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## Trends in Total Cholesterol, Triglycerides, and Low-Density Lipoprotein in US Adults, 1999–2014

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Total cholesterol (TC) levels, triglyceride levels, and low-density lipoprotein cholesterol (LDL-C) levels are linked to coronary heart disease.<sup>1</sup> Between 1999 and 2010, mean TC, triglycerides, and LDL-C levels declined in the United States, regardless of cholesterol-lowering medication use.<sup>2</sup> We used 2013/2014 National Health and Nutrition Examination Survey lipid data in conjunction with 1999 to 2012 data to determine whether earlier trends continued.

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**Author Contributions:** Dr Rosinger 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.

*Concept and design:* Rosinger, Carroll, Ogden.

*Acquisition, analysis, or interpretation of data:* Rosinger, Lacher, Ogden.

*Drafting of the manuscript:* Rosinger, Carroll.

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*Statistical analysis:* Rosinger, Carroll.

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**Correction:** There was an error in the author affiliations and an error in the Results section. Dr Rosinger should have the affiliation “Epidemic Intelligence Service, Centers for Disease Control and Prevention, Atlanta, Georgia,” and Drs Rosinger, Carroll, Lacher, and Ogden should have the affiliation “Division of Health and Nutrition Examination Surveys, National Center for Health Statistics, Centers for Disease Control and Prevention, Hyattsville, Maryland.” Additionally, in the first paragraph of the Results section, in the second sentence, the age-adjusted mean total cholesterol level in 2013/2014 should have been 189 mg/dL, not 89 mg/dL. This article was corrected online. This article was corrected on January 7, 2016.

## Methods |

Eight 2-year National Health and Nutrition Examination Survey cross-sectional cycles between 1999/2000 and 2013/2014 were analyzed for trends in TC levels, triglyceride levels, and LDL-C levels among adults (aged 20 years or older). The National Health and Nutrition Examination Survey uses a stratified, multistage probability design to provide a representative sample of the noninstitutionalized, civilian US population. The National Health and Nutrition Examination Survey was reviewed and approved by the National Center for Health Statistics Ethics Review Board. All participants gave written informed consent. In 2013/2014, the examination response rate for adults was 64% and ranged from 64% to 73% for the cycles between 1999/2000 and 2011/2012.

Cholesterol levels were analyzed on venous samples collected following a standardized protocol. Total cholesterol and triglyceride levels were measured using coupled enzymatic reactions.<sup>3</sup> Low-density lipoprotein cholesterol levels were calculated using the Friedewald equation ( $\text{LDL-C} = \text{TC} - [\text{high-density lipoprotein cholesterol} + \text{triglycerides}/5]$ ) for adults whose triglyceride levels did not exceed 400 mg/dL (to convert to micromoles per liter, multiply by 0.0113). Laboratory and methods changes regarding high-density lipoprotein cholesterol are discussed elsewhere.<sup>2</sup> The laboratories conducting the testing participated in the Centers for Disease Control and Prevention Lipid Standardization Program (<https://www.cdc.gov/labstandards/lsp.html>) ensuring valid measurement comparability owing to slight instrumentation and reagent changes between 1999 and 2014. Lipid-lowering medication use was defined as currently taking medication to lower cholesterol. Examination sample weights were used for TC analysis. Morning fasting sample weights were used in the analysis of triglycerides and LDL-C. Standard errors were estimated by Taylor series linearization and confidence intervals were constructed using the Wald method for means. Significance was set at  $P < .05$ . Analyses were carried out with Stata, version 13.1 (StataCorp).

Geometric means are presented for triglycerides because the distribution was heavily skewed. Arithmetic means are reported for TC and LDL-C. Estimates were age-adjusted using the direct method to the 2000 US Census projected population by age group (20–39 years, 40–59 years, and older than 60 years). Age-adjusted trends were tested with orthogonal contrasts matrices. Significant quadratic trends ( $P < .05$ ) were found for triglycerides and LDL-C, implying the trends changed direction and/or magnitude. We confirmed changes in slope using JoinPoint analysis to find inflection points and piecewise linear regressions to test differences in slope on either side of these points. Age-adjusted linear regressions were plotted using marginal standardization to generate predicted values.

