Circulation

JOURNAL OF THE AMERICAN HEART ASSOCIATION

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Circulation published online April 30, 2012

Circulation is published by the American Heart Association. 7272 Greenville Avenue, Dallas, TX 72514

 Print ISSN: 0009-7322. Online ISSN: 1524-4539

DOI: 10.1161/CIRCULATIONAHA.111.070722

Cardiovascular Health Behavior and Health Factor Changes (1988-2008) and Projections to 2020: Results from the National Health and Nutrition Examination Surveys (NHANES)

Running title: *Huffman et al.; CV health trends and projections to 2020*

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Journal Subject Codes: [8] Epidemiology; [121] Primary prevention; [135] Risk Factors; [100] Health policy and outcome research; [190] Type 2 diabetes

DOI: 10.1161/CIRCULATIONAHA.111.070722

Abstract:

Background - The American Heart Association's (AHA) 2020 Strategic Impact Goals target a 20% relative improvement in overall cardiovascular health using 4 health behavior (smoking, diet, physical activity, body mass) and 3 health factor (plasma glucose, cholesterol, blood pressure) metrics. We sought to define current trends and forward projections to 2020 in cardiovascular health.

Methods and Results - We included 35,059 CVD-free adults (≥20 years old) from the National Health and Nutrition Examination Survey 1988-94 and subsequent 2-year cycles from 1999 to 2008. We calculated population prevalence of poor, intermediate, and ideal health behaviors and factors, and also computed a composite, individual-level Cardiovascular Health Score for all 7 metrics (poor=0 points; intermediate=1 point; ideal=2 points; total range 0-14 points). Prevalence of current and former smoking, hypercholesterolemia, and hypertension declined, whereas prevalence of obesity and dysglycemia increased through 2008. Physical activity levels and low diet quality scores changed minimally. Projections to 2020 suggest that obesity and impaired fasting glucose/diabetes could increase to affect 43% and 77% of US men, and 42% and 53% of US women, respectively. Overall, population-level cardiovascular health is projected to improve by 6% overall by 2020 if current trends continue. Individual-level Cardiovascular Health Score projections to 2020 (men = 7.4 [95% CI, 5.7, 9.1]; women = 8.8 [95% CI, 7.6, 9.9]) fall well below the level needed to achieve a 20% improvement (men = 9.4; women = 10.1).

Conclusions - The AHA 2020 target of improving CV health by 20% by 2020 will not be reached if current trends continue.

Key words: cardiovascular disease risk factors; epidemiology; risk factors; trends

DOI: 10.1161/CIRCULATIONAHA.111.070722

Background

The American Heart Association (AHA) 2020 Strategic Impact Goals target a 20% relative improvement in overall cardiovascular (CV) health in all Americans using 4 health behavior (smoking, diet, physical activity, body weight) and 3 health factor (plasma glucose, cholesterol, blood pressure) metrics.[1] The 2020 goals were conceptualized on the basis of three key concepts of health promotion and disease prevention: 1) effectiveness of primordial prevention; 2) lifecourse nature of cardiovascular disease (CVD) development and CVD risk factors; 3) balance between population- and individual-level prevention.[1] A higher number of health behaviors and factors at ideal levels is associated with substantially lower CV event rates in short- and long-term follow up.[1, 2] However, given the very low prevalence of individuals with ideal CV health,[3] a 20% relative improvement would have a small absolute effect on the population. Concurrent shifts from poor to intermediate levels of health behaviors and factors will also be able needed to realize substantial improvements across the spectrum of CV health. The 20% target was deemed aggressive yet achievable by consensus.[1]

Current trends of these composite CV health metrics are unclear. Decreases in smoking[4] and exposure to secondhand smoke[5] have slowed. Nationally representative data continue to suggest poor dietary quality for most of the population,[6] but increases in obesity prevalence may be slowing.[7] Trends in physical activity are mixed,[4] but diabetes prevalence rates are rising.[4] Total cholesterol levels are decreasing, in part due to a doubling in the use of lipid-lowering drugs.[8] Despite population-level increases in body weight, mean blood pressure and blood pressure control are improving.[9]

We therefore sought to evaluate recent trends in composite CV health metrics and to estimate future levels of CV health behaviors and factors among adults in the United States to

determine whether the AHA 2020 goals will be met if current trends continue.

Methods

We used data from non-institutionalized, non-pregnant, non-lactating adults ≥20 years old in each age, sex, and race/ethnicity group as appropriate who were free from CVD and participated in the Third National Health and Nutrition Examination Survey (NHANES III, 1988-94) and subsequent two-year cycles (1999-2000, 2001-2, 2003-4, 2005-6, 2007-8). Methods of measurement of each health behavior and health factor have been previously reported and are described in the **Supplemental Methods**.[10] We defined CVD as any self-reported history of myocardial infarction, angina, stroke, or heart failure. We calculated prevalence estimates from 1988-2008 of ideal, intermediate, and poor levels of the 7 CV health behaviors and health factors, as defined by the AHA 2020 Impact Goals (**Table 1**).[1]

Statistical Analyses

All analyses were performed using SAS v9.1 (SAS Institute, Cary, NC) taking into account the complex sampling design. We used the standard 2000 US population to adjust the data for age using three age strata (20-39, 40-59 and ≥60 years). To estimate time trends from 1988 to 2008 and average annual change in cardiovascular health factors and behaviors, we performed weighted linear regression using estimated mean values or percentages as dependent variables and survey time as independent variables. We fitted weighted linear regression models with the prevalence as the dependent variables and survey time as independent variables. The beta coefficients indicate the average annual change in the prevalence. Based on the findings, we projected the future situation of year 2020 assuming that trends would continue to change at a similar rate. We calculated prediction intervals based on standard error (SE) of the predicted

prevalence estimates. Reciprocals of variances were used as weights. We projected estimates to 2020 by assuming that trends would continue similarly to those observed over the past two decades in a linear fashion. Since the methodology used to measure diet and physical activity had changed from NHANES III to the 1999-2008 cycles, we excluded NHANES III dietary and physical activity data and only included data from 1999-2008. Likewise, since the methodology used to measure physical activity changed between the 2005-6 and 2007-8 cycles, we excluded 2007-8 cycle physical activity data. We performed a sensitivity analysis by including individuals with CVD, and the overall prevalence trends and 2020 projections were not substantively different (<3% absolute difference in all 2020 projections including individuals with prevalent CVD).

We projected the situation for 2020 by assuming that trends would continue to change at a similar rate. We considered alternative statistical methods such as linear models with a quadratic term for time to assess non-linear trends, but the results differed little from standard linear models with the sole exception of blood pressure trends in women. The majority of our final estimated models had coefficients of determination (R^2) value of 0.80 and better. Results from log-linear and logit models were nearly identical to the results from linear models. In additional, the projected 2020 estimates for blood pressure in women using a model with a quadratic term were substantially lower than a realistic value. Thus, we chose to use the linear models for simplicity. Estimates with a coefficient of variation larger than 30% were considered as unreliable.[11] Data are presented as mean and 95% CI. A p value <0.05 defined statistical significance.

We compared these estimates based on current trends with a 20% improvement in CV health metrics from 2006 to 2020, since the AHA used 2006 as a reference point. A 20%

improvement in CV health was defined as the average of a 20% relative decrease in the prevalence of poor CV health metrics and a 20% relative increase in the prevalence of ideal CV health across the 7 metrics. This method minimizes the likelihood of demonstrating an "improvement" in CV health that is solely driven by a reduction in poor health, which could be due to higher death rates in that group. Categories of ideal, intermediate, and poor levels of each metric are exclusive from each other. Thus, the prevalence estimates across different categories of each item (poor smoking, intermediate smoking and ideal smoking, for example) sum to 100% by definition. For projections to 2020, we created estimates by first accounting for changes in ideal and poor levels of each metric and created estimates for intermediate levels based on the remaining prevalence.

In order to capture individual-level changes in CV health factors and behaviors, we created a composite, individual-level CV Health Score, based on the individual-level composite of all 7 CV health behaviors and health factors (poor=0 points; intermediate=1 point; ideal=2 points; total scale: 0-14 points). This score is not a risk prediction tool but helps to assess individual-level trends amidst population-level trends in CV health. We assessed changes in the score from 1999 to 2006 and performed forward projections to 2020 in a similar manner. We did not calculate CV Health Scores for NHANES III and for the 2007-8 cycle due to methodological differences in diet and physical activity data collection from 1999-2006.

Results

Among 79,932 participants who attended interviews and examination measurements from 1988 to 2008, we analyzed data from up to 35,059 participants. Reasons for exclusion were: age <20 years old (n=38,666, 48.4%), women pregnant or lactating (n=1,628, 2.0%), and prior

cardiovascular disease, defined as prior myocardial infarction, angina, stroke, or heart failure (n=4,579, 5.7%) (**Supplemental Figure 1**). Participants' mean age was 44.4 years, and 51% were women.

Prevalence estimates for adults categorized as poor, intermediate, and ideal for CV health components in 1988-1994 and 2007-8 are displayed by sex in **Tables 2** and **3**. In addition, β coefficients and standard errors from weighted linear regression models, representing trends for each metric by including data from all NHANES samples, and coefficient of determination (R^2), are displayed.

Prevalence of current smoking, physical activity (1999-2006 only), high cholesterol, and high blood pressure (i.e. – poor levels of these metrics) all decreased from 1988-2008, though trends in physical activity and in high blood pressure in women were not statistically significant, while a corresponding increase in ideal smoking status (never smoker or quit >12 months) was observed. However, there was not a significant increase in the prevalence of individuals with ideal levels of physical activity, cholesterol, or blood pressure. Conversely, obesity and dysglycemia increased substantially in both sexes from 1988-2008. Furthermore, there was minimal increase in healthy diet score in men and no change in women during the period of observation (1999-2008).

