4-41.3)	<.001	<.001
Mexican American								
Both sexes	4323	2.4 (1.8-3.0)	2156	6.0 (4.9-7.2)	1999	14.4 (12.9-16.1)	<.001	<.001
Men	2159	2.2 (1.4-3.4)	1018	5.2 (3.9-6.8)	958	14.6 (13.2-16.2)	<.001	<.001
Women	2164	2.5 (1.7-3.7)	1138	6.7 (5.5-8.1)	1041	14 (11.9-16.5)	<.001	<.001
Non-Hispanic white								
Both sexes	6547	3.4 (2.9-4.1)	4395	9.8 (9.1-10.6)	5379	15.9 (14.8-17.0)	<.001	<.001
Men	3039	3.2 (2.6-4)	2110	11.3 (10.1-12.5)	2673	17.4 (15.9-18.9)	<.001	<.001
Women	3508	3.6 (2.9-4.5)	2285	8.5 (7.6-9.5)	2706	14.6 (13.1-16.2)	<.001	<.001
Non-Hispanic black								
Both sexes	4509	2.8 (2.3-3.4)	1726	7.0 (6.1-8.1)	2217	15.1 (13.9-16.5)	<.001	<.001
Men	2026	2.2 (1.6-3.0)	798	8.5 (7.1-10.1)	1072	15.4 (13.4-17.6)	<.001	<.001
Women	2483	3.2 (2.5-4.0)	928	6.0 (4.8-7.5)	1145	14.9 (13.2-16.8)	<.001	<.001

[a] All estimates are based on weighted data. Age-adjusted by direct method to the year 2000 population using the age groups 20 to 39 years, 40 to 59 years, and 60 years or older.
[b] Applying the Bonferroni method for adjusting for multiple comparisons for all adults, for men, and for women, there were 3 implied comparisons and an $\alpha=.017(\alpha=.05/3)$ was used. For the 6 sex and race/ethnicity groups, an $\alpha=.008$ ($\alpha=.05/6$) was used.
[c] The α levels given in footnote "b" were used to adjust for multiple comparisons.
[d] Includes data for race/ethnicity groups not shown separately.

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Table 4. Age-Adjusted Mean Total, HDL, and Non-HDL Cholesterol Levels by Sex and Race/Ethnicity Among Adults Aged 20 Years or Older Not Using Lipid-Lowering Medications, 1988-2010[a]

