Secular Trends in Cardiovascular Disease Risk Factors According to Body Mass Index in US Adults

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Context Prevalence of obesity in the United States has increased dramatically in recent decades, but the magnitude of change in cardiovascular disease (CVD) risk factors among the growing proportion of overweight and obese Americans remains unknown.

Objective To examine 40-year trends in CVD risk factors by body mass index (BMI) groups among US adults aged 20 to 74 years.

Design, Setting, and Participants Analysis of 5 cross-sectional, nationally representative surveys: National Health Examination Survey (1960-1962); National Health and Nutrition Examination Survey (NHANES) I (1971-1975), II (1976-1980), and III (1988-1994); and NHANES 1999-2000.

Main Outcome Measures Prevalence of high cholesterol level (≥240 mg/dL [≥6.2 mmol/L] regardless of treatment), high blood pressure (≥140/90 mm Hg regardless of treatment), current smoking, and total diabetes (diagnosed and undiagnosed combined) according to BMI group (lean, <25; overweight, 25-29; and obese, ≥30).

Results The prevalence of all risk factors except diabetes decreased over time across all BMI groups, with the greatest reductions observed among overweight and obese groups. Compared with obese persons in 1960-1962, obese persons in 1999-2000 had a 21-percentage-point lower prevalence of high cholesterol level (39% in 1960-1962 vs 18% in 1999-2000), an 18-percentage-point lower prevalence of high blood pressure (from 42% to 24%), and a 12-percentage-point lower smoking prevalence (from 32% to 20%). Survey × BMI group interaction terms indicated that compared with the first survey, the prevalence of high cholesterol in the fifth survey had fallen more in obese and overweight persons than in lean persons ($P<.05$). Survey × BMI changes in blood pressure and smoking were not statistically significant. Changes in risk factors were accompanied by increases in lipid-lowering and antihypertensive medication use, particularly among obese persons. Total diabetes prevalence was stable within BMI groups over time, as nonsignificant 1- to 2-percentage-point increases occurred between 1976-1980 and 1999-2000.

Conclusions Except for diabetes, CVD risk factors have declined considerably over the past 40 years in all BMI groups. Although obese persons still have higher risk factor levels than lean persons, the levels of these risk factors are much lower than in previous decades.

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There has been a marked increase in overweight and obesity in the United States over the past 25 years, with the prevalence of obesity among adults aged 20 to 74 years rising from 13% to 31%.[1-3] This increase in prevalence of obesity has occurred among both men and women and across all racial/ethnic and age groups. Prospective cohort studies as well as national surveys have shown that obese individuals have an increased risk of several adverse health outcomes, notably hypertension, diabetes, cardiovascular disease (CVD), arthritis, disability, and mortality.[4-8] Accordingly, numerous clinical consensus panels and public health organizations have recommended that persons with a body mass index (BMI) of 30 or higher, or with risk factors and a BMI of 25 or higher, achieve and maintain a lower weight.[9,10]

Despite the scope and magnitude of the observed increases in obesity, the health implications of these trends for the US population remain unclear. Al-

See also pp 1861 and 1918.

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though increases in obesity have been accompanied by increases in diabetes,[11-13] the association between obesity trends and other CVD risk factors remains less certain. In the overall population, mortality rates from ischemic heart disease as well as levels of key CVD risk factors have declined during the past 30 years,[14-19] but whether comparable improvements have occurred across levels of BMI remains unknown.

Using data from the 5 consecutive nationally representative health surveys conducted during the last 40 years, we examined whether long-term secular changes in levels of key cardiovascular risk factors have been different in overweight or obese persons compared with lean persons. We examined changes in current smoking status, diagnosed and undiagnosed diabetes, and high blood pressure and high total cholesterol levels. For blood pressure and cholesterol, we analyzed actual values, regardless of treatment, so that levels could be influenced by trends in medical care as well as by environmental and behavioral changes that may have occurred.

