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Article

Global trends in total cholesterol by gender (1980-2018)

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SUMMARY

Elevated cholesterol is a major risk factor for cardiovascular disease, one of the leading noncommunicable diseases (NCDs) worldwide. Monitoring long-term cholesterol trends helps evaluate the success of public health efforts and medical treatments aimed at reducing this risk. This study examines global trends in average total cholesterol levels among adult men and women from 1980 to 2018. Using data from the NCD Risk Factor Collaboration, we applied gender-specific linear regressions, a multivariate regression with interaction terms, and time series modeling to evaluate changes over time. We hypothesized that total cholesterol levels decreased in both genders during the period from 1980 to 2018. We observed a steady and significant decline in cholesterol levels for both genders, with men experiencing a steeper decrease. Women consistently had slightly higher cholesterol levels, and their decline was slower. Notably, the rate of decline accelerated after 2013 for both genders. The time series model confirmed strong year-to-year persistence in cholesterol trends. Together, our findings suggest improvements in global cholesterol levels across time, likely due to public health efforts and medical advances, but also highlight a gender gap that may require more targeted attention.

INTRODUCTION

Cholesterol is a broad term for a group of lipids essential for human life (1). It is an integral part of cell membranes, contributing to their fluidity and permeability. Additionally, it is the precursor to many different biological compounds, such as vitamin D and steroid hormones. Cholesterol also serves as an important component of other compounds used for the absorption of fat-soluble vitamins. Due to the primarily water-insoluble properties of cholesterol, it is transported through the bloodstream inside different lipoproteins, including high-density lipoprotein (HDL), intermediate-density lipoprotein (IDL), low-density lipoprotein (LDL), and very-low-density lipoprotein (VLDL). Therefore, by measuring the concentrations of lipoproteins, the total blood cholesterol concentration can be estimated (1).

Lipoproteins have a hydrophobic interior and a hydrophilic exterior (1). During cholesterol transport through the bloodstream, the hydrophobic cholesterol resides within the lipoprotein particles. The most significant lipoproteins that influence atherosclerosis risk are LDL and HDL. LDL serves as a major transporter for circulating cholesterol, while HDL retrieves excess cholesterol for excretion (1). LDL cholesterol, or “bad” cholesterol, contributes to plaque buildup, while HDL, or “good” cholesterol, helps remove it (2). Clinically, LDL levels above 130 mg/dL and HDL levels below 40 mg/dL have been associated with increased cardiovascular risk (2).

High levels of cholesterol in the body can become harmful. Hypercholesterolemia, a condition where LDL cholesterol levels are abnormally elevated, has been linked to an increased risk of premature atherosclerosis (1). Atherosclerosis involves the buildup of plaque, a fatty substance, on artery walls that can lead to a variety of vascular complications, including stroke and angina. Current studies have found that an increase in HDL levels is associated with a decreased risk of atherosclerosis, though clinical trials and genetic analyses have yielded insignificant results (3, 4). Consequently, treatments mitigating premature atherosclerosis mainly aim to decrease LDL levels.

Trends in total cholesterol levels among patients with hypercholesteremia have shown that efforts to reduce LDL have been successful (5). In U.S. adults with hypercholesterolemia, an increasing proportion achieved total cholesterol levels below 200 mg/dL by 2018. These improvements are clinically meaningful, as a 1 mmol/L (~38.67 mg/dL) reduction in LDL cholesterol is associated with an approximately 22% decrease in cardiovascular events (5). In addition, variables, such as gender, age, BMI, and hypertension, were related to the control of total cholesterol. Altogether, these data suggest that maintaining a healthy cholesterol level is crucial to maintaining a healthy body and cardiovascular health.