## Results |

Thirty-nine thousand forty-nine adults 20 years or older had TC levels analyzed, and 17486 and 17096 had triglyceride levels and LDL-C levels analyzed, respectively. Age-adjusted mean TC decreased between 1999/2000 (204 mg/dL; 95% CI, 202–206 [to convert to micromoles per liter, multiply by 0.0259]) and 2013/2014 (189 mg/dL; 95% CI, 188–191 mg/dL) with significant linear ( $P < .001$ ) but not quadratic trends and with a 6-mg/dL drop

between 2011/2012 and 2013/2014 (Table; Figure, A). Age-adjusted geometric mean triglyceride levels decreased from 123 mg/dL (95% CI, 118–129 mg/dL) in 1999/2000 to 97 mg/dL (95% CI, 92–102 mg/dL) in 2013/2014 ( $P=.02$  quadratic trend) with a 13-mg/dL drop since 2011/2012 (Figure, B). Mean LDL-C levels decreased from 126 mg/dL (95% CI, 124–129 mg/dL; to convert to micromoles per liter, multiply by 0.0259) to 111 mg/dL (95% CI, 110–113 mg/dL) during the 8 survey cycles ( $P=.001$  quadratic trend), with a 4-mg/dL drop between 2011/2012 and 2013/2014 (Figure, C). JoinPoint analysis and piecewise regressions found an inflection point at 2011/2012 for triglyceride values and 2 inflection points for LDL-C at 2003/2004 and 2011/2012, which reflect significantly steeper negative slopes. Between 1999/2000 and 2013/2014, the decreasing trends in TC, triglycerides, and LDL-C levels described in previous paragraphs were similar when stratified by lipid-lowering medications.

## Discussion |

Between 1999/2000 and 2013/2014, a significant decline in triglyceride levels and LDL-C levels occurred with significantly steeper negative slopes observed between 2011/2012 and 2013/2014. A steady decreasing trend continued in 2013–2014<sup>2</sup> in mean TC levels.