METHODS

Overall Design and Study Population

The National Health Examination Survey (NHES) and the National Health and Nutrition Examination Surveys (NHANES) are a series of cross-sectional health examination surveys representative of the United States civilian noninstitutionalized population. They were conducted in 1960-1962 (NHES), 1971-1975 (NHANES I), 1976-1980 (NHANES II), 1988-1994 (NHANES III), and 1999-2000 (NHANES 1999-2000). Each of the surveys followed a stratified multistage probability design in which a sample of the US population is selected. Detailed descriptions of the plan and operation of each survey have been published.[20-24] To maximize comparability across the 5 surveys, we restricted analyses to examined, nonpregnant adults who were aged 20 to 74 years. This consisted of 6257, 12 911, 11 765, 14 319, and 3601 persons in the 5 surveys, respectively.

NHANES III and NHANES 1999-2002 have undergone institutional review board approval and included written informed consent. Institutional review board approval using current standards was not obtained for NHES, NHANES I, or NHANES II, but internal human subjects review was conducted.

Measurements

Each survey included a standardized examination to obtain information on height, weight, and CVD risk factors. Weight and height were measured by a standard protocol and used to calculate BMI; ie, weight in kilograms divided by the square of height in meters. We refer to BMI groups of <25, 25 to 29.9, and ≥30 as "lean," "overweight," and "obese," respectively. Four CVD risk factors were analyzed: serum total cholesterol concentration, blood pressure, smoking status, and diabetes. These risk factors were chosen because they were assessed in at least 4 surveys, using similar methods across all surveys.

Cholesterol analyses were conducted on venous blood serum samples and standardized according to previously published methods.[16,25,26] The samples were frozen at −20°C and shipped weekly on dry ice to the laboratory conducting the lipid analyses. The NHES and NHANES I measurements were made in the Centers for Disease Control and Prevention Lipid Standardization Laboratory. The NHANES II, III, and 1999-2000 measurements were made in lipid research clinic laboratories that were standardized for cholesterol measurements according to the criteria of the CDC–National Heart, Lung, and Blood Institute Lipid Standardization Program.

Blood pressure was measured according to standard protocols that differed somewhat across the 5 surveys.[15] For consistency, we used only blood pressure measurements conducted in the mobile examination center with participants in a seated position. Because large adult and thigh blood pressure cuffs were available only for the latter 2 surveys, blood pressure could be overestimated among obese persons in early surveys. Thus, we computed an adjusted blood pressure according to methods suggested by Maxwell et al[27] to account for arm circumference and cuff size.[28]

Previously diagnosed diabetes was determined by asking participants whether a physician or other health care professional had ever told the respondent that he or she had diabetes. For the latter 3 surveys, undiagnosed diabetes was assessed among subsamples (n=3786, n=5791, and n=1434 in NHANES II, III, and 1999-2000, respectively) of nondiabetic persons randomly assigned to a morning fasting examination session.[29-32] Procedures for blood collection and processing have been described.[23,24,29,31,32] We used American Diabetes Association diagnostic criteria for undiagnosed diabetes (fasting glucose level ≥126 mg/dL [6.99 mmol/L]). Total diabetes prevalence was calculated as the sum of the diagnosed diabetes from the interview sample and undiagnosed diabetes from the fasting morning sample, adjusted using methods previously described.[30]

To determine current cigarette smoking, respondents were asked, "Have you smoked at least 100 cigarettes in your entire life?" and "Do you smoke cigarettes now?" Current smoking was defined as a positive answer to both questions. Smoking was not assessed in the NHES and, thus, is reported only for the latter 4 surveys. For NHANES I, only a subsample of persons aged 25 to 74 years were asked about smoking. Thus, for smoking, we restricted our analyses to persons aged 25 to 74 years for the remaining surveys (n=3823, n=10 389, n=12641, and n=3271 among NHANES I, II, III, and 1999-2000, respectively).