Projected prevalence trends to 2020 (95% confidence intervals) for ideal, intermediate, and poor CV health metrics, assuming current trends continue, are also presented in **Tables 2** and **3** (right-hand columns). Current smoking decreased significantly from 1998-2008 in both men and women with projected prevalence in 2020 reaching 23% in men and 16% in women. Prevalence of former smokers who had quit > 12 months ago or never smokers (ideal CV health) increased in both groups as well and is projected to be 4.5% and 4.3% in men and women in

2020. Among current smokers, the mean number of cigarettes per day was lower in both men and women and in all age groups. (**Supplemental Figure 2**).

The prevalence of ideal healthy diet score=4 or 5 increased minimally from 0.3% to 0.6% in men (p=0.04) and from 0.9% to 1.4% in women (p=0.02) between 1999-2008. The projected prevalence of ideal healthy diet score will reach only 1.2% in men and 1.9% in women by 2020. The mean healthy diet score was minimally increased between 1999-2008 in men (0.78 to 0.84 healthy diet components; p=0.04) and in women (1.04 to 1.10; p=0.33). The healthy diet scores were slightly higher for adults ≥ 60 years in both men and women from 2000 to 2006, but these differences were small and are projected to narrow further by 2020 (**Supplemental Figure 3**).

Physical inactivity prevalence declined non-significantly from 1999 to 2006 in both men (37% to 30%, p=0.40) and women (42% to 32%, p=0.87). Corresponding increases in the prevalence of intermediate and ideal physical activity levels were also not statistically significant in either sex. Projections to 2020 appear unreliable given fewer time periods and wide variance of this measure. Median minutes of activity per week was <150 minutes in all age and sex groups from 2000 to 2006 (**Supplemental Figure 4**).

Mean BMI and obesity rates increased substantially from 20% in NHANES III to 32% by 2007-8 in men and are projected to reach 43% by 2020 if current trends continue. Similar trends were observed in women where 2020 prevalence projections of obesity reach 42%. There was a corresponding rise in mean BMI and decrease in the prevalence of ideal BMI < 25 kg/m^2 (**Supplemental Figure 5**).

Trends in dysglycemia prevalence rates were similar. Diabetes prevalence and impaired fasting glucose increased in both men and women. The 2020 projected prevalence of diabetes is 14% in men and 8% in women, and <50% of women and <25% of men will have ideal FPG

levels (<100 mg/dl). Among individuals with diabetes, hemoglobin A1c values are projected to decrease (7.5% to 7.2% from 2008 to 2020) in men, but remain stable in women (**Supplemental Figure 6**). Among individuals without diabetes, the mean fasting plasma glucose increased to 104 mg/dl in men and 99 mg/dl in women in 2008, with 2020 projections reaching 108 mg/dl and 101 mg/dl, respectively, if current trends continue (**Supplemental Figure 7**).

The mean total cholesterol fell from 204 mg/dl to 196 mg/dl in men and 206 mg/dl to 199 mg/dl in women from 1998 to 2008. By 2020, mean total cholesterol is projected to decrease in both men (to 191 mg/dl) and women (to 194 mg/dl) by 2020 (**Supplemental Figure 8**). The corresponding prevalence of high cholesterol (≥240 mg/dl) decreased from 19% to 14% in men ($p<0.01$) and from 21% to 15% in women ($p<0.01$) from 1988 to 2008. However, the prevalence of individuals with intermediate cholesterol increased significantly. This group includes individuals with untreated levels of 200-239 mg/dl and those with total cholesterol <200 mg/dl on medical therapy (**Supplemental Figures 9-10**).

The prevalence of high blood pressure decreased from 21% to 16% in men ($p<0.01$) and from 17% to 13% in women ($p=0.22$) with a significant increase in the prevalence of intermediate levels of untreated blood pressure (120-139 mmHg systolic or 80-89 mmHg diastolic) or blood pressure treated to <140/<90 mmHg in women but not men. Mean systolic blood pressure is projected to be 119 mmHg in men and women by 2020. Older adults (≥ 60 years) had declines in mean systolic blood pressure, whereas middle-aged adults (40-59 years) and younger adults (20-39 years) did not (**Supplemental Figure 11**). Decreases in mean SBP over time were most pronounced among groups using blood pressure-lowering agents, in whom SBP was lower across all ages during all cycles (**Supplemental Figures 12-13**).

Projections in CV Health: Will a 20% Improvement Be Achieved by 2020?

Figure 1 shows the prevalence of ideal (green), intermediate (yellow), and poor (red) CV health metrics in 2006 (AHA 2020 Impact Goals baseline year) and 2020 projections assuming current trends continue. Additionally, **Figure 1** provides 2020 targets for each CV health metric, assuming a 20% relative increase in ideal CV health prevalence metrics and a 20% relative decrease in poor CV health prevalence metrics for men and women.

Projected decreases in the prevalence of poor CV health will meet the 20% improvement if current trends continue for smoking, physical activity, blood pressure, and cholesterol. However, fewer and more modest increases in the prevalence of ideal CV health metrics are projected for smoking, diet, physical activity). Overall, we estimate a 6.04% relative improvement in the prevalence of overall CV health based on current trends using the methods outlined by the AHA. This would be well short of the AHA target.

CV Health Score

Figure 2 shows the distributions of the individual-based CV Health Score over 5 NHANES cycles from 1999-2006. The highest overall mean score occurred during the 2005-6 cycle (yellow curves). Furthermore, from 1999 to 2006, mean CV Health Scores did not significantly change for men (7.9 to 7.8 points; p=0.48) or women (8.2 to 8.4 points; p=0.46). If these current trends continue to 2020, the mean scores are projected to be 7.4 (95% CI: 5.7, 9.1) for men and 8.8 (95% CI: 7.6, 9.9) for women. These estimates are substantially lower than the target scores necessary to achieve a 20% relative improvement in individual-level cardiovascular health (9.4 for men; 10.1 for women).

Discussion

Summary of Results

From 1988 to 2008, significant declines in the prevalence of smoking, high cholesterol, and high blood pressure (in men) have been offset by substantial increases in the prevalence of obesity and dysglycemia. Healthy diet scores have changed minimally, and physical inactivity has trended lower, albeit not significantly. The declines in high cholesterol and high blood pressure are not matched with a concomitant increase in the prevalence of ideal cholesterol and blood pressure levels, suggesting that individuals are moving toward intermediate levels of each health factor, a stratum that includes individuals treated to cholesterol and/or blood pressure target.

Worrying increases in BMI and dysglycemia are matched by a concomitant decrease in the prevalence of normal weight and euglycemic adults, consistently suggesting adverse population-level shifts in each metric. Our projections may overestimate the future prevalence of impaired fasting glucose (intermediate CV health), since some individuals will likely develop diabetes by crossing the 126 mg/dl FPG threshold and will not contribute to these projected mean values.

Implications

Our estimated 6% relative improvement in CV health from 2006 to 2020 is far short of the AHA's 2020 Impact Goals' target of improving CV health by 20%. Furthermore, we project no changes in the mean individual CV Health Score for both men and women. In addition to worsening CV health metrics, current trends will likely lead to stagnating age-adjusted fatal and non-fatal CVD event rates in the context of rising health care costs, based upon unfavorable coronary heart disease mortality trends among Americans aged 35-54 years old.[12] The AHA has recently estimated that between 2010 and 2030 direct costs for CVD (including hypertension, coronary heart disease, heart failure, stroke, and all other CVD) will increase from $273 billion to $818 billion, while indirect costs will rise from $172 billion to $276 billion, unless substantial

changes to prevent and control CVD are adopted.[13]

The optimal combination of primordial,[14] primary, and secondary prevention approaches—realized through a mixture of medical and public health/policy interventions—will be critical for any high functioning health system to reduce the prevalence of poor CV health metrics. The goals of this approach are to 1) provide high quality, equitable management of individuals with risk factors and disease and 2) shift individuals from intermediate to ideal levels or, optimally, to maintain ideal health CV metrics throughout the lifespan. This has been shown to lead to greater longevity and health,[15] compression of morbidity,[16] dramatically low lifetime risks for CVD (which account for competing risks),[17] and remarkably lower health care utilization and costs (annual, lifetime, and last-year-of-life).[18] Given these compelling findings, the improvement in CV health through quantifiable metrics has received increasing attention, including being part of Healthy People 2020 as a named objective.[19]

Potential targets for intervention

These results reinforce the central importance of comprehensive tobacco control policies as well as the prevention and management of obesity through diet, exercise, and judicious use of therapies for weight loss to improve CV health in adults. While declines in tobacco consumption are encouraging, tobacco remains the leading cause of preventable death and disability, including a substantial burden of non-CVD such as lung cancer and chronic lung disease. The downstream impact of obesity on other CV health metrics such as dysglycemia, blood pressure, and possibly cholesterol suggests that reversal of body weight trends will have substantial benefits across the spectrum of CV health.

The World Health Organization has also prioritized tobacco control and healthier diet policies, suggesting several population-level "best buy" policy options for non-communicable,

chronic disease prevention that are relevant to the United States CV health and the AHA's 2020 Impact Goals. These include: 1) public smoking bans, 2) tobacco advertising restrictions, 3) increased tobacco excise taxes (especially relevant at the state level given the wide variation across the United States[20]), 4) reduced salt in the food supply, 5) replacement of trans fats with polyunsaturated fats, and 6) mass media campaigns to promote healthy diets and physical activity.[21] In concert with policy changes, more rigorous improvements in individual lifestyle behaviors and factors and medical treatment and control (including combination therapy for high-risk individuals) are needed to help shift individuals from poor to intermediate to ideal CV health.[19]

Strengths/Limitations

The strengths of our results include its large, nationally representative sample size and 20 year measurement period. However, our study has limitations. First, measures of diet and physical activity are prone to sampling variability, as noted by the wide confidence intervals for these estimates, and misclassification due to self-reporting. In addition, we relied upon fewer NHANES cycles for trend tests and 2020 projections for diet and physical activity. Our estimates for diet and physical activity may be unstable and should be interpreted cautiously. Second, future trends may not be linear, as we have assumed. For example, recent obesity increases may be plateauing; conversely, recent cholesterol and blood pressure declines may also be plateauing, which may contribute to the flattening coronary heart disease mortality rates in young men and women in the US, UK and elsewhere.[12, 22] Finally, we created a simple composite cardiovascular health score to examine individual-level cardiovascular health. This score weighs the presence of all intermediate or poor levels of the 7 metrics equally. Prior studies indicate that some adverse health factors, such as current smoking or diabetes, may be associated with greater relative risks

for cardiovascular events than other factors. However, the present score is not intended as a measure to estimate risk; rather, it serves as a means for monitoring the distribution (poor, intermediate or ideal) of all 7 metrics at the individual level across the population. Furthermore, Folsom et al.[2] recently demonstrated that there were roughly equal step-wise decreases in hazards for cardiovascular events for each additional single health behavior or health factor present at ideal levels.