	1988-1994		1999-2002		2007-2010			
	No. of Participants	Mean (95% CI), mg/dL	No. of Participants	Mean (95% CI), mg/dL	No. of Participants	Mean (95% CI), mg/dL	*P* Value for Linear Trend, 1988-1994 to 2007-2010[b]	*P* Value for Comparison of 1999-2002 and 2007-2010[c]
Total Cholesterol								
All race/ethnicity groups[d]								
Both sexes	14 732	206 (204-207)	7591	204 (202-205)	8628	199 (198-201)	<.001	<.001
Men	6924	204 (202-206)	3546	203 (201-205)	4142	197 (195-199)	<.001	<.001
Women	7808	207 (205-208)	4645	204 (202-206)	4486	200 (199-202)	<.001	.005
Mexican American								
Both sexes	4073	205 (202-208)	1888	201 (199-204)	1618	200 (198-203)	.01	.67
Men	2042	205 (202-208)	902	203 (199-207)	782	203 (200-206)	.34	.84
Women	2031	204 (202-207)	986	199 (196-201)	836	197 (196-199)	<.001	.50
Non-Hispanic white								
Both sexes	6044	206 (204-208)	3643	205 (203-207)	4029	200 (198-202)	<.001	<.001
Men	2821	204 (202-206)	1725	203 (200-206)	1956	196 (194-198)	<.001	<.001
Women	3223	207 (205-209)	1918	206 (204-208)	2073	202 (200-204)	.001	.02
Non-Hispanic black								
Both sexes	4024	203 (202-205)	1397	199 (195-202)	1574	193 (191-195)	<.001	.003
Men	1813	201 (199-203)	631	195 (191-200)	758	192 (189-195)	<.001	.21
Women	2211	205 (203-207)	766	200 (197-204)	816	193 (190-197)	<.001	.005
HDL Cholesterol								
All race/ethnicity groups[d]								
Both sexes	14 632	50.8 (50.1-51.5)	7591	51.7 (51-52.5)	8628	53.2 (52.5-54)	<.001	.008
Men	6869	45.7 (45-46.5)	3546	46.3 (45.5-47.1)	4142	47.7 (46.8-48.5)	<.001	.02
Women	7763	55.5 (54.6-56.3)	4645	56.6 (55.5-57.6)	4486	58.3 (57.4-59.1)	<.001	.01
Mexican American								
Both sexes	4042	48.6 (47.8-49.4)	1888	48.9 (48.2-49.6)	1618	49.7 (48.5-50.9)	.11	.21
Men	2019	45.2 (44.4-46)	902	45.2 (44.3-46)	782	46.0 (44.9-47.2)	.25	.22
Women	2023	52.1 (51.1-53)	986	52.9 (51.8-54.1)	836	53.8 (52.1-55.4)	.07	.40
Non-Hispanic white								
Both sexes	5999	50.6 (49.7-51.4)	3643	51.7 (50.7-52.8)	4029	53.3 (52.3-54.4)	<.001	.03
Men	2800	45.0 (44.1-45.9)	1725	45.9 (45-46.8)	1956	47.2 (46.1-48.3)	.002	.06
Women	3199	55.8 (54.7-56.9)	1918	57.1 (55.6-58.5)	2073	58.9 (57.6-60.2)	<.001	.06
Non-Hispanic black								
Both sexes	4005	55.3 (54.5-56.2)	1397	55.0 (53.9-56.1)	1574	56.8 (55.8-57.8)	.02	.01
Men	1806	52.6 (51.4-53.8)	631	51.6 (50.0-53.1)	758	53.5 (52.3-54.8)	.28	.05
Women	2199	57.4 (56.5-58.4)	766	57.5 (56.3-58.7)	816	59.4 (57.9-60.9)	.03	.04
Non-HDL Cholesterol								
All race/ethnicity groups[d]								
Both sexes	14 627	155 (153-156)	7590	152 (150-154)	8628	146 (145-147)	<.001	<.001
Men	6868	158 (156-160)	3546	157 (154-159)	4142	149 (148-151)	<.001	<.001
Women	7759	151 (149-153)	4044	147 (145-149)	5652	142 (140-144)	<.001	<.001
Mexican American								
Both sexes	4042	156 (154-158)	1888	152 (150-155)	1618	151 (148-153)	.002	.39
Men	2019	159 (156-162)	902	158 (154-163)	782	157 (153-160)	.28	.61
Women	2023	152 (150-155)	986	146 (143-149)	836	144 (141-146)	<.001	.31
Non-Hispanic white								
Both sexes	5997	155 (153-157)	3643	153 (151-155)	4029	146 (145-148)	<.001	<.001
Men	2800	159 (157-161)	1725	157 (154-160)	1956	149 (147-151)	<.001	<.001
Women	3197	151 (149-153)	1918	149 (146-151)	2073	143 (141-145)	<.001	.002
Non-Hispanic black								
Both sexes	4002	148 (146-150)	1396	144 (140-147)	1574	136 (134-138)	<.001	<.001
Men	1805	148 (146-151)	631	144 (139-148)	758	139 (135-142)	<.001	.06
Women	2197	147 (145-150)	765	143 (139-147)	816	134 (131-147)	<.001	<.001

Abbreviation: HDL, high-density lipoprotein.
SI conversions: To convert total, HDL, and non-HDL cholesterol to mmol/L, multiply by 0.0259.
[a] All estimates are based on weighted data. Age-adjusted by direct method to the year 2000 population using the age groups 20 to 39 years, 40 to 59 years, and 60 years or older.
[b] Applying the Bonferroni method for adjusting for multiple comparisons for all adults, for men, and for women, there were 3 implied comparisons and an $\alpha = .017$($\alpha = .05/3$) was used. For the 6 sex and race/ethnicity groups, an $\alpha = .008$ ($\alpha = .05/6$) was used.
[c] The α levels given in footnote "b" were used to adjust for multiple comparisons.
[d] Includes data for race/ethnicity groups not shown separately.

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women ($P<.001$ by Satterthwaite-adjusted F test for trend) and decreases in non–HDL-C of approximately 6 mg/dL per year were also observed over this 22-year period ($P<.001$ by Satterthwaite-adjusted F test for trend). High-density lipoprotein cholesterol increased by approximately 2 mg/dL per year in both men and women ($P<.001$ by Satterthwaite-adjusted F test for trend) (eTable 4).