Definitions of Primary Outcomes

We defined high blood pressure as systolic blood pressure of at least 140 mm Hg or diastolic blood pressure of at least 90 mm Hg[28] using the cuff-size–corrected measurements. We defined high total cholesterol level as at least 240 mg/dL (6.20 mmol/L).[33] High blood pressure and high cholesterol level were defined according to levels of control regardless of use of medications. These definitions better capture the impact of

Table 1. Survey Sample Characteristics*

Characteristics	NHES 1960-1962 (n = 6257)	NHANES I 1971-1975 (n = 12 911)	NHANES II 1976-1980 (n = 11 765)	NHANES III 1988-1994 (n = 14 319)	NHANES 1999-2000 (n = 3601)
Age distribution, %, y					
20-44	54.4	54.2	56.2	60.4	57.5
45-64	34.9	35.3	32.8	28.4	32.2
65-74	10.8	10.5	11.0	11.2	10.3
Female, %	52.6	52.2	51.9	50.8	50.4
High school education, %	31.8	34.6	32.0	23.1	23.3
Height, mean, cm	166.4	168.0	168.3	168.9	169.1
Weight, mean, kg	70.3	71.6	71.9	76.1	80.4
BMI in each category, mean†					
Overall	25.4	25.3	25.3	26.6	28.0
<25	21.9	21.8	21.9	22.1	22.2
25-29.9	27.2	27.1	27.1	27.2	27.4
≥30	33.6	34.1	34.2	34.8	35.8
Respondents in each BMI category, %					
<25	52.1	53.4	54.0	45.4	36.3
25-29.9	33.3	32.3	31.5	32.1	33.3
≥30	14.6	14.3	14.5	22.5	30.4

Abbreviations: NHANES, National Health and Nutrition Examination Survey; NHES, National Health Examination Survey.
*Estimates are weighted to be representative of the US noninstitutionalized population aged 20 to 74 years.
†Body mass index (BMI) was calculated as weight in kilograms divided by the square of height in meters.

secular clinical and public health factors and are less vulnerable to recall bias than definitions based on treatment status. Although current standards recommend lower levels of total cholesterol and blood pressure, these cut points represent common definitions of risk factors across the period of our study (1960-2000). Smoking was defined as smoking status at the time of the survey. Total diabetes was defined as either previously diagnosed diabetes (by self-report) or, for those without previously diagnosed diabetes, a fasting glucose level of at least 126 mg/dL (6.99 mmol/L). Since fasting glucose measurements were available only for the latter 3 surveys, we conducted additional analyses of diagnosed diabetes across all 5 surveys.

Participants were asked about whether they had been told by a physician to take prescribed medicine to lower blood cholesterol level and whether they were currently taking medication for high blood pressure. These were used to define the prevalence of medication use, with the entire population used as the denominator. We also used this information to perform additional analyses in which we defined the outcome as having a high level or taking medication treatment for the condition. For the latter analysis, prevalence of lipid-lowering medication use during the first 3 surveys (1960-1980) was assumed to be zero.

Statistical Analysis

For all surveys, sampling weights had been calculated that take into account unequal probabilities of selection resulting from the sample design, nonresponse, and planned oversampling of certain subgroups. Data management was conducted using SAS software, version 9.1.[34] Standard errors were calculated with SUDAAN software, version 9.0, to account for the complex sample and to apply survey weights to make results representative of the civilian, noninstitutionalized US population.[35] For estimates of total diabetes, we computed standard errors using a jackknife variance estimator because the summation of diagnosed and undiagnosed diabetes violated assumptions of statistical independence.[36] For high cholesterol, high blood pressure, smoking, and diagnosed diabetes, we used multiple logistic regression and computed predictive marginals to estimate the prevalence of each CVD risk factor by survey and BMI group when controlling for age and sex.[36] Predictive marginals are a type of direct standardization in which the predicted values from the logistic regression models are averaged over the covariate distribution of the population. Using the predictive marginals and standard errors, we present differences and 95% confidence intervals (CIs) in prevalence of risk factors over time according to BMI group. Significance of interaction terms between BMI groups and survey years from the logistic models were assessed to determine if changes throughout the 40-year period and between the first and last surveys differed by BMI group.

RESULTS

TABLE 1 lists the characteristics of the participants across the 5 NHANES surveys, weighted to the US population. In addition to the previously reported increases in body weight and BMI,[1,2] substantial increases in educational level occurred across the period covered by the surveys. Within BMI strata, there were generally only minor increases in mean BMI across surveys. Within the obese category, however, mean BMI increased from 33.6 in 1960-1962 to 35.8 in 1999-2000.