Large-scale clinical guidelines have significantly influenced the treatment of cholesterol in at-risk populations (6,7,8). The 2013 American College of Cardiology/American Heart Association (ACC/AHA) guidelines recommended treating individuals based on cardiovascular risk rather than fixed cholesterol targets, representing a major shift in clinical practice (6). The 2018 updated guidelines expanded on this approach by emphasizing early lifestyle intervention, especially for younger adults, and considering additional therapy options for high-risk individuals (7). The real-world impact of these guidelines on patient outcomes was examined the following year (8). Although high-intensity statin use increased between 2013 and 2016, the percentage of patients reaching their cholesterol targets did not improve as expected (8). This suggests that following treatment guidelines alone may not always result in better cholesterol control and more work may be needed to ensure those guidelines are implemented effectively across different healthcare settings.

Combining medication with lifestyle and education efforts is also important for reducing LDL levels in patients. Successful cholesterol management requires not just pharmaceutical intervention but also changes in diet and behavior, as well as informed patient participation (9). At the public health level, screening and awareness also play a vital role. A 2005 report by the Centers for Disease Control and Prevention on cholesterol screening trends in the United States found that although awareness increased between 1991 and 2003, many states

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still fell short of screening goals (10). Additionally, disparities in screening rates were noted among younger adults and certain racial and ethnic groups (10). Together, these findings support a comprehensive approach to lowering cholesterol levels and reducing cardiovascular risk, integrating medical treatment with lifestyle modification, education, and improved screening access.

Despite progress in cholesterol management, important gaps remain in understanding long-term global trends and potential differences across populations. In this study, we aimed to examine how total cholesterol levels have changed over time and whether these trends differ by gender at the global level. To address this, we analyzed data from the NCD Risk Factor Collaboration (NCD-RisC), which aggregates high-quality, population-level cholesterol data from over 200 countries (11). Because the dataset is global, it provides a robust foundation for examining long-term worldwide trends. Based on prior research, public health initiatives, and the introduction of new cholesterol-management guidelines, we hypothesized that total cholesterol levels decreased in both genders during the period from 1980 to 2018. We applied gender-specific linear regressions, a multivariate regression with interaction terms, and time series modeling to evaluate changes in total cholesterol levels over time. Our analysis revealed a consistent decline in total cholesterol levels for both men and women, with a steeper decrease observed in men. We observed strong year-to-year persistence, and notably, the rate of decline accelerated after 2013 for both genders. These findings support our hypothesis and suggest overall improvement in global cholesterol levels over time, while also highlighting a gender gap that may require more targeted public health strategies. The results of this study provide updated insights into how population-level cholesterol has changed over time and contribute to an improved understanding of gender differences in cardiovascular risk.

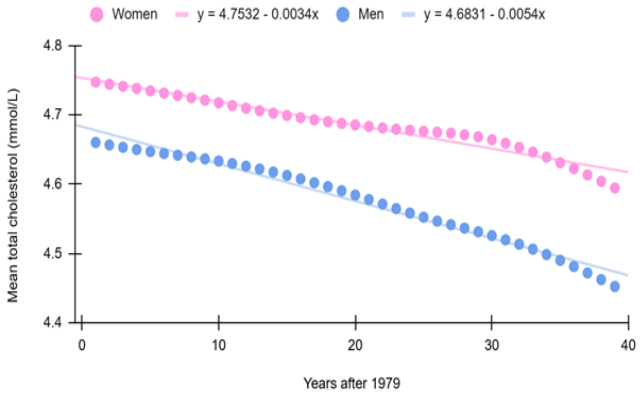

Figure 1. Mean total cholesterol levels (mmol/L) in men and women from 1980-2018. Data were derived from the NCD Risk Factor Collaboration (NCD-RisC) spanning from 1980 to 2018. Each point represents the annual global average total cholesterol level, with blue circles indicating men and pink circles indicating women. Lines show fitted linear regression trends for each gender. The linear regression is pres¬ented in blue for men (R^2 = 0.979, S = 0.0090, β_0 = 4.6831, T = 1565.69, p = 0.000, SE = 0.0030, 95% CI [4.6770, 4.6892], β_1 = -0.0054, T = -41.1990, p = 0.000, SE = 0.0001, 95% CI [-0.0056, -0.0052]). For women, the linear regression is represented by the pink line (R^2 = 0.956, S = 0.0084, β_0 = 4.7532, T = 1589.14, p = 0.000, SE = 0.0030, 95% CI [4.7471, 4.7593], β_1 = -0.0034, T = -26.0742, p = 0.000, SE = 0.0001, 95% CI [-0.0036, -0.0032]). The corresponding regression equations are displayed on the plot (p < 0.0001). Cholesterol levels declined over time for both genders, with a slower rate of decline observed in women.