Conclusions

If current trends continue, overall cardiovascular health is projected to improve by only 6% from 2006 to 2020, far below the AHA 2020 Strategic Impact Goals target of 20%. This projection reflects modest, further declines in tobacco consumption, high cholesterol, and high blood pressure, offset by increases in obesity and dysglycemia. Continued individual-level primary and secondary preventive measures should be complemented by an increased national commitment to promote primordial prevention. The potential reductions in cardiovascular disease burden if the AHA 2020 Impact Goals target of 20% improvement in overall CV health were achieved could be substantial, rapid, and associated with substantial cost savings.[23-26]

Funding Sources: Dr. Huffman was supported by a NHLBI-sponsored cardiovascular epidemiology and prevention training grant during part of this work (5 T32 HL069771-08). Role of the Sponsor: All data used in this study were collected by the National Center for Health Statistics, Centers for Disease Control and Prevention. The findings and conclusions in this article are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.

Conflict of Interest Disclosures: None.

References:

1. Lloyd-Jones DM, Hong Y, Labarthe D, Mozaffarian D, Appel LJ, Van Horn L, Greenlund K, Daniels S, Nichol G, Tomaselli GF, Arnett DK, Fonarow GC, Ho PM, Lauer MS, Masoudi FA, Robertson RM, Roger V, Schwamm LH, Sorlie P, Yancy CW, Rosamond WD. Defining and setting national goals for cardiovascular health promotion and disease reduction: The American Heart Association's strategic impact goal through 2020 and beyond. *Circulation*. 2010;121:586-613.

2. Folsom AR, Yatsuya H, Nettleton JA, Lutsey PL, Cushman M, Rosamond WD. Community prevalence of ideal cardiovascular health, by the American Heart Association definition, and relationship with cardiovascular disease incidence. *J Am Coll Cardiol*. 2011;57:1690-1696.

3. Bambs C, Kip KE, Dinga A, Mulukutla SR, Aiyer AN, Reis SE. Low prevalence of "ideal cardiovascular health" in a community-based population: The Heart Strategies Concentrating On Risk Evaluation (Heart SCORE Study). *Circulation*. 2011;123:850-857.

4. CDC/NCHS. Early release of selected estimates based on data from the 2010 National Health Interview Survey. Available at: http://www.cdc.gov/nchs/nhis/released201106.htm#6. Accessed 24 June 2011.

5. Chen CI, Burton T, Baker CL, Mastey V, Mannino D. Recent trends in exposure to secondhand smoke in the United States population. *BMC Public Health*. 2010;10:359.

6. US Department of Agriculture and US Department of Health and Human Services. Dietary Guidelines for Americans, 2010. 7th edition, Washington, DC: US Government Printing Office, December 2010.

7. Flegal KM, Carroll MD, Ogden CL, Curtin LR. Prevalence and trends in obesity among US adults, 1999-2008. *JAMA*. 2010;303:235-241.

8. Cohen JD, Cziraky MJ, Cai Q, Wallace A, Wasser T, Crouse JR, Jacobson TA. 30-year trends in serum lipids among United States adults: Results from the National Health and Nutrition Examination Survey II, III, and 1999-2006. *Am J Cardiol*. 2010;106:969-975.

9. Egan BM, Zhao Y, Axon RN. US trends in prevalence, awareness, treatment, and control of hypertension, 1988-2008. *JAMA*. 2010;303:2043-2050.

10. CDC/NCHS. National Health and Nutrition Examination Survey. Available at: http://www.cdc.gov/nchs/nhanes.htm. Accessed 28 June 2011.

11. Analytic and reporting guidelines: The National Health and Nutrition Examination Survey (NHANES). Hyattsville, MD. National Center for Health Statistics, Centers for Disease Control and Prevention, 2006.

12. Ford ES, Capewell S. Coronary heart disease mortality among young adults in the US from 1980 through 2002: Concealed leveling of mortality rates. *J Am Coll Cardiol*. 2007;50:2128-2132.

13. Heidenreich PA, Trogdon JG, Khavjou OA, Butler J, Dracup K, Ezekowitz MD, Finkelstein EA, Hong Y, Johnston SC, Khera A, Lloyd-Jones DM, Nelson SA, Nichol G, Orenstein D, Wilson PW, Woo YJ. Forecasting the future of cardiovascular disease in the United States: A policy statement from the American Heart Association. *Circulation*. 2011;123:933-944.

14. Strasser T. Reflections on cardiovascular diseases. *Interdisciplinary Sci Rev*. 1978;3:225–230.

15. Stamler J, Stamler R, Neaton JD, Wentworth D, Daviglus ML, Garside D, Dyer AR, Liu K, Greenland P. Low risk-factor profile and long-term cardiovascular and noncardiovascular mortality and life expectancy: Findings for 5 large cohorts of young adult and middle-aged men and women. *JAMA*. 1999;282:2012-2018.

16. Daviglus ML, Liu K, Pirzada A, Yan LL, Garside DB, Feinglass J, Guralnik JM, Greenland P, Stamler J. Favorable cardiovascular risk profile in middle age and health-related quality of life in older age. *Arch Intern Med*. 2003;163:2460-2468.

17. Lloyd-Jones DM, Leip EP, Larson MG, D'Agostino RB, Beiser A, Wilson PW, Wolf PA, Levy D. Prediction of lifetime risk for cardiovascular disease by risk factor burden at 50 years of age. *Circulation*. 2006;113:791-798.

18. Daviglus ML, Liu K, Greenland P, Dyer AR, Garside DB, Manheim L, Lowe LP, Rodin M, Lubitz J, Stamler J. Benefit of a favorable cardiovascular risk-factor profile in middle age with respect to Medicare costs. *N Engl J Med*. 1998;339:1122-1129.

19. Healthy People 2020 Objectives. Available at: http://www.healthypeople.gov/2020/topicsobjectives2020/overview.aspx?topicid=21. Accessed 24 June 2011.

20. Schroeder SA, Warner KE. Don't forget tobacco. *N Engl J Med*. 2010;363:201-204.

21. Global status report on non-communicable diseases. Geneva, World Health Organization, 2010.

22. O'Flaherty M, Bishop J, Redpath A, McLaughlin T, Murphy D, Chalmers J, Capewell S. Coronary heart disease mortality among young adults in Scotland in relation to social inequalities: Time trend study. *BMJ*. 2009;339:b2613.

23. National Institute for Health and Clinical Excellence. Prevention of cardiovascular disease at population level. 2010. Available at: http://guidance.nice.org.uk/ph25. Accessed 23 June 2011.

24. Barton P, Andronis L, Briggs A, McPherson K, Capewell S. Effectiveness and cost effectiveness of cardiovascular disease prevention in whole populations: Modelling study. *BMJ*. 2011;343:d4044.

25. Capewell S, Ford ES, Croft JB, Critchley JA, Greenlund KJ, Labarthe DR. Cardiovascular risk factor trends and potential for reducing coronary heart disease mortality in the United States of America. *Bull World Health Organ*. 2010;88:120-130.

26. Capewell S, O'Flaherty M. Rapid mortality falls after risk-factor changes in populations. *Lancet*. 2011;378:752-753.

DOI: 10.1161/CIRCULATIONAHA.111.070722

Table 1. Definitions of cardiovascular health metrics, as defined by the American Heart Association's 2020 Strategic Impact Goals committee.

	Level of Cardiovascular Health		
Metric	**Poor**	**Intermediate**	**Ideal**
Smoking	Current smoker	Quit smoking <12 months	Never smoker or quit smoking ≥12 months
Diet*	Diet score = 0-1	Diet score = 2-3	Diet score = 4-5
Physical Activity**	No physical activity	1-149 minutes per week of moderate intensity, 1-74 minutes per week of vigorous intensity, or 1-149 moderate plus vigorous intensity activity (whereby time in vigorous activity is doubled)	(≥ 150 minutes per week of moderate intensity, ≥ 75 minutes per week of vigorous intensity, or ≥ 150 minutes per week of moderate plus vigorous intensity activity (in which time in vigorous activity is doubled)
Body Weight	BMI ≥ 30 kg/m^2	BMI = 25-29.9 kg/m^2	BMI < 25 kg/m^2
Glucose/Diabetes	FPG ≥ 126 mg/dl or diagnosed diabetes mellitus with HbA1c ≥7%	FPG = 100-125 mg/dl or diagnosed diabetes mellitus with HbA1c <7%	Fasting plasma glucose (FPG) <100 mg/dl
Cholesterol	Total cholesterol ≥240 mg/dl or treated total cholesterol >200 mg/dl	Total cholesterol = 200-239 mg/dl or treated to total cholesterol <200 mg/dl	Total cholesterol < 200 mg/dl
Blood Pressure	Treated blood pressure <140/<90 mmHg, and SBP ≥ 140 mmHg or DBP ≥ 90 mmHg	SBP = 120-139 or DBP = 80-89, or treated blood pressure <140/<90 mmHg	Blood pressure <120/<80 mmHg

*Diet score (scale: 0-5) was calculated based on one point for each of 5 components, including ≥4.5 cups per day of fruits/vegetables, ≥2 servings of fish per week (3.5 ounce servings), <1500mg per day of sodium, ≤ 450 kcal (36 ounces) per week of sweets/sugar-sweetened beverages, and ≥ 3 servings per day of whole grains (1.1 gram of fiber in 10 gram of carbohydrate; 1 ounce equivalent servings).
**Leisure-time physical activity
BMI = body mass index; FPG = fasting plasma glucose; SBP = systolic blood pressure; DBP = diastolic blood pressure

DOI: 10.1161/CIRCULATIONAHA.111.070722

Table 2. Prevalence estimates (95% CI) and 2020 projections of poor, intermediate, and ideal levels of cardiovascular health components for US men: National Health and Nutrition Examination Surveys (1988-2008).