As has been previously documented,[15,16,19] there were large reductions (33% to 52% relative to baseline) in the prevalence of high cholesterol level, high blood pressure, and smoking in the overall population during the past 30 to 40 years (TABLE 2). However, the prevalence of obesity and diagnosed diabetes doubled during this period, and between 1976-1980 and 1999-2000, the prevalence of total (diagnosed and undiagnosed) diabetes increased by 55%.[1,2,29,32]

CVD Disease Risk Factors by BMI

Between 1960-1962 and 1999-2000, the age- and sex-adjusted prevalence of high cholesterol, high blood pressure, and smoking levels decreased among all BMI groups (Table 2). The prevalence of total diabetes remained stable within BMI groups across decades, while the prevalence of diagnosed diabetes increased among overweight and obese groups.

Absolute reductions in the prevalence of high cholesterol between 1960 and 2000 were greater for overweight (21-percentage-point decline; 95% CI, 17%-25%) and obese persons (21-percentage-point decline; 95% CI, 15%-27%) than for those of lean persons (12-percentage-point decline; 95% CI, 8%-16%). Obese persons had a 9- to 12-percentage-point higher prevalence of high cholesterol level than lean persons across all surveys, but by 1999-2000, this difference was only 2.7 percentage points. The overall test for the 8 survey × BMI interaction terms was not statistically significant. However, the interaction terms comparing change in prevalence of high cholesterol level between the first and fifth surveys showed a statistically significantly greater reduction in prevalence of high cholesterol level among obese ($P=.02$) and overweight ($P<.05$) persons compared with lean persons.

Prevalence of high blood pressure also tended to decline more over time among obese (18 percentage points; 95% CI, 13%-23%) and overweight (17 percentage points; 95% CI, 13%-21%) persons than among lean persons (14 percentage points; 95% CI, 11%-18%). However, the prevalence of high blood pressure among obese persons remained at least twice that of lean persons (24% vs 11%) in 1999-2000. Moreover, survey × BMI group interaction terms comparing the first and fifth surveys were not statistically significant for obese ($P=.25$) and overweight ($P=.76$) persons compared with lean persons, indicating that secular declines in high blood pressure did not differ by BMI.

The prevalence of smoking was lowest among obese persons and highest among lean persons across all 5 surveys (Table 2). This prevalence declined among all BMI groups by a similar magnitude (12- to 13-percentage-point change across groups) such that about one third of lean persons and one fifth of obese persons reported smoking in 1999-2000. Survey × BMI interaction terms were not significant for smoking.

Prevalence of total diabetes (diagnosed and undiagnosed combined) was stable over time within BMI groups, increasing by only 1 to 2 percentage points between 1976-1980 and 1999-2000. In contrast, prevalence of diagnosed diabetes was about 2.5 to 3.5 times as high in 2000 as in 1960 among overweight (from 1.6% to 4.2%) and obese (from 2.9% to 10.1%) persons (Table 2). The survey × BMI group interaction comparing diagnosed diabetes prevalence in the first vs fifth surveys was statistically significant for obese persons ($P=.03$) but not overweight persons ($P=.28$), indicating that secular increases in prevalence of diagnosed diabetes were greater among obese than lean persons.

Table 2. Age- and Sex-Adjusted Trends in Cardiovascular Risk Factors in the US Population Aged 20 to 74 Years*