COMMENT

Between 1988 and 2010, there were declining trends in age-adjusted mean TC, non–HDL-C, and LDL-C levels for adults overall, for men, and for women aged 20 years or older. The declines observed between 1988-1994 and 1999-2002 have continued to 2007-2010. The *Healthy People 2010* guideline[29] of an age-adjusted mean TC level of 200 mg/dL or less has been achieved in adults, in men, in women, and in all race/ethnicity and sex subgroups. However, the age-adjusted mean LDL-C level in adults of 116 mg/dL is higher than the optimal range of below 100 mg/dL associated with a lower risk of CHD.[9] Age-adjusted mean HDL-C levels have increased in men and women between 1988 and 2010. Although the age-adjusted geometric mean triglyceride level increased in adults overall,

Table 5. Age-Adjusted Geometric Mean Serum Triglyceride and Mean LDL Cholesterol Levels by Sex and Race/Ethnicity Among Adults Aged 20 Years or Older Not Using Lipid-Lowering Medications, 1988-2010[a]

	1988-1994		1999-2002		2007-2010		*P* Value for Linear Trend, 1988-1994 to 2007-2010	*P* Value for Comparison of 1999-2002 and 2007-2010[b]
	No. of Participants	Mean (95% CI), mg/dL	No. of Participants	Mean (95% CI), mg/dL	No. of Participants	Mean (95% CI), mg/dL		
Triglycerides								
All race/ethnicity groups[c]								
Both sexes	6518	117 (113-120)[d]	3466	121 (117-125)[d]	3867	107 (105-110)[d]	<.001	<.001
Men	3032	127 (122-132)[e]	1640	131 (124-138)[e]	1821	116 (111-120)[e]	.004	<.001
Women	3486	108 (104-112)[d]	1826	113 (109-116)[d]	2046	100 (97-103)[d]	<.001	<.001
Mexican American								
Both sexes	1810	133 (128-138)	895	138 (130-146)	760	124 (118-129)	.02	.005
Men	897	136 (129-143)	432	142 (130-154)	366	133 (123-143)	.80	.30
Women	913	130 (125-135)	463	134 (125-143)	394	113 (108-118)	<.001	<.001
Non-Hispanic white								
Both sexes	2714	119 (115-123)	1680	123 (119-127)	1767	108 (105-111)	<.001	<.001
Men	1261	130 (123-136)	798	134 (126-142)	832	116 (110-121)	.003	<.001
Women	1453	110 (105-114)[d]	882	114 (110-118)[d]	935	101 (97-105)[d]	.008	<.001
Non-Hispanic black								
Both sexes	1738	92 (89-95)	598	93 (88-97)	696	87 (83-91)	.08	.07
Men	762	100 (95-105)	270	96 (89-102)	327	93 (86-99)	.08	.48
Women	976	87 (83-91)	328	90 (85-96)	369	83 (78-87)	.15	.03
LDL Cholesterol								
All race/ethnicity groups[c]								
Both sexes	6380	128 (127-130)	3367	124 (122-126)	3806	119 (117-120)	<.001	<.001
Men	2948	131 (129-133)	1570	127 (124-130)	1779	119 (117-121)	<.001	<.001
Women	3432	126 (123-128)[f]	1797	122 (119-124)[f]	2027	118 (115-120)	<.001	.01
Mexican American								
Both sexes	1756	125 (123-127)	854	122 (119-125)	747	120 (117-123)	.009	.39
Men	858	127 (124-130)	406	126 (122-130)	356	123 (119-127)	.09	.30
Women	898	123 (121-126)	448	118 (115-121)	391	117 (113-121)	.006	.69
Non-Hispanic white								
Both sexes	2652	129 (127-131)	1633	125 (123-128)	1736	119 (116-121)	<.001	<.001
Men	1227	132 (129-134)	762	127 (124-131)	813	119 (116-121)	<.001	<.001
Women	1425	126 (123-129)[f]	871	123 (120-126)[f]	923	118 (115-121)	<.001	.01
Non-Hispanic black								
Both sexes	1720	127 (124-130)	594	121 (118-124)	691	117 (114-119)	<.001	.04
Men	752	128 (124-132)	267	120 (117-124)	325	117 (113-121)	<.001	.26
Women	968	126 (123-129)	327	121 (117-126)	366	116 (112-120)	<.001	.07