	NHANESIII (1988-1994)	2007-2008	β (ΣE)	P value	R^2	2020 projection (95% CI)
Smoking						
Poor	**30.8** (27.9, 33.8)	**25.6** (21.1, 30.2)	-0.29 (0.08)	0.02	0.77	**22.5** (16.5, 28.5)
Intermediate	**1.9** (1.0, 2.9)	**2.7** (1.4, 4.0)	0.08†§ (0.04)	0.07	0.59	**4.5** (1.5, 7.5)
Ideal	**67.3** (64.3, 70.2)	**71.7** (67.7, 75.6)	0.21 (0.08)	0.05	0.65	**73.0** (66.7, 79.3)
Healthy Diet*						
Poor	**82.5** (78.3, 86.6)	**81.6** (78.7, 84.5)	0.03§ (0.15)	0.85	0.02	**82.0** (72.5, 91.6)
Intermediate	**17.2** (13.2, 21.3)	**17.8** (14.6, 21.0)	-0.07§ (0.16)	0.71	0.05	**16.8** (7.2, 26.5)
Ideal	**0.3** (0, 0.8)	**0.6** (0, 1.2)	0.04† (0.01)	0.04	0.81	**1.2** (0.3, 2.1)
Physical Activity**						
Poor	**36.8** (31.3, 42.2)	**30.4** (24.0, 36.9)	-0.80§ (0.69)	0.36	0.40	**17.3** (0, 65.0)
Intermediate	**18.4** (14.4, 22.3)	**20.2** (15.6, 24.8)	0.44§ (0.23)	0.19	0.65	**26.6** (10.3, 42.9)
Ideal	**44.8** (38.4, 51.3)	**49.4** (43.5, 55.2)	0.33§ (0.79)	0.72	0.10	**56.1** (0, 100)
Body Weight						
Poor	**19.9** (17.5, 22.1)	**31.6** (27.3, 36.0)	0.83 (0.07)	< 0.01	0.97	**43.4** (37.9, 49.4)
Intermediate	**41.2** (37.9, 44.1)	**40.2** (35.8, 44.5)	-0.05§ (0.07)	0.48	0.12	**39.8** (34.5, 45.0)
Ideal	**38.9** (36.0, 42.4)	**28.2** (25.1, 31.3)	-0.75 (0.07)	< 0.01	0.96	**16.8** (11.7, 21.8)
Glucose/Diabetes						
Poor	**5.5** (4.1, 7.0)	**11.1** (8.0, 14.3)	0.27† (0.08)	0.03	0.65	**13.6** (4.9, 22.3)
Intermediate	**26.6** (23.2, 29.6)	**50.5** (45.1, 55.9)	1.33 (0.28)	< 0.01	0.85	**63.1** (37.8, 88.3)
Ideal	**67.9** (64.8, 71.2)	**38.4** (32.7, 44.0)	-1.60 (0.34)	< 0.01	0.85	**23.3** (0, 53.7)
Cholesterol						
Poor	**18.6** (15.9, 20.8)	**13.8** (10.8, 16.8)	-0.30 (0.05)	< 0.01	0.88	**10.0** (5.7, 14.3)
Intermediate	**34.9** (31.9, 37.5)	**39.6** (34.3, 44.8)	0.31 (0.08)	0.02	0.80	**43.5** (37.3, 49.7)
Ideal	**46.5** (43.8, 50.0)	**46.6** (41.6, 51.7)	-0.01§ (0.12)	0.92	0.01	**46.5** (37.0, 55.8)
Blood Pressure						
Poor	**21.0** (18.3, 23.5)	**15.7** (12.8, 18.5)	-0.35 (0.03)	< 0.01	0.96	**11.2** (8.3, 14.2)
Intermediate	**46.0** (42.6, 49.0)	**48.6** (44.2, 53.0)	0.11§ (0.11)	0.40	0.18	**48.7** (39.8, 57.7)
Ideal	**33.0** (30.6, 35.9)	**35.7** (31.8, 39.6)	0.21§ (0.1.0)	0.10	0.53	**40.1** (29.6, 50.4)

* NHANES III data replaced with NHANES 1999-2000, given different methods used.
**NHANES III and NHANES 2007-8 data replaced with NHANES 1999-2000 and 2005-6 data, respectively, given different methods used.
†Coefficient of variation > 0.3. §P>0.05 for the null hypothesis that β=0; all others, p<0.05.

DOI: 10.1161/CIRCULATIONAHA.111.070722

Table 3. Prevalence estimates (95% CI) and 2020 projections of poor, intermediate, and ideal levels of cardiovascular health components for US women: National Health and Nutrition Examination Surveys (1988-2008).

	NHANESIII (1988-1994)	2007-2008	β (ΣE)	P value	R^2	2020 projection (95% CI)
Smoking						
Poor	**25.3** (22.6, 27.8)	**19.9** (16.0, 23.8)	-0.33 (0.05)	< 0.01	0.90	**15.9** (11.6, 20.6)
Intermediate	**1.2** (0.6, 2.0)	**2.7** (1.4, 4.0)	0.11† (0.02)	< 0.01	0.90	**4.2** (2.3, 6.3)
Ideal	**73.5** (70.6, 76.2)	**77.4** (73.1, 81.6)	0.22 (0.05)	< 0.01	0.85	**79.9** (76.0, 83.6)
Healthy Diet*						
Poor	**71.2** (66.4, 75.9)	**70.7** (67.0, 74.3)	0.03§ (0.19)	0.86	0.01	**71.2** (58.8, 83.6)
Intermediate	**27.8** (23.2, 32.6)	**27.9** (24.5, 31.3)	-0.08§ (0.17)	0.67	0.07	**26.9** (14.9, 38.9)
Ideal	**0.90** (0.01, 1.85)	**1.4** (0.4, 0.4)	0.04† (0.02)	0.09	0.67	**1.9** (0.8, 2.8)
Physical Activity**						
Poor	**42.2** (37.1, 47.4)	**31.7** (26.6, 36.7)	-1.70§ (0.47)	0.07	0.87	**4.8** (0, 41.0)
Intermediate	**20.4** (14.8, 25.9)	**25.3** (21.3, 29.4)	0.76§ (0.41)	0.21	0.64	**40.2** (7.4, 73.0)
Ideal	**37.4** (30.5, 44.3)	**43.0** (38.1, 47.8)	0.77§ (0.26)	0.09	0.82	**55.0** (35.5, 74.6)
Body Weight						
Poor	**25.2** (22.2, 27.5)	**34.1** (29.6, 38.6)	0.63 (0.09)	< 0.01	0.92	**42.2** (33.3, 51.0)
Intermediate	**25.8** (23.5, 28.1)	**29.2** (25.0, 38.6)	0.15§ (0.10)	0.22	0.34	**29.9** (20.9, 38.9)
Ideal	**49.0** (46.2, 52.4)	**36.7** (32.5, 40.9)	-0.78 (0.13)	< 0.01	0.90	**27.9** (15.5, 40.3)
Glucose/Diabetes						
Poor	**4.6** (3.3, 5.8)	**6.3** (3.8, 8.8)	0.10†§ (0.05)	0.11	0.50	**8.3** (2.2, 14.4)
Intermediate	**16.5** (14.0, 18.8)	**36.6** (30.9, 42.2)	0.91 (0.24)	0.02	0.78	**44.3** (21.9, 66.8)
Ideal	**78.9** (76.2, 81.8)	**57.1** (51.2, 63.1)	-1.07 (0.25)	0.01	0.82	**47.4** (24.2, 70.5)
Cholesterol						
Poor	**21.1** (18.6, 23.5)	**14.9** (11.7, 18.0)	-0.40 (0.06)	<0.01	0.92	**10.0** (5.3, 14.8)
Intermediate	**31.3** (28.1, 34.0)	**39.0** (35.8, 42.3)	0.48 (0.08)	< 0.01	0.90	**44.5** (37.8, 51.1)
Ideal	**46.1** (44.8, 50.9)	**47.6** (42.2, 50.0)	-0.08§ (0.08)	0.36	0.21	**45.5** (39.2, 52.0)
Blood Pressure						
Poor	**16.9** (14.8, 19.0)	**12.8** (10.3, 15.4)	-0.21§ (0.14)	0.22	0.34	**11.7** (0, 23.8)
Intermediate	**30.2** (27.5, 32.6)	**35.9** (31.6, 40.3)	0.33 (0.06)	< 0.01	0.85	**39.4** (33.9, 44.8)
Ideal	**52.9** (50.6, 55.5)	**51.2** (47.3, 55.2)	-0.18§ (0.12)	0.20	0.36	**48.9** (36.7, 61.0)