Risk Factors by BMI Group†	NHES 1960-1962	NHANES I 1971-1975	NHANES II 1976-1980	NHANES III 1988-1994	NHANES 1999-2000	Total Change (95% Confidence Interval)
High total cholesterol level (≥240 mg/dL)						
<25	27.1	22.3	22.1	13.8	15.2	−11.9 (−15.7 to −8.1)
25.0-29.9	39.2	33.1	31.2	23.3	18.7	−20.5 (−24.5 to −16.5)
≥30	38.9	33.1	31.5	23.0	17.9	−21.0 (−27.1 to −14.9)
Overall	33.6	28.2	27.2	19.0	17.0	−16.6 (−19.8 to −13.4)
High blood pressure (systolic ≥140 mm Hg or diastolic ≥90 mm Hg)						
<25	24.8	27.7	20.9	10.8	10.5	−14.3 (−17.5 to −11.1)
25.0-29.9	31.8	32.0	27.6	15.0	14.9	−16.9 (−21.3 to −12.5)
≥30	41.6	46.5	35.6	22.3	23.7	−17.9 (−23.0 to −12.9)
Overall	30.8	33.1	26.3	14.8	14.9	−15.9 (−18.9 to −12.9)
Smoking						
<25	. . .	44.7	41.4	34.0	31.3	−13.4 (−19.1 to −7.7)
25.0-29.9	. . .	36.6	33.1	27.0	24.3	−12.3 (−17.0 to −7.6)
≥30	. . .	32.5	29.7	23.6	20.2	−12.3 (−19.0 to −5.6)
Overall	. . .	39.2	36.0	29.3	26.4	−12.8 (−16.5 to −9.1)
Total diabetes (diagnosed/undiagnosed)						
<25	. . .	. . .	3.4	3.2	4.0	0.6 (−1.2 to 2.4)
25.0-29.9	. . .	. . .	4.3	6.3	6.3	2.0 (−0.2 to 4.2)
≥30	. . .	. . .	12.3	15.0	14.0	1.7 (−2.1 to 5.5)
Overall	. . .	. . .	5.3	7.4	8.1	2.8 (1.3 to 4.3)
Diagnosed diabetes						
<25	1.5	2.6	2.4	2.1	2.8	1.3 (0.1 to 2.5)
25.0-29.9	1.6	2.8	3.0	4.6	4.2	2.6 (1.0 to 4.2)
≥30	2.9	5.9	6.3	9.0	10.1	7.2 (5.4 to 9.0)
Overall	1.8	3.4	3.5	4.6	5.0	3.2 (2.1 to 4.1)

Abbreviations: NHANES, National Health and Nutrition Examination Survey; NHES, National Health Examination Survey. Ellipses indicate data not collected.
SI conversion: To convert total cholesterol to mmol/L, multiply by 0.0259.
*All prevalence estimates are age- and sex-adjusted percentages. Denominators vary for cholesterol (n = 47 754), blood pressure (n = 47 172), and diabetes (n = 48 800) because of missing data and for smoking (n = 30 124) because of missing data, smaller age range (25-74 years), and no data collected as part of the NHES.
†Body mass index (BMI) was calculated as weight in kilograms divided by the square of height in meters.

Trends in Antihypertensive and Lipid-Lowering Medications

The proportion of the overall population receiving medication treatment for high cholesterol level and high blood pressure increased among all BMI groups (TABLE 3). The prevalence of treatment for high cholesterol increased more among obese persons (from 3.5% to 9.2%) than among lean persons (from 2.2% to 4%), although the survey × BMI group interaction terms were not significant. The prevalence of treatment for high blood pressure increased significantly more among obese persons (from 11% to 28%) and overweight persons (from 6% to 17%) than among lean persons (from 5% to 8%) ($P<.01$ for interaction terms).

When we examined prevalence estimates using a definition of risk as having either high levels or receiving treatment, there were still reductions in prevalence over time (TABLE 4). However, the magnitude of reduction in prevalence over time was less than observed in our primary analyses when risk levels were defined irrespective of treatment (Table 2). For example, the magnitude of reductions in prevalence of having high cholesterol levels or taking medication ranged from 9 to 13 percentage points across the 3 BMI groups. The magnitude of reductions in prevalence of having high blood pressure levels or receiving medication ranged from 4 to 10 percentage points across the 3 BMI groups, with the smallest reduction noted in the obese group ($P<.01$ for interaction term).

COMMENT

In this unique series of nationally representative surveys of the US adult population, we documented a substantial decline in the prevalence of key CVD risk factors over the last 3 to 4 decades, affecting obese, overweight, and lean segments of the population. Among obese persons today, prevalence of high cholesterol, high blood pressure, and smoking are now 21, 18, and 12 percentage points lower, respectively, than among obese persons 30 to 40 years ago. The corresponding reductions among lean persons have been somewhat less, with average declines of 12 to 14 percentage points. Although obesity remains associated with a higher prevalence of important CVD risk factors, differences in total cholesterol levels across BMI groups may be narrowing, and for blood pressure and smoking improvements have been similar across BMI groups. Thus, obese and overweight