RESULTS

To determine whether there was a decrease in total cholesterol levels from 1980 to 2018, we analyzed previously published data on mean total cholesterol in men and women from the NCD-RisC database (11). This global dataset compiles standardized measurements from more than 1,100 population-based studies, encompassing approximately 102 million adults aged 18 to 100 years across 200 countries and territories (11). The dataset contains age-standardized national means, allowing comparison of global trends over nearly four decades.

We calculated mean total cholesterol levels across 39 observations for each gender over the study period (1980-2018). Mean values were slightly higher in women (mean = 4.69 mmol/L, SD = 0.04) compared to men (mean = 4.58 mmol/L, SD = 0.06) (**Figure 2**). Variability was low in both groups, with slightly greater dispersion observed among men. The interquartile ranges were narrow, indicating relatively consistent values over time within each group. Overall, the distributions for both men and women appeared stable, with no extreme values observed (**Figure 2**). The absence of extreme outliers and the consistent distribution of values support the use of regression analysis to assess temporal trends.

Gender-specific Linear Regressions Show Decline in Cholesterol

To quantitatively assess temporal trends in mean total cholesterol levels, we conducted separate simple linear regressions for men and women. The coefficient of determination (R^2) was used to assess model fit, representing the proportion of variability in cholesterol levels explained by year.

For men, we found a linear relationship that showed the majority of the variability in male cholesterol levels could be explained by year (R^2 = 0.979) (**Figure 1**). The downward slope indicated a consistent and statistically significant decline in male cholesterol from 1980 to 2018 (p < 0.0001; **Figure 1**). For women, the corresponding model also demonstrated strong model fit (R^2 = 0.956; **Figure 1**) and a significant downward trend (p < 0.0001; **Figure 1**).

Period-specific Linear Regressions Show Accelerated Decline after 2013

To further assess whether the rate of decline changed after major cholesterol-management guidelines were introduced in 2013, we ran separate simple linear regressions for the pre-2013 (1980-2012) and post-2013 (2013-2018) periods. For men, the rate of decline increased from 0.0049 mmol/L per year before 2013 to 0.0092 mmol/L per year after 2013 (**Figure 3**). For women, the rate of decline increased from 0.0029 mmol/L per year before 2013 to 0.0089 mmol/L per year after 2013 (**Figure 3**). Across all four regressions, strong model fit was observed (R^2 = 0.982-0.999), and significant downward trends were observed across all models (p < 0.0001; **Figure 3**). These results indicate that the decline in total cholesterol

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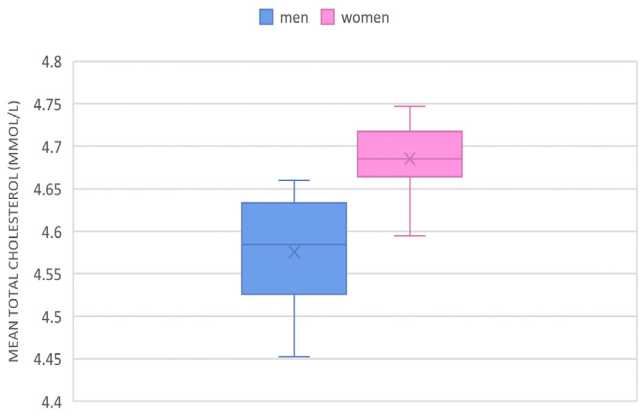