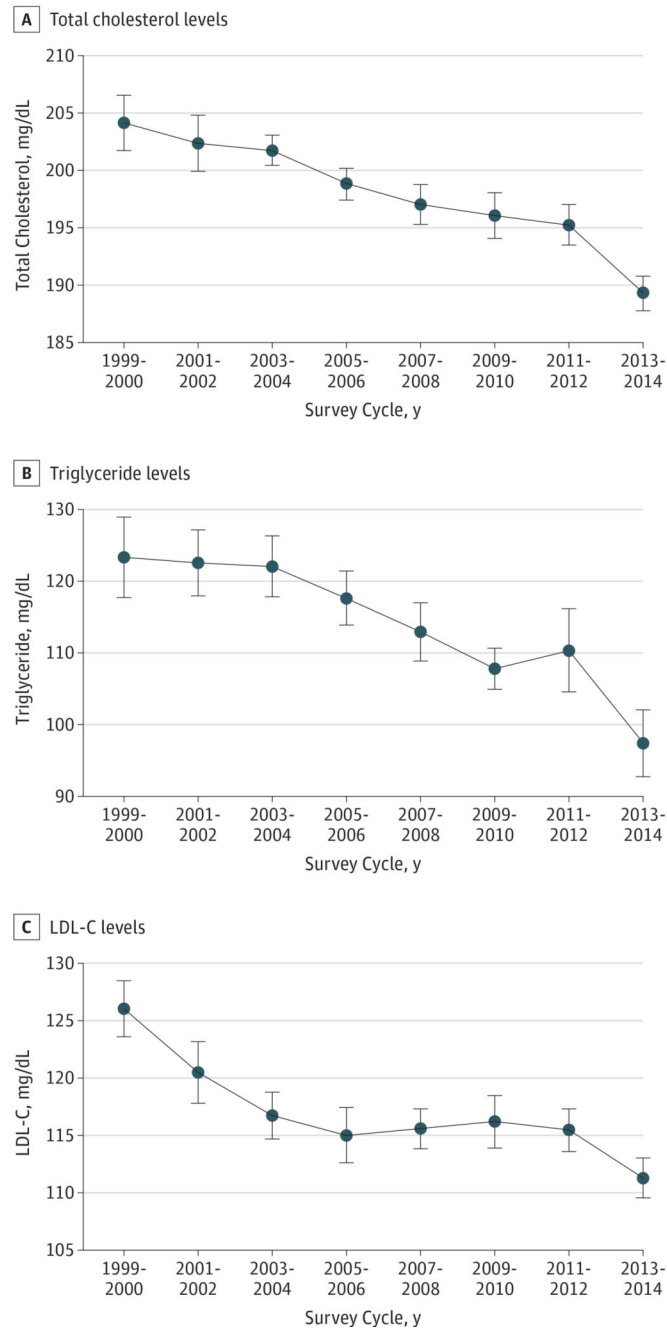
Removal of trans-fatty acids in foods has been suggested as an explanation for the observed trends of triglycerides, LDL-C levels, and TC levels.<sup>4</sup> With increased interest in triglycerides for cardiovascular health,<sup>5</sup> the continued drop of triglycerides, LDL-C levels, and TC levels at a population level represents an important finding and may be contributing to declining death rates owing to coronary heart disease since 1999.<sup>6</sup>

## Acknowledgments

**Disclaimer:** The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the National Center for Health Statistics, Centers for Disease Control and Prevention.

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**Figure 1. Age-Adjusted Total Cholesterol, Triglyceride, and Low-Density Lipoprotein Cholesterol (LDL-C) Trends for US Adults Aged 20 Years and Older, 1999 to 2014**

A, Predicted total cholesterol levels and 95% confidence intervals in a sample size of 39 049. B, Predicted log-transformed triglyceride levels and 95% confidence intervals; log-transformed values were exponentiated after the regression, sample size of 17 406. C, Predicted LDL-C levels and 95% confidence intervals in a sample size of 17 096. Figure generated using marginal standardization from age-adjusted linear regression models. Data source: Centers for Disease Control and Prevention/National Center for Health Statistics, the National Health and Nutrition Examination Survey.

SI conversion factors: To convert LDL-C to micromoles per liter, multiply by 0.0259; to convert total cholesterol to micromoles per liter, multiply by 0.0259; to convert triglycerides to micromoles per liter, multiply by 0.0113.

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Table.

Age-Adjusted Arithmetic Mean Total Cholesterol, Geometric Mean Triglycerides, and Arithmetic Mean Low-Density Lipoprotein, by Lipid-Lowering Medication Status in US Adults Aged 20 Years and Older, 1999 to 2014<sup>a</sup>