Table 3. Age- and Sex-Adjusted Prevalence of US Adults Aged 20 to 74 Years Reporting Cholesterol and Blood Pressure Medication Use*

Medication Use by BMI Group†	NHES 1960-1962	NHANES I 1971-1975	NHANES II 1976-1980	NHANES III 1988-1994	NHANES 1999-2000	Total Change (95% Confidence Interval)
Cholesterol						
<25	. . .	. . .	. . .	2.2	4.0	1.8 (0.4 to 3.2)
25.0-29.9	. . .	. . .	. . .	3.3	9.1	5.8 (3.6 to 8.0)
≥30	. . .	. . .	. . .	3.5	9.2	5.7 (3.9 to 7.5)
Overall	. . .	. . .	. . .	3.0	7.4	4.4 (3.2 to 5.6)
Blood pressure						
<25	4.7	5.6	6.8	5.9	8.2	3.5 (1.1 to 5.9)
25.0-29.9	6.0	8.6	11.8	11.8	16.7	10.7 (7.9 to 13.5)
≥30	11.4	14.2	18.9	19.9	27.6	16.2 (12.1 to 20.2)
Overall	6.7	8.7	11.3	11.2	15.5	8.8 (6.6 to 11.0)

Abbreviations: NHANES, National Health and Nutrition Examination Survey; NHES, National Health Examination Survey. Ellipses indicate data not collected.
*All prevalence estimates are age- and sex-adjusted percentages. Denominators vary for cholesterol medication use (n = 17 918) and blood pressure medication use (n = 49 794).
†Body mass index (BMI) was calculated as weight in kilograms divided by the square of height in meters.

Table 4. Age- and Sex-Adjusted Prevalence of High Levels of or Current Treatment for Cholesterol and Blood Pressure Among US Adults Aged 20 to 74 Years*

High Level or Medication Use by BMI Group†	NHES 1960-1962	NHANES I 1971-1975	NHANES II 1976-1980	NHANES III 1988-1994	NHANES 1999-2000	Total Change (95% Confidence Interval)
Cholesterol						
<25	27.3	22.4	22.3	15.5	18.1	−9.2 (−13.0 to −5.4)
25.0-29.9	38.9	32.8	31.0	25.1	26.6	−12.3 (−18.2 to −6.4)
≥30	38.6	32.9	31.3	25.1	25.2	−13.4 (−19.7 to −7.1)
Overall	33.5	28.1	27.1	20.8	22.5	−11.0 (−14.2 to −7.8)
Blood pressure						
<25	26.0	28.9	23.5	13.7	16.2	−9.8 (−13.6 to −6.0)
25.0-29.9	33.3	34.5	32.4	21.7	25.0	−8.3 (−12.7 to −3.9)
≥30	43.5	49.6	43.2	33.4	39.1	−4.4 (−9.9 to 1.1)
Overall	32.2	35.1	30.8	20.8	24.2	−8.0 (−11.4 to −4.6)

Abbreviations: NHANES, National Health and Nutrition Examination Survey; NHES, National Health Examination Survey.
*All prevalence estimates are age- and sex-adjusted percentages. Denominators vary for high cholesterol level/medication use (n = 47 752) and high blood pressure/medication use (n = 47 714).
†Body mass index (BMI) was calculated as weight in kilograms divided by the square of height in meters.

persons may be at lower risk of CVD now than in previous eras.

Diabetes is a notable exception to the observed reduction in risk factors, as prevalence of total diabetes (ie, diagnosed and undiagnosed combined) did not decrease within BMI groups. This was accompanied by a 55% increase in total diabetes among the overall population (ie, all BMI groups combined), presumably due to an increasing proportion of the population moving into the obese categories. Diagnosed diabetes alone, on the other hand, increased more among obese persons than other groups, but presumably due to greater increases in detection among obese than lean persons. In a detailed examination of diabetes trends,[13] we recently found that undiagnosed diabetes decreased considerably among the most obese persons (particularly those with BMI >35), and the proportion of total cases that were diagnosed increased dramatically. These observations, combined with our findings of increased cholesterol-lowering and antihypertensive medication use, also suggest that the health care system is placing greater emphasis on preventive care among obese persons.