Figure 2. Distribution of mean total cholesterol levels (mmol/L) by gender from 1980 to 2018. Box plots summarize annual global mean total cholesterol levels for men and women using data from the NCD Risk Factor Collaboration (NCD-RisC). For men, the mean cholesterol level was 4.58 mmol/L (SD = 0.06, n = 39, min = 4.45, Q1 = 4.53, median = 4.58, Q3 = 4.63, max = 4.66). For women, the mean cholesterol level was 4.69 mmol/L (SD = 0.04, n = 39, min = 4.59, Q1 = 4.67, median = 4.69, Q3 = 4.72, max = 4.75). Boxes represent the interquartile range (Q1-Q3), center lines indicate the median, the "x" symbols indicate the mean values, and whiskers represent the minimum and maximum values.

accelerated after 2013 for both genders, although the rate of decline remained consistently slower in women across all years (**Figure 3**).

To better interpret the practical implications of these differing rates of decline, we estimated how long it would take for yearly changes to accumulate into a meaningful population-level difference. We used a one standard deviation threshold of about 0.05 mmol/L, representing the average year-to-year variability across both men and women, as a benchmark for a meaningful response. Based on the regression slopes, men would reach a significant cholesterol reduction in about 10 years before 2013 and 5 years after 2013 (**Figure 3**). For women, the corresponding times are approximately 17 years before 2013 and 6 years after 2013 (**Figure 3**).

Multivariate Analysis Shows Slower Decline in Women

A multivariate linear regression model was fit to assess the combined effect of time, gender, and their interaction. This model demonstrated a strong fit to the data (R^2 = 0.987), indicating that approximately 98.7% of the variation was explained by year, gender, and the interaction between year and gender (**Table 1**). The negative coefficient for year (-0.0054) confirms an overall downward trend in the global population (**Table 1**). The gender coefficient (+0.0701) measures the average difference between men and women, showing that women had slightly higher cholesterol levels than men across the study period (**Table 1**). The positive interaction term (+0.00197) shows that the decline in cholesterol level over time varies by gender; specifically, the decline was less steep for women (-0.0034) compared to men (-0.0054) (**Table 1**). All coefficients were statistically significant ($p < 0.0001$; **Table 1**). Together, the above results confirm that while cholesterol levels decreased for both genders, women's decline occurred at a slower rate, consistent with the trends identified in the separate linear regressions (**Figure 1**).

Time Series Autoregressive Model Shows Strong Year-to-Year Persistence

To assess whether current cholesterol levels depend on those from previous years, we applied an autoregressive model of the first order (AR(1)). This type of time series model measures how a value at a given time point relates to its value in the previous time point. In this analysis, we used the mean total cholesterol from the preceding year to predict the mean total cholesterol in the year of interest. Separate AR(1) models were fit for men and women to examine whether cholesterol trends showed persistence over time.

For both men and women, cholesterol values in consecutive years were highly correlated, demonstrating strong year-to-year persistence in global cholesterol levels (AR(1) = 0.998; **Tables 2 and 3**). These findings indicate that average cholesterol levels changed only gradually from one year to the next. This finding aligns with the steady downward trends identified in the linear and multivariate analyses, suggesting that improvements in cholesterol levels occur slowly over long periods.

The AR(1) models demonstrated good model fit for both men and women, as supported by the AIC, BIC, and log likelihood values (**Tables 2 and 3**). The Augmented Dickey-Fuller test indicated that the series was non-stationary, consistent with the presence of a persistent long-term downward trend in cholesterol levels.