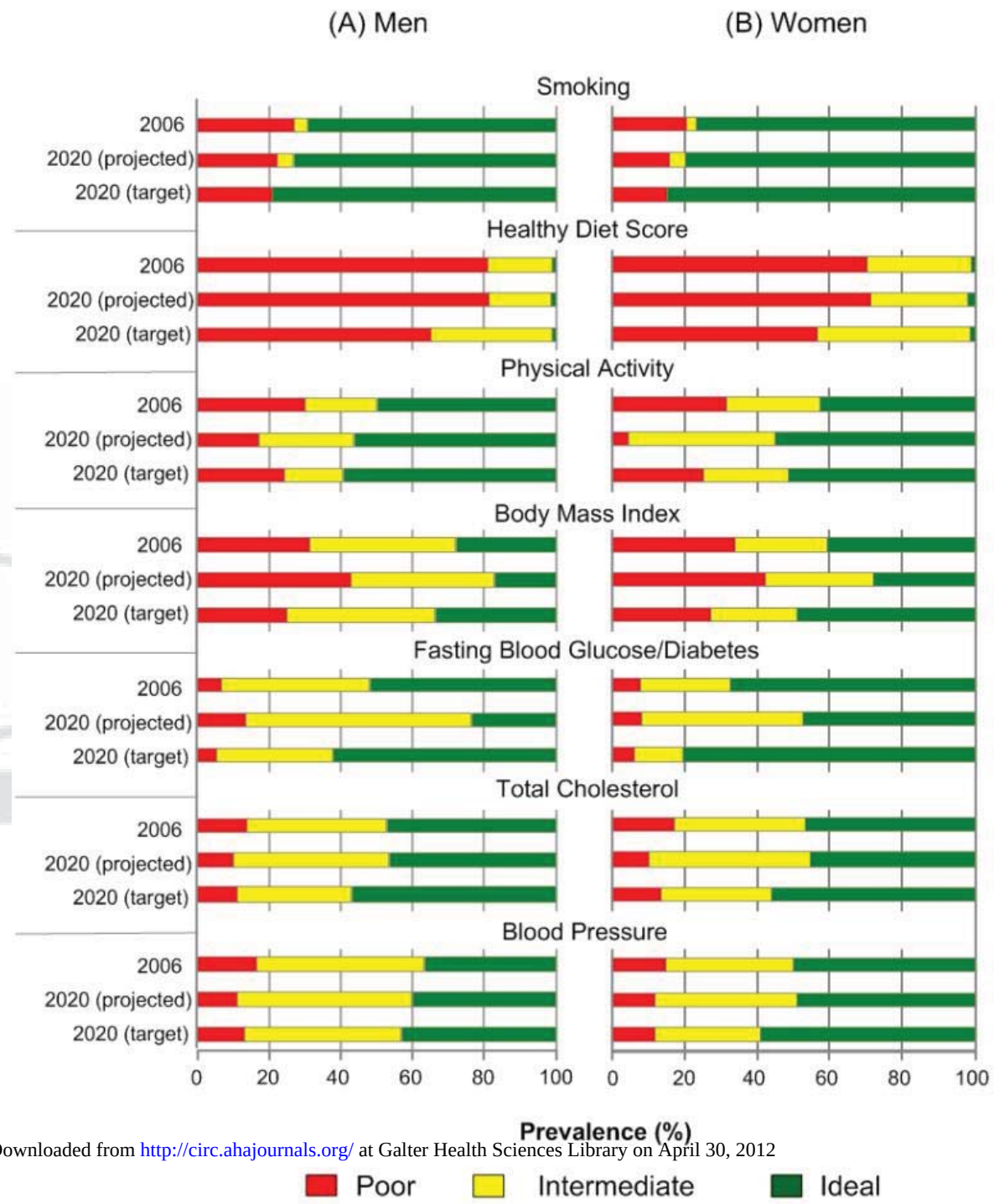
* NHANES III data replaced with NHANES 1999-2000, given different methods used.
**NHANES III and NHANES 2007-8 data replaced with NHANES 1999-2000 and 2005-6 data, respectively, given different methods used.
†Coefficient of variation > 0.3. §P>0.05 for the null hypothesis that β=0; all others, p<0.05.

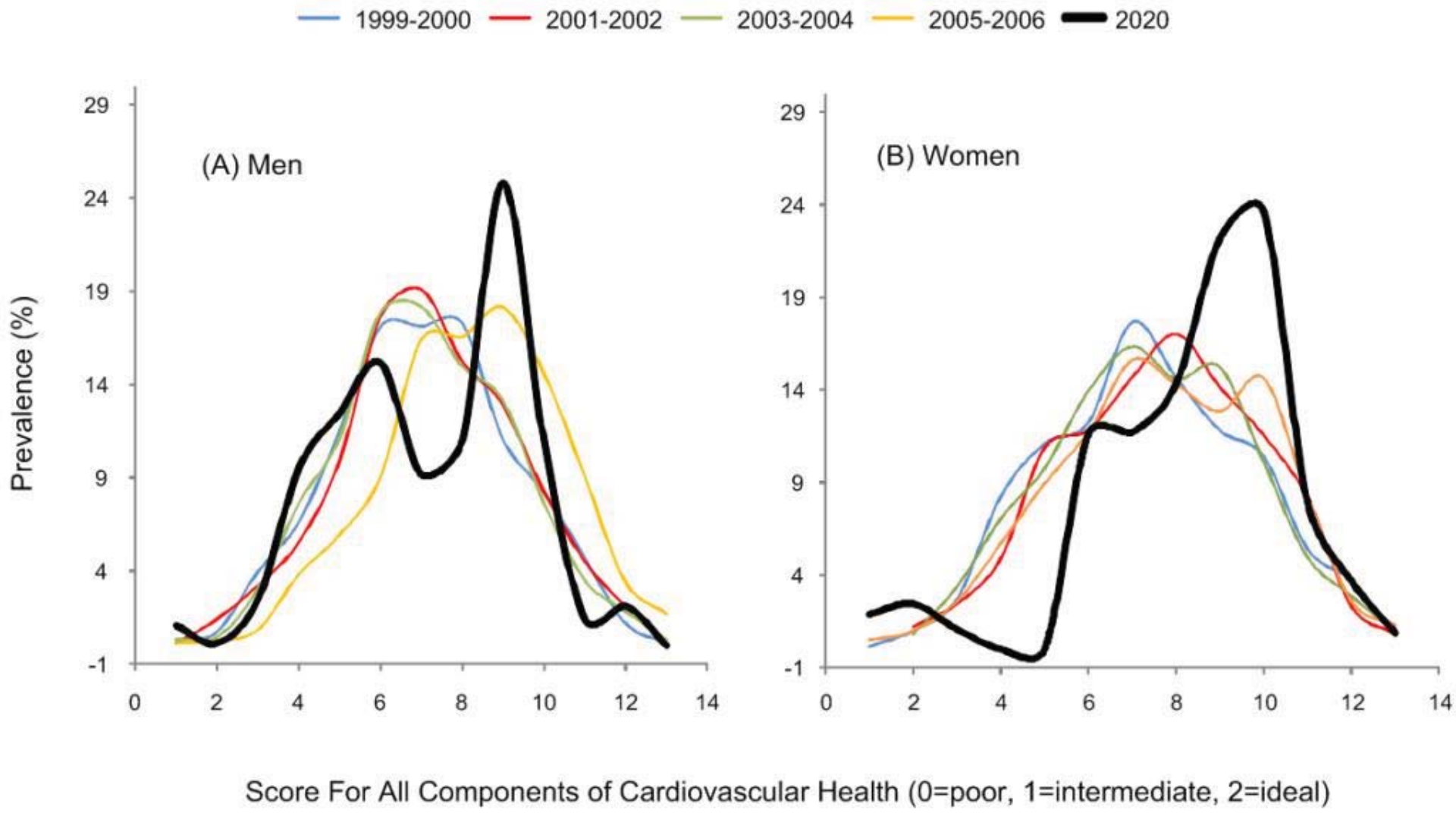
DOI: 10.1161/CIRCULATIONAHA.111.070722

Figure Legends:

Figure 1. Prevalence of ideal (green), intermediate (yellow), and poor (red) CV health metrics in 2006 (AHA 2020 Impact Goals baseline year) and 2020 projections assuming current trends continue. 2020 targets for each CV health metric, assuming a 20% relative increase in ideal CV health prevalence metrics and a 20% relative decrease in poor CV health prevalence metrics for men and women.

Figure 2. Distributions of the individual-based CV Health Score over 5 NHANES cycles from 1999-2006.





SUPPLEMENTAL MATERIAL

Supplemental Methods (1): NHANES Methods of Measurement for Health Behaviors and Factors

Supplemental Figures (14): Flowchart of participants (1); continuous variable data trends (13)

Supplemental Methods

NHANES Methods of Measurement for Health Behaviors and Factors

Details regarding NHANES survey questionnaires, examination components and laboratory components are available at: http://www.cdc.gov/nchs/nhanes.htm.