Header	Mean (95% CI)										P Value	
	1999–2000	2001–2002	2003–2004	2005–2006	2007–2008	2009–2010	2011–2012	2013–2014	Linear Trend, 1999–2000 to 2013–2014	Quadratic Trend, 1999–2000 to 2013–2014		
<i>b,c</i> No.	4118	4691	4476	4481	5332	5696	4913	5342				
Total cholesterol, mg/dL <sup>d</sup>	204 (202–206)	202 (200–205)	201 (200–203)	199 (197–200)	197 (195–199)	196 (194–198)	195 (193–197)	189 (188–191)	<.001	0.13		
<i>b,c</i> No.	369	479	649	640	981	1036	932	1061				
TC: LL meds, mg/dL <sup>d</sup>	209 (200–218)	212 (204–220)	217 (198–235)	206 (198–214)	197 (187–207)	186 (176–195)	192 (181–204)	191 (185–197)	<.001	0.67		
<i>b,c</i> No.	3590	4001	3637	3652	4137	4491	3960	4268				
TC: no LL meds, mg/dL <sup>d</sup>	205 (202–207)	203 (200–205)	203 (201–204)	200 (199–202)	200 (200–201)	199 (196–201)	199 (197–201)	193 (191–195)	<.001	0.19		
<i>b,e</i> No.	1819	2163	1952	1959	2347	2595	2286	2365				
Triglycerides, mg/dL, geometric <sup>d</sup>	123 (118–129)	122 (117–126)	121 (117–126)	117 (113–121)	112 (108–116)	107 (105–110)	110 (104–115)	97 (92–102)	<.001	0.02		
<i>b,e</i> No.	149	215	295	287	442	473	451	481				
Triglycerides: LL meds, mg/dL <sup>d</sup>	146 (139–153)	151 (122–187)	152 (126–183)	175 (141–218)	143 (127–160)	131 (108–158)	122 (104–142)	116 (100–136)	0.001	0.02		
<i>b,e</i> No.	1614	1852	1578	1601	1808	2059	1826	1875				
Triglycerides: no LL meds, mg/dL <sup>d</sup>	121 (116–127)	120 (115–125)	118 (113–123)	113 (109–116)	110 (106–114)	105 (102–108)	107 (102–113)	94 (90–99)	<.001	0.07		
<i>b,f</i> No.	1772	2095	1900	1907	2296	2550	2244	2332				
LDL-C, mg/dL <sup>d</sup>	126 (124–129)	121 (118–123)	117 (115–119)	115 (113–117)	116 (114–117)	116 (114–118)	115 (114–117)	111 (110–113)	<.001	0.001		
<i>b,f</i> No.	144	210	285	273	422	461	437	475				

	Mean (95% CI)										P Value	
	1999–2000	2001–2002	2003–2004	2005–2006	2007–2008	2009–2010	2011–2012	2013–2014	Linear Trend, 1999–2000 to 2013–2014	Quadratic Trend, 1999–2000 to 2013–2014		
<b>Header</b>												
LDL-C: LL meds, mg/dL <sup>d</sup>	117 (113–122)	121 (110–132)	119 (91–147)	122 (114–130)	120 (106–135)	107 (96–119)	107 (89–126)	107 (99–116)	0.03	0.21		
No. <sup>b,f</sup>	1574	1793	1540	1564	1778	2028	1798	1849				
LDL-C: no LL meds, mg/dL <sup>d</sup>	127 (125–130)	122 (119–124)	119 (116–121)	117 (114–120)	118 (116–120)	119 (116–122)	119 (117–121)	115 (113–117)	<.001	0.002		

Abbreviations: LDL-C, low-density lipoprotein; LL, meds, lipid-lowering medication; TC, total cholesterol.

SI conversion factor: To convert low-density lipoprotein cholesterol to micromoles per liter, multiply by 0.0259; to convert total cholesterol to micromoles per liter, multiply by 0.0259; to convert triglycerides to micromoles per liter, multiply by 0.0113.

<sup>a</sup>Data from the National Health and Nutrition Examination Survey; estimates are weighted.

<sup>b</sup>Unweighted sample size.

<sup>c</sup>Thirty-nine thousand forty-nine adults 20 years or older had TC levels analyzed and 37 883 have information on lipid-lowering medications.

<sup>d</sup>95% CI calculated using Wald method for means.

<sup>e</sup>Seventeen thousand four hundred eighty-six adults 20 years or older had triglyceride levels analyzed and 17 006 have information on lipid-lowering medications.

<sup>f</sup>Seventeen thousand ninety-six adults 20 years or older had LDL-C levels analyzed and 16 631 have information on lipid-lowering medications.