DISCUSSION

Based on the above results, we observed consistent declines in total cholesterol levels across multiple analytical

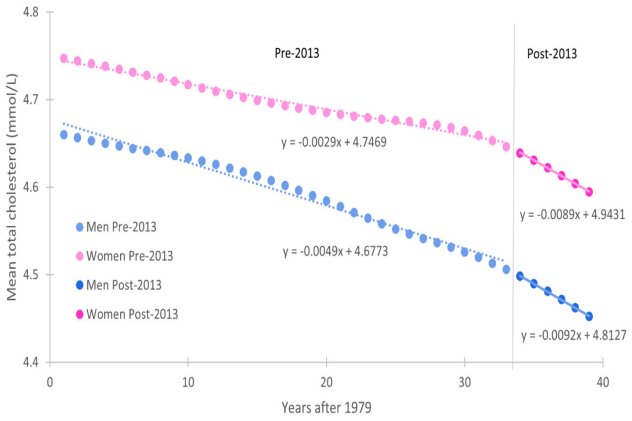

Figure 3. Period-specific linear regression analysis of mean total cholesterol levels (mmol/L) before and after 2013 by gender. Data were derived from the NCD Risk Factor Collaboration (NCD-RisC) spanning from 1980 to 2018. Separate simple linear regressions were performed for men and women during the pre-2013 (1980-2012) and post-2013 (2013-2018) periods. For men, the rate of decline increased from -0.0049 before 2013 (R^2 = 0.982, SE = 0.00012, T = -40.7495, $p < 0.0001$) to -0.0092 after 2013 (R^2 = 0.999, SE = 0.00013, T = -69.3188, $p < 0.0001$). For women, the rate of decline increased from -0.0029 before 2013 (R^2 = 0.986, SE = 0.00006, T = -47.0957, $p < 0.0001$) to -0.0089 after 2013 (R^2 = 0.999, SE = 0.00013, T = -66.7120, $p < 0.0001$). The slope coefficient represents the estimated yearly rate of change in cholesterol levels within each time period.

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	Coeff	SE Coeff	T	P	Lower 95%	Upper 95%
Constant	4.683055	0.002868	1632.933	0.0000	4.67734	4.688769
Gender	0.070136	0.004056	17.29291	0.0000	0.062055	0.078218
Year	-0.0054	0.000125	-42.9683	0.0000	-0.00562	-0.00512
Interaction	0.001971	0.000177	11.15408	0.0000	0.001619	0.002323

S = 0.008783 R^2 = 0.987004

Table 1. Multiple linear regression results for mean total cholesterol levels (mmol/L) from 1980 to 2018. The dependent variable is mean total cholesterol, with predictors including gender (women coded as 1, men coded as 0), year (after 1979), and the interaction between gender and year. The coefficient of Year represents the average yearly rate of change in cholesterol for men, the coefficient of Gender represents the baseline difference between women and men, and the coefficient of the interaction term indicates whether the rate of change differs by gender. A positive interaction coefficient means that women's cholesterol declined more slowly over time. Reported values include the regression coefficient (Coeff), intercept (Constant), standard error of the coefficient estimate (SE Coeff), *t*-statistic (T), *p*-value (P), and 95% confidence interval (Lower 95%, Upper 95%). S represents the residual standard error, and R^2 indicates the proportion of variance in cholesterol levels explained by the model.

approaches, including gender-specific linear models, multivariate analysis, and time series modeling. These findings provide converging evidence of long-term improvement in cholesterol levels across the adult population. The overall decline in global cholesterol levels accelerated after 2013, aligning with the introduction and gradual worldwide adoption of clinical guidelines and lipid-lowering therapies. While the ACC/AHA cholesterol management guidelines were developed primarily in the United States, similar approaches emphasizing early screening, statin use, and risk-based treatment have since been observed internationally (11). This diffusion of best practices may partly explain the consistent downward global trends, including the faster rate of decline observed after 2013.

These results also align with broader public health developments over recent decades, including increased cholesterol awareness campaigns, improved access to screening, and healthier dietary patterns in many countries (10). These initiatives have likely contributed to earlier detection and more proactive management of cholesterol, supporting the steady decline in average cholesterol levels observed over time (5, 10). However, the slower decline among women suggests that gender-specific differences in education, screening, or treatment may still exist. For example, differences in healthcare access, risk perception, or clinical management may influence the effectiveness of public health interventions in women (12). Addressing these gaps through targeted outreach, enhanced screening efforts, and gender-informed prevention strategies may help achieve more equitable reductions in cardiovascular risk across populations.