Health Behaviors

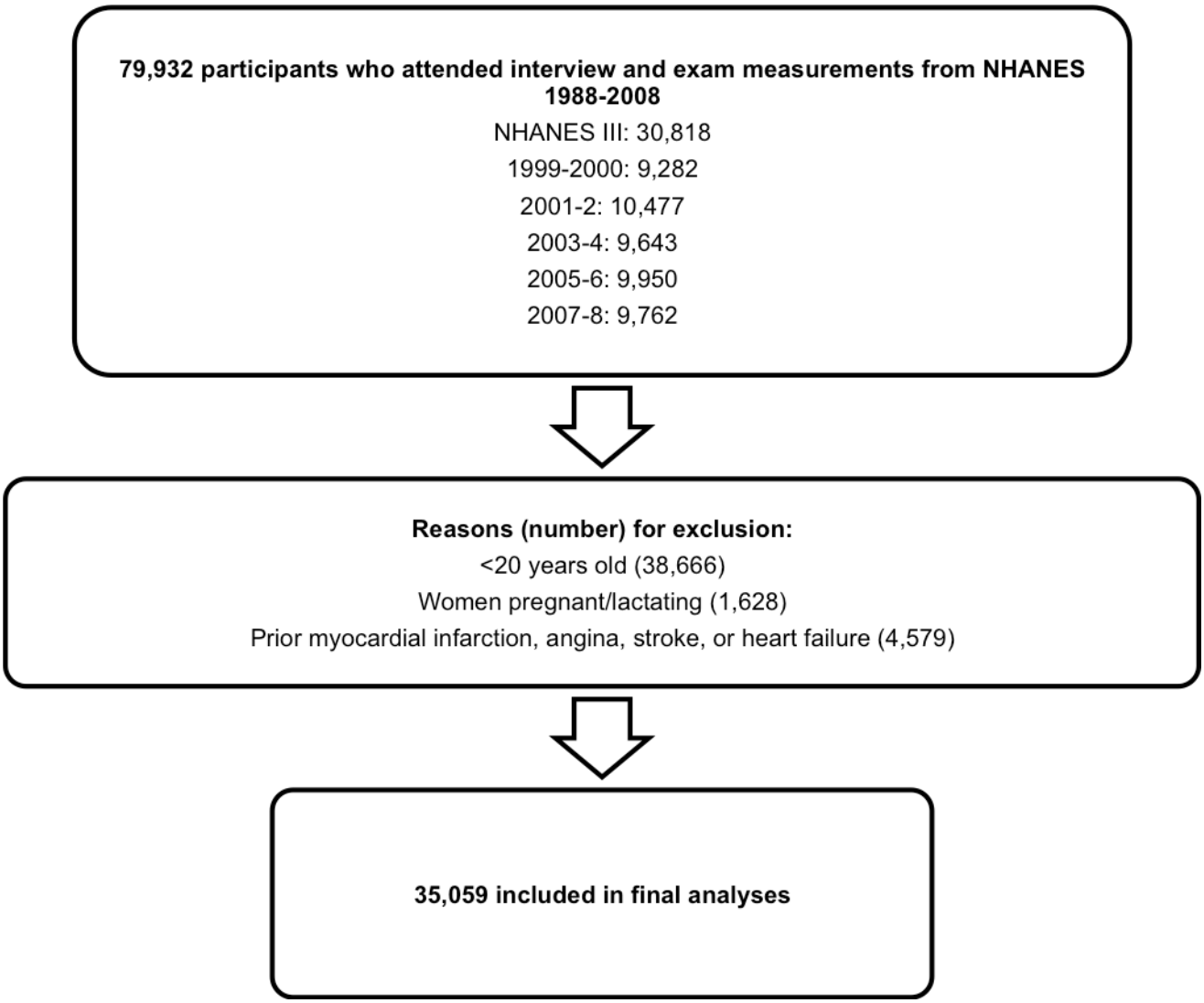
Participants were asked about smoking habits through the following questions, "Do you now smoke cigarettes?" and "How long has it been since you quit smoking cigarettes?" Former smokers were divided into quit ≤12 months (intermediate CV health) and quit >12 months (ideal CV health).
Participants were surveyed about their dietary habits from 1999-2008 through a combination of food frequency questionnaire and 24-hour dietary recall performed three to seven days following mobile examination center (MEC) examination. Interviewees were provided a set of measuring guides to assist their recall. Leisure-time physical activity was queried from 1999-2006 using the following questions, "Over the past 30 days, what moderate activity or activities did you do?" and "Over the past 30 days, how often did you perform (that activity)?" Similar questions were asked regarding vigorous activities. Activities were coded to estimate metabolic equivalents (METs) for moderate and vigorous activities.

Health Factors

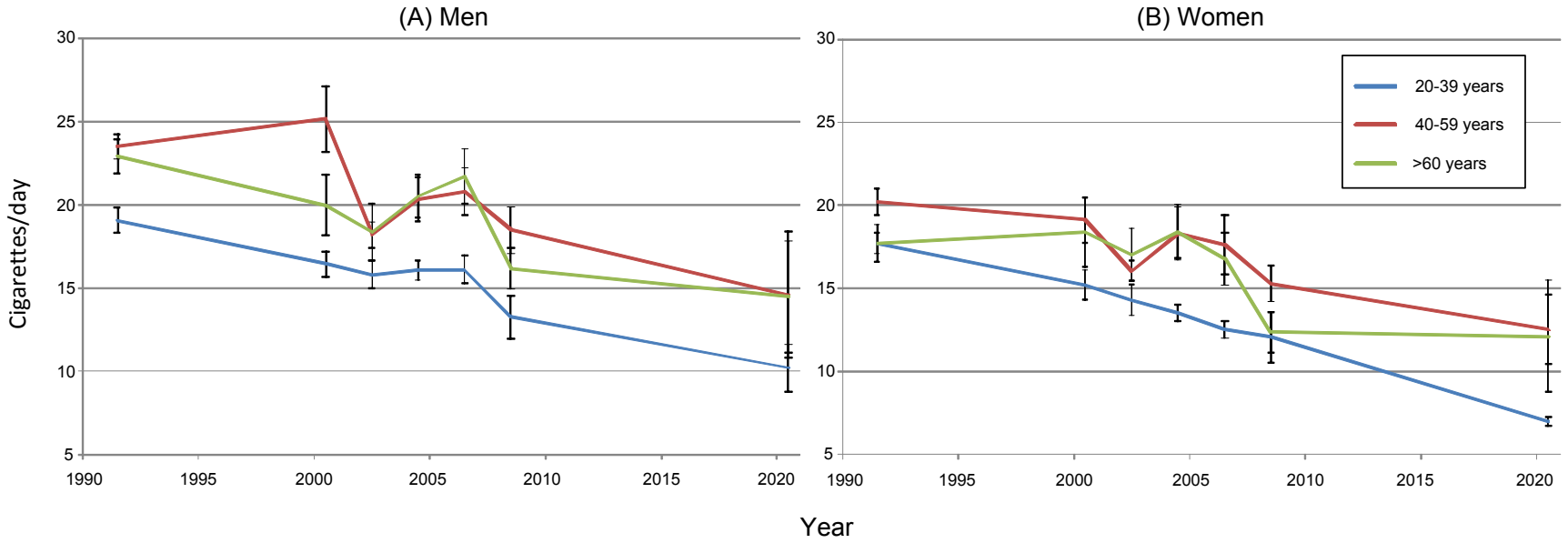
Height and weight were measured in a MEC examination with standardized equipment and techniques. Body mass index was calculated by dividing weight in kilograms by height in meters squared. Diabetes was defined by fasting blood glucose ≥ 126 mg/dl or affirmative response to one or more of the following questions: "Have you ever been told by a doctor that you have diabetes? Are you now taking insulin? Are you now taking diabetes pills to lower your blood sugar?" Total cholesterol, HDL cholesterol, and triglycerides were measured in participants fasting >8 hours. LDL cholesterol was measured using the Friedewald equation if triglycerides were <400 mg/dl (LDL cholesterol = total cholesterol – HDL cholesterol – triglycerides/5). Medical treatment of high cholesterol was queried by asking, "To lower your blood cholesterol, have you ever been told by a doctor or other health professional to take prescribed medicine?" followed by "Are you now following this advice to take prescribed medicine?" Blood pressure was measured by trained personnel using a mercury sphygmomanometer and an inflatable cuff at the level of the heart, after the participant rested for 5 minutes in a seated position with both feet on the floor. Three blood pressure measurements were recorded and the mean of the last two recordings was used; if fewer than three measurements were performed, the second (if two) or first (if one) recording was used. Medical treatment of elevated blood pressure was queried by asking, "Because of your hypertension/high blood pressure, have you ever been told to take a prescribed medicine?" followed by, "Are you now taking a prescribed medicine?"

Supplemental Figures.

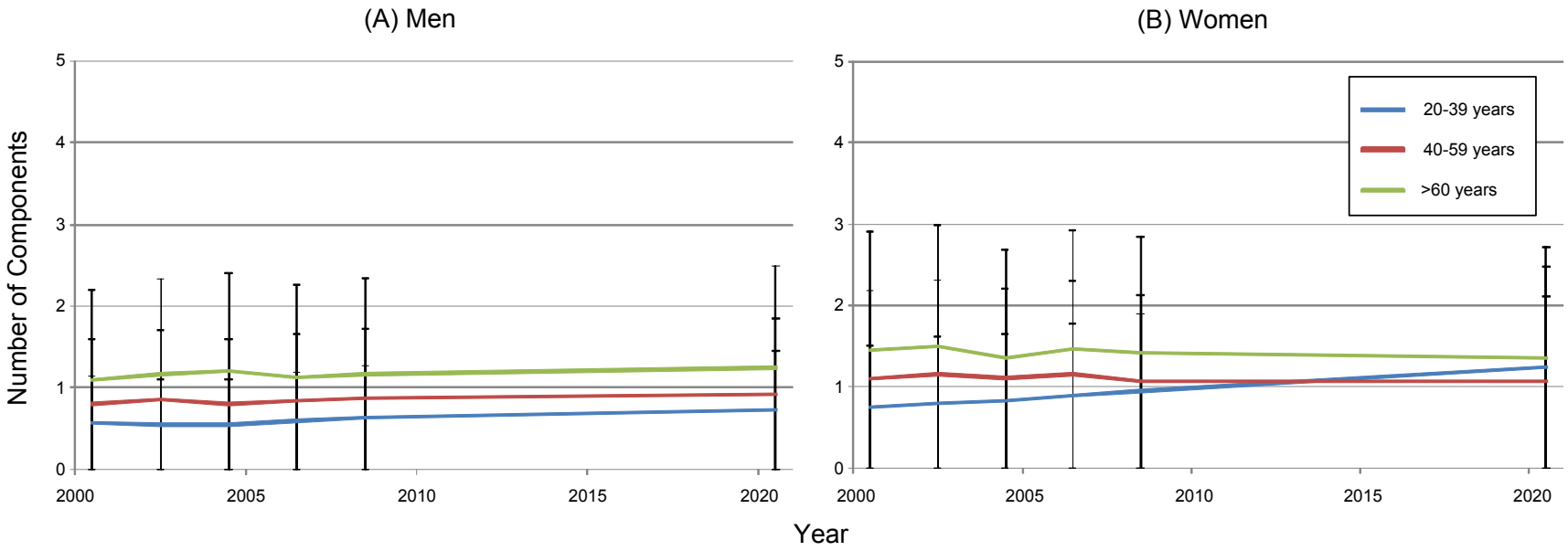
Supplemental Figure 1. Flowchart of participants from NHANES (1988-2008) included in analyses.