Abbreviation: LDL, low-density lipoprotein.
SI conversions: To convert triglycerides to mmol/L, multiply by 0.0113. To convert LDL cholesterol to mmol/L, multiply by 0.0259.
[a] All estimates are based on weighted data. Age-adjusted by direct method to the year 2000 population using the age groups 20 to 39 years, 40 to 59 years, and 60 years or older.
[b] Applying the Bonferroni method for adjusting for multiple comparisons for all adults, for men, and for women, there were 3 implied comparisons and an $\alpha=.017(.05/3)$ was used. For the 6 sex and race/ethnicity groups, an $\alpha=.008$ (.05/6) was used.
[c] Includes data for race/ethnicity groups not shown separately.
[d] Significant quadratic trends; ie, an increase in geometric mean between 1988-1994 and 1999-2002 followed by a decrease between 1999-2002 and 2007-2010 ($P<.001$).
[e] Significant quadratic trends; ie, an increase in geometric mean between 1988-1994 and 1999-2002 followed by a decrease between 1999-2002 and 2007-2010 ($P<.005$).
[f] Significantly different from men of the same race/ethnicity ($P<.001$).

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in men, and in women between 1988-1994 and 1999-2002, it decreased thereafter. These same patterns in HDL-C and triglycerides were also observed in adults not receiving lipid-lowering medications.

Declining trends in mean TC, non–HDL-C, and LDL-C levels over this 22-year period have also been observed for all adults, for men, and for women not taking lipid-lowering medications and for obese adults of both sexes; these trends persisted after controlling for the possible confounding effects of race/ethnicity, age, BMI, and use of lipid-lowering medications.

Declines in TC and LDL-C have been reported elsewhere. A community-based study conducted in 3 geographically different parts of France suggested significant declines in TC and LDL-C from 1997 to 2007.[30] A report on trends in TC in 199 countries and territories indicated that TC declined in high-income regions of the world (Australasia, North America, and Western Europe).[31]

The favorable trends in TC, non–HDL-C, and LDL-C may be due in part to a decrease in consumption of *trans*-fatty acids or other healthy lifestyle changes,[32] in addition to an increase in the percentage of adults taking lipid-lowering medications. They are unlikely to be the result of changes in physical activity, obesity, or intake of saturated fat. The intake of saturated fat as a percentage of calories did not decrease between 1999 and 2008.[33] Little progress was made from 1998 to 2008 in increasing leisure-time physical activity levels of adults as measured by the criteria defined in the 2008 Physical Activity Guidelines.[34-36] Also, the prevalence of obesity among adults remains high at more than one-third of the population.[37,38] Although the percentage of adults receiving lipid-lowering medications continued to increase between 1999-2002 and 2007-2010, declining trends in TC, non–HDL-C, and LDL-C also occurred for adults not taking lipid-lowering medications. The effect of intake of *trans*-fatty acids on TC, non–HDL-C, and LDL-C, controlling for the possible confounding effects of healthy lifestyles including physical activity, weight loss, and diet, still needs to be investigated.

There is some evidence that the increase in HDL-C and the decrease in triglycerides between 1999 and 2010 are due to changes in cigarette smoking and carbohydrate intake. The age-adjusted percentage of current smokers aged 18 years or older declined from 1999 to 2010.[39] Also, there was a decreasing trend in the age-adjusted mean carbohydrate intake of both men and women from 1999 to 2008.[33] Increases in use of specific types of lipid-lowering medications that may also increase HDL-C slightly and decrease triglycerides might also contribute to these changes.

This study had some limitations. Our analysis of trends in lipids among adults is based on 3 NHANES survey periods. Data from other future surveys are needed to confirm the favorable trends. Also, the use of lipid-lowering medications is based on self-report of any lipid-lowering medications rather than on specific types of lipid-lowering medications. The change in the method of measuring HDL-C could have affected the HDL-C results. However, during all 3 survey periods, the values were standardized according to the CDC Lipid Standardization Program to minimize method effects.

In summary, between 1988 and 2010, there was a favorable trend in serum lipid levels among US adults. Further work is needed to assess simultaneously the effects of *trans*-fatty acids, lipid-lowering medications, and healthy lifestyle factors on TC, HDL-C, non–HDL-C, LDL-C, and triglycerides.

Author Contributions: Ms Carroll had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.
Study concept and design: Carroll.
Analysis and interpretation of data: Carroll, Kit, Lacher, Shero, Mussolino.
Drafting of the manuscript: Carroll, Mussolino.
Critical revision of the manuscript for important intellectual content: Carroll, Kit, Lacher, Shero, Mussolino.
Statistical analysis: Carroll, Kit, Mussolino.
Obtained funding: Mussolino.
Administrative, technical, or material support: Lacher, Shero.
Study supervision: Carroll.

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Online-Only Material: The 4 eTables and Author Video Interview are available at http://www.jama.com.

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