While this study provides insight into cholesterol trends over nearly four decades, there are a few limitations. First, the dataset did not include data beyond 2018, which limits the ability to assess whether these trends have continued in more recent years. Second, the analysis was conducted at the population level without stratifying by age, so age-related differences in cholesterol patterns could not be explored. Third, the study did not examine region- or country-specific trends, meaning any geographic differences in public health policies, healthcare access or lifestyle factors were not captured. Including this information would allow for comparisons of how different local strategies influence cholesterol trends across populations and could help identify regions where public health interventions have been more or less effective.

Future research could address these limitations by incorporating more recent data and disaggregating results by both region and age. These factors are particularly important, as cholesterol levels often vary across geographic areas due to differences in diet, healthcare systems, socioeconomic conditions, and national and cultural approaches to disease prevention. Differences in healthcare policies and cultural attitudes toward preventive care may further contribute to variation in cholesterol management across countries. In addition, cholesterol levels tend to change across the lifespan, generally rising through adulthood before declining slightly in older age due to metabolic and hormonal factors. Understanding how region and age interact with public health interventions would provide a more complete picture of global cardiovascular risk.

Despite these limitations, this research contributes to the growing body of literature examining long-term population health trends and reinforces the value of using large-scale, high-quality global datasets to inform public health planning. Continued investigation across specific demographic groups, such as individuals with pre-existing heart disease, younger/older adults, or those underrepresented in screening efforts, will be essential for designing more equitable and effective interventions to reduce hypercholesterolemia and related cardiovascular risks worldwide.

MATERIALS AND METHODS

Data Source

The dataset was retrieved from the NCD-RisC 2020 database, which provides publicly available standardized aggregate data of mean total cholesterol (11). The specific variables used in this analysis were the year, gender, and the average total cholesterol level in mmol/L. The dataset compiled data from more than 1,100 population-based studies, representing approximately 102 million adults aged 18 to 100 years across more than 200 countries and territories. The

	Coeff	SE Coeff	T	P	Lower 95%	Upper 95%
Constant	4.556844	0.104	43.733	0.000000	4.352621	4.761068
Y_{t-1}	0.998369	0.039	25.521	0.000000	0.921695	1.075043
AIC = -278.955125		BIC = -273.964440			Log likelihood = 142.477563	

Table 2. Autoregressive AR(1) model results for mean total cholesterol levels (mmol/L) in men from 1980 to 2018. The dependent variable is current year's mean total cholesterol, and the predictor is the previous year's mean total cholesterol (Y_{t-1}). The coefficient of Y_{t-1} reflects the degree of year-to-year persistence in cholesterol levels. Reported values include the regression coefficients (Coeff), standard error of the coefficient estimate (SE Coeff), *t*-statistic (T), *p*-value (P), and 95% confidence interval (Lower 95%, Upper 95%). Model fit is evaluated using the Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), and log likelihood.

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	Coeff	SE Coeff	T	P	Lower 95%	Upper 95%
Constant	4.663593	0.193	24.217	0.000000	4.286159	5.041027
y_{t1}	0.997974	0.038	26.424	0.000000	0.923950	1.071998
AIC = -296.975121			BIC = -291.984436		Log likelihood = 151.487560	

Table 3. Autoregressive AR(1) model results for mean total cholesterol levels (mmol/L) in women from 1980 to 2018. The dependent variable is current year's mean total cholesterol, and the predictor is the previous year's mean total cholesterol (Y_{t-1}). The coefficient of Y_{t-1} reflects the degree of year-to-year persistence in cholesterol levels. Reported values include the regression coefficients (Coeff), standard error of the coefficient estimate (SE Coeff), *t*-statistic (T), *p*-value (P), and 95% confidence interval (Lower 95%, Upper 95%). Model fit is evaluated using the Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), and log likelihood.

data were age-standardized to the World Health Organization standard population to allow global comparability. Each contributing study was evaluated using strict inclusion and exclusion criteria to ensure representativeness and data quality. The dataset also underwent extensive validation procedures, including constraint checks and outlier analyses, to minimize reporting errors and maintain consistency across sources.