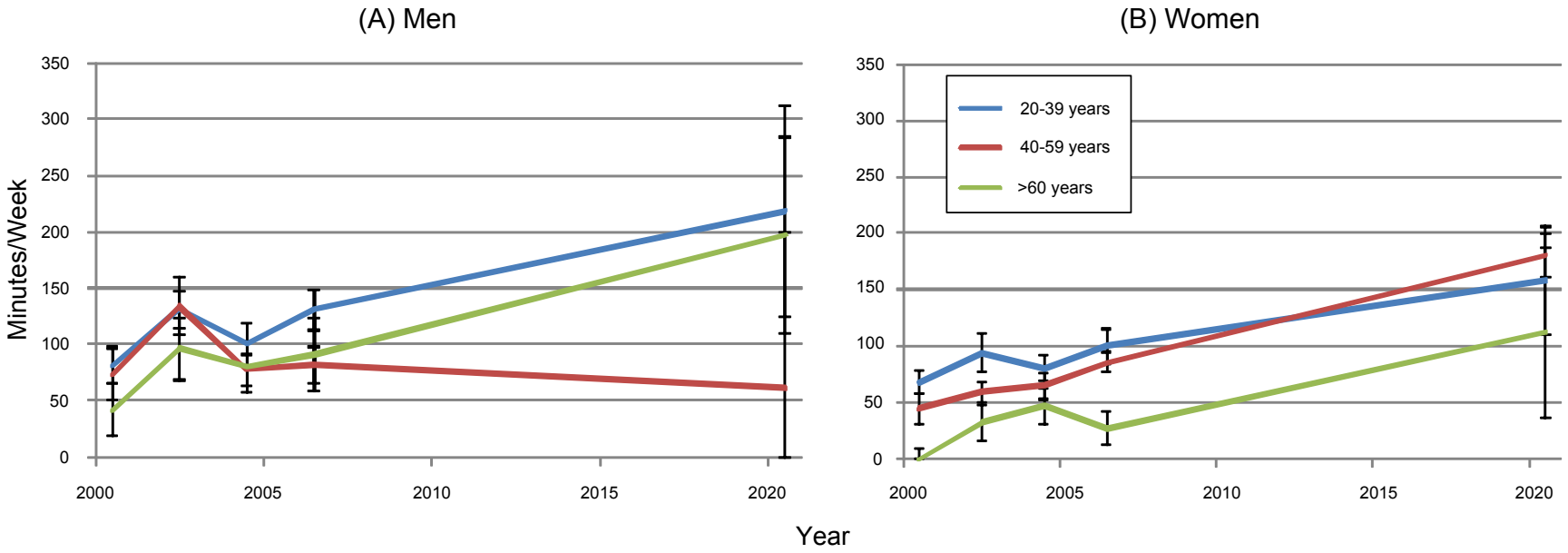
Supplemental Figure 2. Trends for mean (SE) daily cigarette consumption among smokers in U.S. adults (≥20 years) from 1991 to 2008 and projected estimates for 2020 by sex and age group: National Health and Examination Surveys.



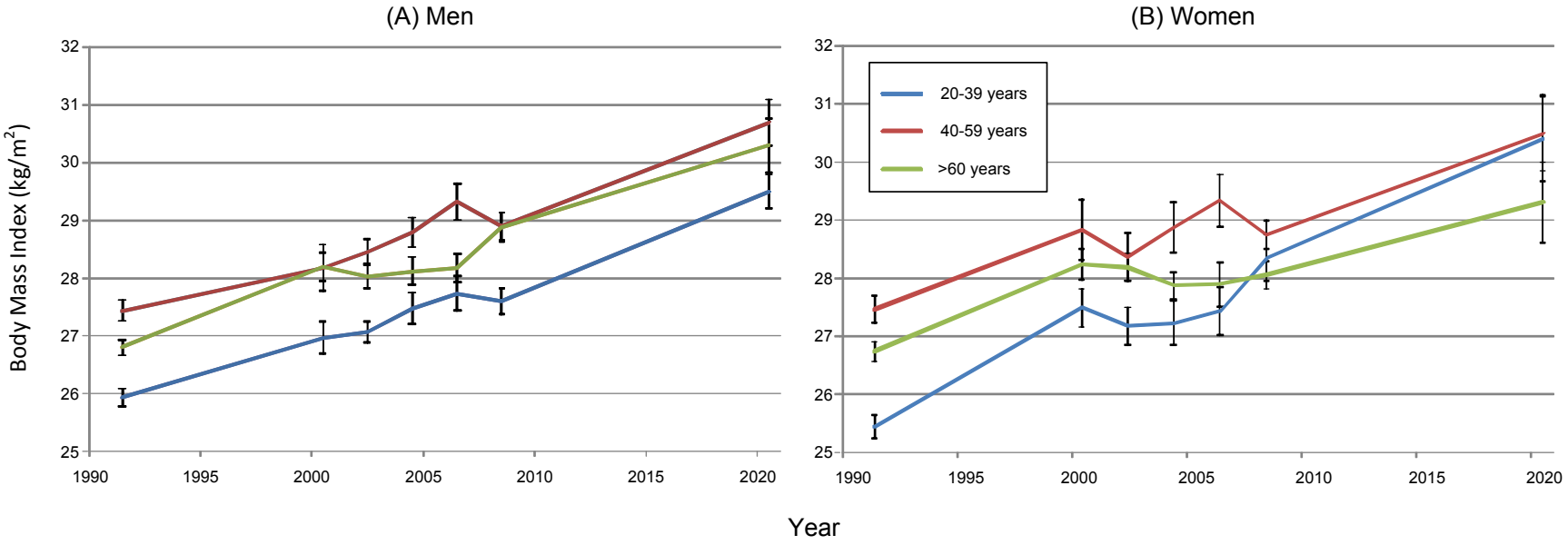
Supplemental Figure 3. Trends for mean (SE) number of ideal Healthy Diet Score components in U.S. adults (≥20 years) from 2001 to 2008 and projected estimates for 2020 by sex and age group: National Health and Examination Surveys.



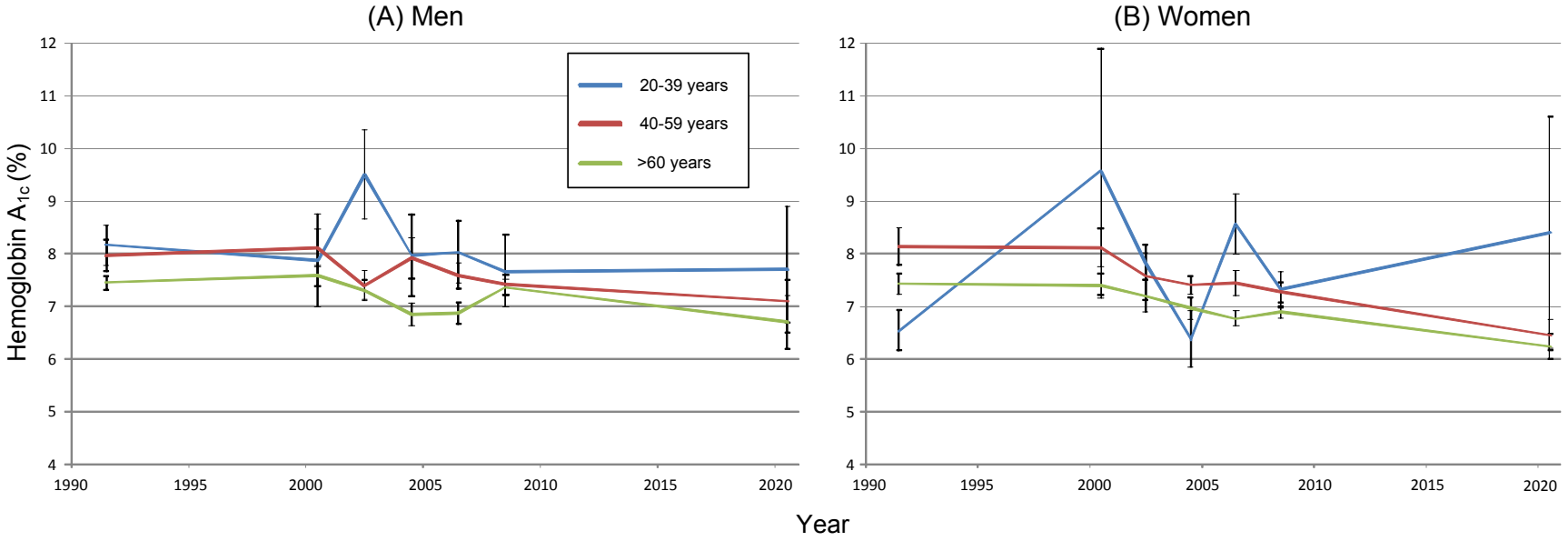
Supplemental Figure 4. Trends for median (SE) leisure time physical activity (minutes/week) in U.S. adults (≥20 years) from 2001 to 2008 and projected estimates for 2020 by sex and age group: National Health and Examination Surveys.



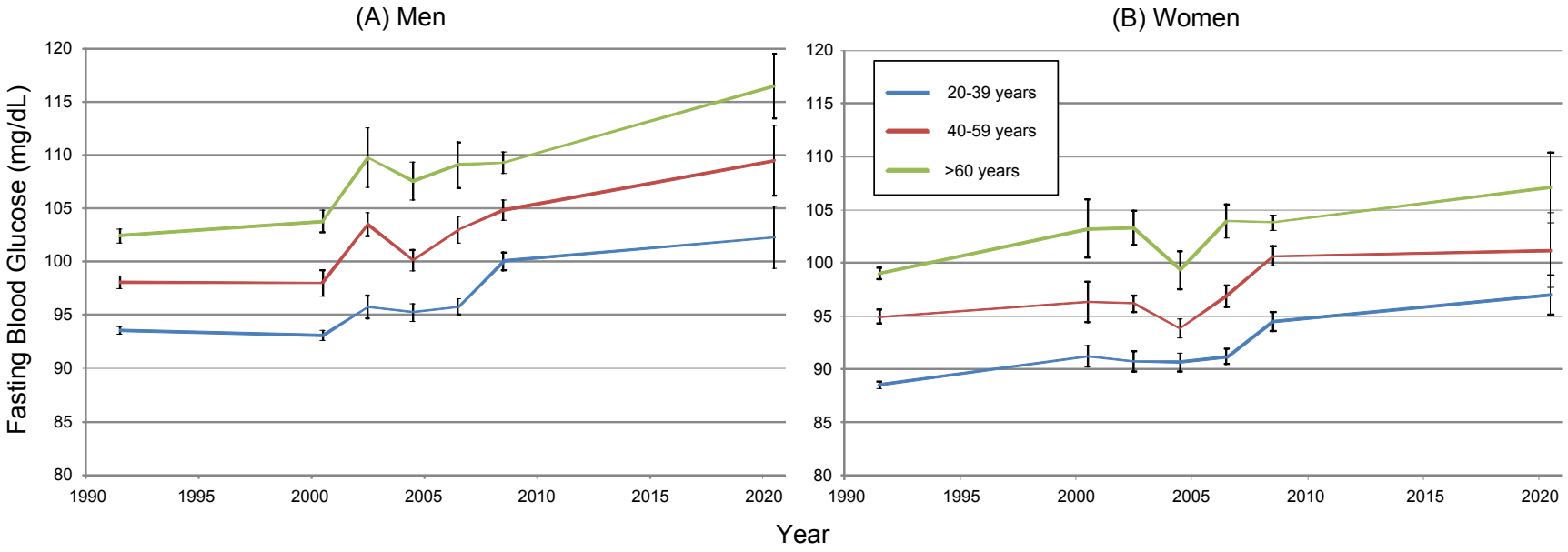
Supplemental Figure 5. Trends for mean (SE) body mass index in U.S. adults (≥20 years) from 1991 to 2008 and projected estimates for 2020 by sex and age group: National Health and Examination Surveys.