The observation that obese persons now have better CVD risk factor profiles than their leaner counterparts did 20 to 30 years ago, combined with trend data in the general population, suggests that other factors may be compensating for the increases in obesity.[15,17,18,37-43] Studies have documented a mixture of both deleterious and beneficial trends in the US population. Trends promoting obesity include increases in total calories, portion sizes, refined carbohydrates, and fast food intake.[18,39-41,44,45] Healthy trends include decreases in the proportion of dietary saturated fat; increases in fruits, vegetables, and the proportion of polyunsaturated and monounsaturated fats in the diet[17,18,39-43]; and decreased smoking, which, ironically, may have contributed somewhat to increasing obesity.[43] Although trends in overall physical activity levels remain unclear, recent estimates suggest walking prevalence may have increased, particularly among obese persons.[46] All of these changes appear to be overlaid on a background of increased awareness, aggressive identification, and pharmacological treatment of high cholesterol and blood pressure levels.[15,37,38] Increased awareness about obesity and its association with CVD may have further fueled the changes observed among overweight and obese persons. The net result of these phenomena may be a population that is, paradoxically, more obese, diabetic, arthritic, disabled, and medicated, but with lower overall CVD risk.[2,4-7,47]

Although our study does not directly address the *causes* of changes in risk factors, our results are consistent with both pharmacological and nonpharmacological factors playing a causal role. Two observations support a role for pharmacological factors: First, we found that the prevalence of lipid-lowering and antihypertensive medication increased in all groups, particularly among obese persons. Second, when we defined our outcomes as either high levels or receipt of treatment, we found that the magnitude of reduction was less than in our primary analyses, where risk was defined irrespective of treatment. However, we interpret these latter findings with caution because changes in clinical definitions and treatment guidelines over time make people more likely to be treated at lower levels of risk in later surveys. This could have the effect of overestimating prevalence in later surveys when we define risk as either high levels or receipt of treatment. Furthermore, our observation that risk factors were lower over time regardless of whether treatment was part of the definition suggests that nonpharmacological factors influenced these trends as well.

Our findings are supported by other ecologic observations, including reductions in CVD and ischemic heart disease mortality in the general population,[14,19] as well as simultaneous BMI increases and CVD risk factor reductions in the Minnesota Heart Survey.[18] A report from the WHO-MONICA study[48] that examined the correlation between changes in risk factors and coronary heart disease (CHD) incidence rates from 38 separate international populations found that increasing BMI trends were actually associated with declining CHD rates among men; among women, there was no association between changes in BMI and CHD. These findings from the WHO-MONICA study suggest that changes in obesity are a relatively minor determinant of CHD trends and remind us that BMI is only one among many determinants of CVD risk.

Our analyses have several limitations. First, we did not examine BMI-specific trends in dietary intake, physical activity levels, lipid subfractions, body fat distribution, inflammation markers, musculoskeletal disorders, or health-related quality of life. Second, the lack of extra-large blood pressure cuffs in early surveys could exaggerate earlier blood pressure levels as well as declines in blood pressure among obese persons over time. However, we corrected all blood pressure values for cuff size and arm circumference. Third, the sample size for NHANES 1999-2000 was considerably smaller than the earlier surveys. Inferences about changes between the latter 2 surveys should thus be drawn with caution. Fourth, our analyses did not adjust for shifts in race/ethnicity over survey years because of changes in the way race/ethnicity was assessed. However, when we adjusted for nonwhite race, we found essentially no difference in our findings. Finally, we examined some risk factors irrespective of treatment. This assumes, not quite correctly, that a person is considered not at risk despite receiving treatment as long as their risk factor levels are controlled. We selected this approach because we were interested in capturing the full range of secular trends that may have occurred, whether from medical care, behavioral, or environmental sources. Note, however, that for diabetes we had no comparable measure for risk subsequent to treatment because levels of glycemia were not assessed among persons with diabetes. Thus, there may have been some level of CVD risk reduction associated with improving glycemic control and better treatment that we could not measure.