Descriptive Statistics

Before modeling, we summarized key properties of the dataset to characterize averages, variability, and distribution. For each gender, we calculated mean cholesterol level across 39 years, the sum of cholesterol values, the sum of squared deviations from the mean, the sample standard deviation, and quartile landmarks (minimum, Q1, median, Q3, maximum). These descriptive statistics provided a baseline understanding of the global data spread and helped confirm the suitability of the data for linear modeling. Several statistical methodologies were then applied to analyze trends in the data (13, 14).

Simple Linear Regression

Gender-specific linear regressions were fitted for both men and women using a single independent variable, year, and a dependent variable, mean total cholesterol (mmol/L):

$$\text{Cholesterol}_t = \beta_0 + \beta_1(\text{Year}) + \varepsilon_t$$

where β_1 represents the yearly rate of change for each gender. Model fit was assessed using the coefficient of determination (R^2), which indicated the proportion of variance in cholesterol explained by year. Confidence intervals and *t*-tests were used to assess statistical significance of the slope estimates for each gender at the 5% significance level.

To further assess whether the rate of decline changed after major cholesterol-management guidelines were introduced in 2013, we ran separate simple linear regressions for the pre-2013 (1980-2012) and post-2013 (2013-2018) periods for each gender. The slope (β_1) from each regression represents the average yearly change in total cholesterol within that period. Comparing the pre- and post-2013 slopes allowed us to evaluate whether the downward trend accelerated following the implementation of updated global treatment guidelines.

Multivariate Linear Regression

A multivariate linear regression was conducted to test whether the rate of change differed between men and women. In this model, the dependent variable was again mean total cholesterol (mmol/L), and the independent variables were Year, Gender (men = 0, women = 1), and an interaction term (Year × Gender):

$$\text{Cholesterol}_t = \beta_0 + \beta_1(\text{Year}) + \beta_2(\text{Gender}) + \beta_3(\text{Year} * \text{Gender}) + \varepsilon_t$$

Because gender was coded with men as the reference group (men = 0), the coefficient for Year (β_1) represented the average annual change in mean total cholesterol for men. The coefficient for Gender (β_2) represented the baseline difference between women and men, and the coefficient for the interaction term (β_3) represented the difference in average annual rate of change between genders. A positive β_3 indicated that women's cholesterol declined at a slower rate than men. Model fit and statistical significance were evaluated using R^2, *t*-tests, and confidence intervals as described above.

Time Series Analysis

To examine persistence across years, separate first-order autoregressive models (AR(1)) were estimated for men and women. The dependent variable was current-year mean cholesterol, and the independent variable was previous-year mean cholesterol:

$$\text{Cholesterol}_t = \alpha + \rho\text{Cholesterol}_{t-1} + \varepsilon_t$$

where ρ measured how strongly cholesterol levels in one year depend on those in the preceding year. A coefficient closer to 1 suggested strong year-to-year persistence. Model performance was evaluated using the log-likelihood, Akaike Information Criterion (AIC), and Bayesian Information Criterion (BIC) where lower AIC/BIC values indicated better model fit. The Augmented Dickey-Fuller test was used to assess stationarity and detect the presence of long-term trends.

Software

All analyses were performed using a combination of Google Sheets, Microsoft Excel, and Python. Simple linear regressions and data visualization were conducted in Google Sheets using the built-in LINEST function and trendline tools. The multivariate regression with interaction terms was carried out in Microsoft Excel through the Data Analysis Toolpak, which provided coefficient estimates, p-values, and model fit statistics. The AR model was implemented in Python using the *statsmodels* library (15). All statistical tests were two-tailed with a significance threshold of 0.05.

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