In summary, our study found that with the exception of diabetes, CVD risk factor levels have declined over recent decades among all BMI groups. While obesity remains associated with elevated levels of several CVD risk factors compared with lean persons, their levels of risk factors have now diminished such that they are lower than those of lean individuals 20 to 30 years ago. In addition to determining the key reasons for the favorable trends we observed, future studies should examine whether these changes extend to incidence of morbidity, including cardiovascular disease incidence and disability. Despite our encouraging findings, a considerable proportion of lean as well as obese persons still have elevated levels of modifiable risk factors, particularly when one considers that the current definitions of risk factor control are more aggressive than the definitions used in this trend analyses. Clinical and public health efforts should continue to emphasize maintenance of healthy lifestyle behaviors for lean as well as overweight and obese persons.

Author Contributions: Dr Gregg 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: Gregg, Cheng, Imperatore, Williams, Narayan, Williamson.
Acquisition of data: Imperatore.
Analysis and interpretation of data: Gregg, Cheng, Cadwell, Imperatore, Williams, Flegal, Williamson.
Drafting of the manuscript: Gregg, Cheng, Flegal.
Critical revision of the manuscript for important intellectual content: Gregg, Cheng, Cadwell, Imperatore, Williams, Flegal, Narayan, Williamson.
Statistical analysis: Gregg, Cheng, Cadwell, Imperatore, Williams, Flegal, Williamson.
Administrative, technical, or material support: Gregg.
Study supervision: Narayan.
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In Reply: Drs Harrison and Young criticize the source of the estimate for IT project failures. This is understandable because most of what we hear about, and most publicly reported information including the research literature, tends to be biased in favor of successes.[1] In addition, when does a system "fail"—when it is rejected by users, when it does not perform as was promised, or when its implementation costs 3 times the budgeted figure? Good estimates are hard to find, and we opted for a conservative one. Other sources are comparable. Surveys of chief information officers conducted yearly since 1994 have suggested that only 15% to 30% of IT projects are completed successfully, on time, and within budget. About 30% are abandoned uncompleted, and the remainder have serious cost or time overruns (by a factor of 2-3) or are seriously deficient in their ultimate functionality.[2,3] A Computer-based Patient Record Institute study in 1998 showed a dismal 95% failure rate in the case of electronic patient records.[4] Finally, even if the proportion of successful systems is higher than we thought, that is no reason for comfort, because the system studied by Koppel et al[5] would have been considered a "success" by most accounts. We agree, though, that more research is required into the area of success and failure. At the same time, we also argue that there is already much known about these failures, but that understanding is at risk of being ignored in the current climate of enthusiasm.

We agree with most of Dr Mitchell's points. We do not believe that the development of useful computer-based aids to clinical work is completely impossible but, rather, that it is difficult and may be impossible using traditional development methods. Ethnographic techniques are superb tools to truly understand the nature of work processes, and we have frequently argued for such methods ourselves.

Most important is the awareness that a vision of organizational change has to precede IT systems implementation for beneficial results to be achieved. That vision should recognize that clinical IT projects are incredibly complex social endeavors in unforgiving environments that happen to involve computers, as opposed to IT projects that happen to involve physicians.[6] Throwing IT at a health care system to remedy high medication error rates will not be effective unless the organizational reasons for those failures also are addressed. These reasons are hidden in the "messy details" of clinical work[7]: complexity; uncertainty; conflicting goals; gaps in supplies, procedures, and coordination; brittleness of tools and organizational routines; and the lack of acceptance that high-risk work environments require "high-reliability" working routines and organizational structures. As long as these deeper issues remain unaddressed, introducing IT, particularly technologies focused on improving decision making by individual clinicians, will not advance us much further.

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CORRECTIONS

Error in Table: In the Original Contribution entitled "Secular Trends in Cardiovascular Disease Risk Factors According to Body Mass Index in US Adults" published in the April 20, 2005, issue of *JAMA* (2005;293:1868-1874), Table 1 contained an error. The row labeled "High school education, %" should have been labeled "Less than high school education, %."

Incorrect Dosage: In the Special Communication entitled "Update on the Treatment of Tuberculosis and Latent Tuberculosis Infection" published in the June 8, 2005, issue of *JAMA* (2005;293:2776-2784), there was an incorrect dosage in Table 2. The daily isoniazid dosage for adults should be 5 mg/kg not 300 mg/kg.