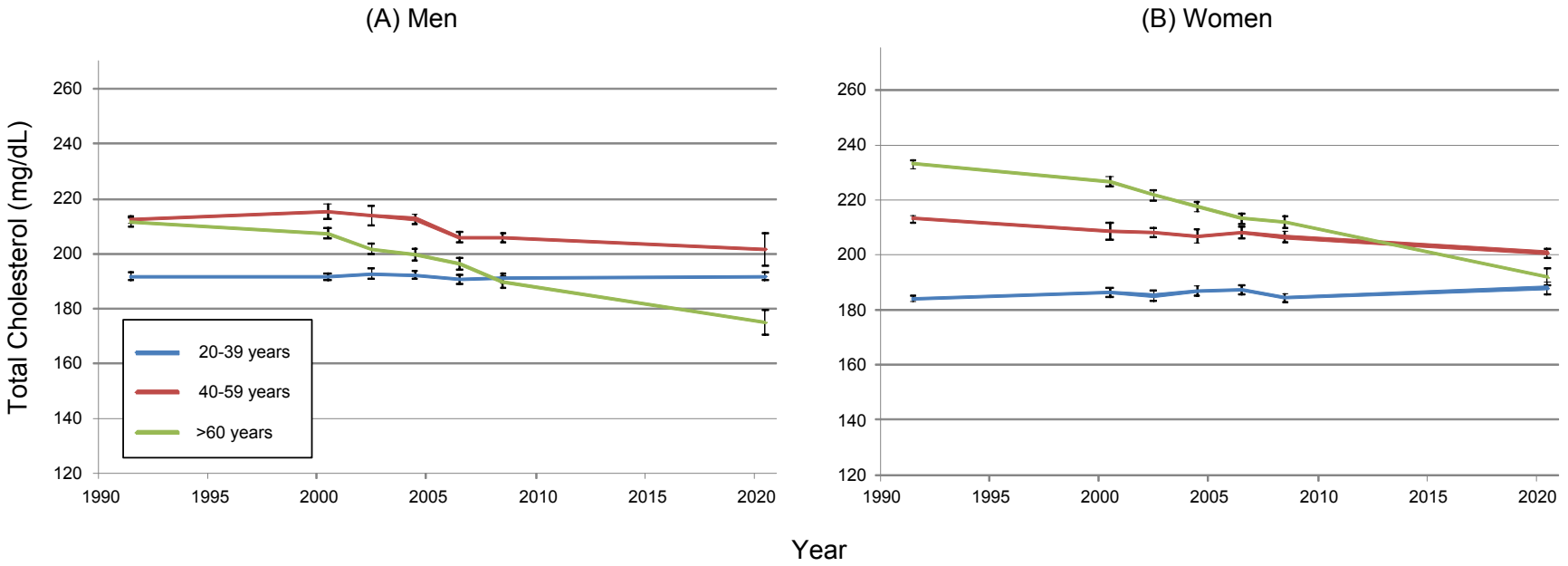
Supplemental Figure 6. Trends for mean (SE) hemoglobin A_{1c} in U.S. adults (≥20 years) from 1991 to 2008 and projected estimates for 2020 by sex and age group: National Health and Examination Surveys.



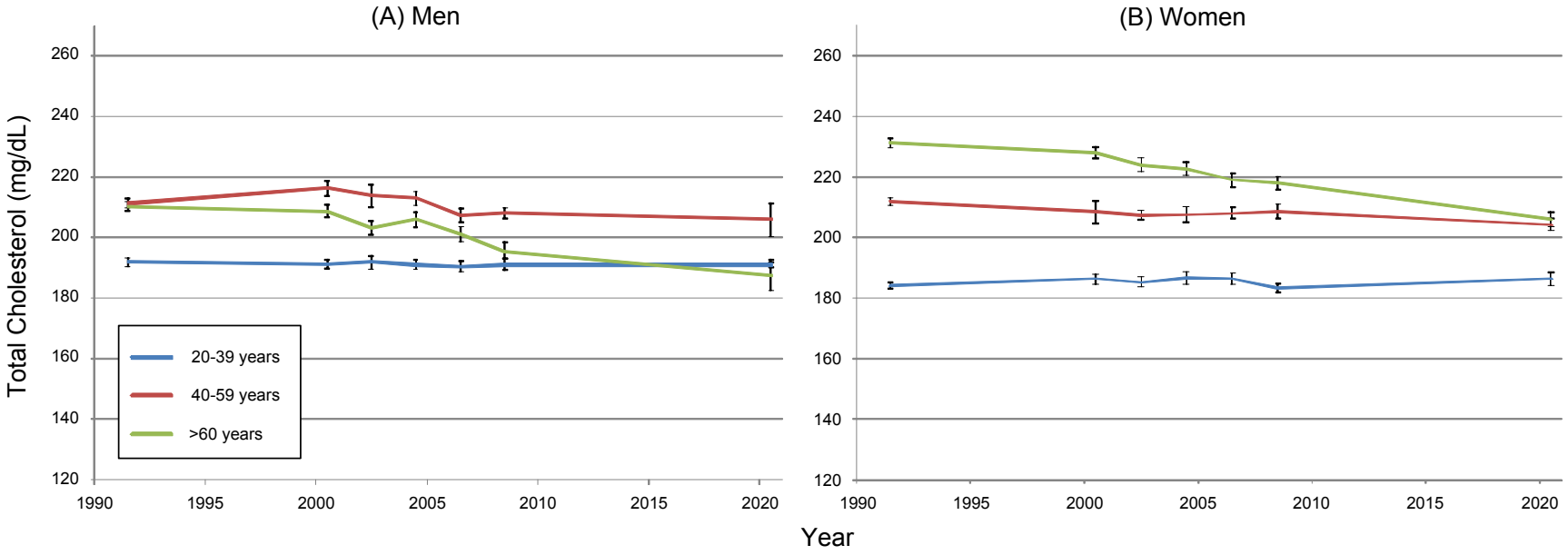
Supplemental Figure 7. Trends for mean (SE) fasting blood glucose in U.S. adults (≥20 years) without diabetes from 1991 to 2008 and projected estimates for 2020 by sex and age group: National Health and Examination Surveys.



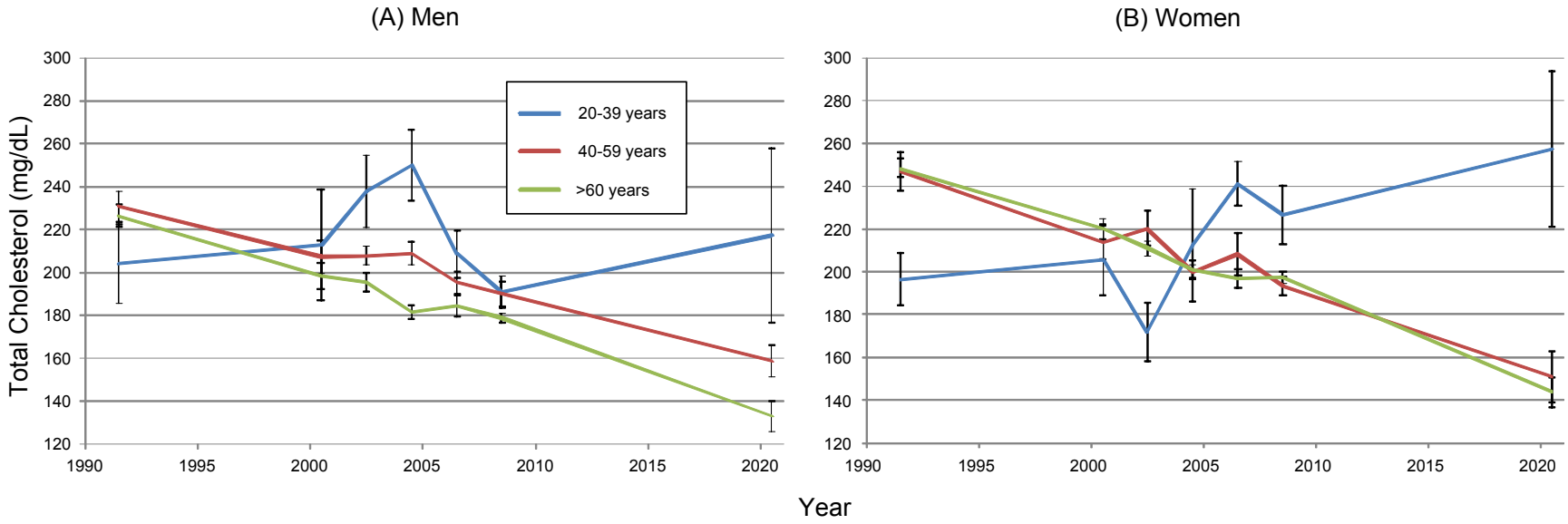
Supplemental Figure 8. Trends for mean (SE) total cholesterol in U.S. adults (≥20 years) from 1991 to 2008 and projected estimates for 2020 by sex and age group: National Health and Examination Surveys.



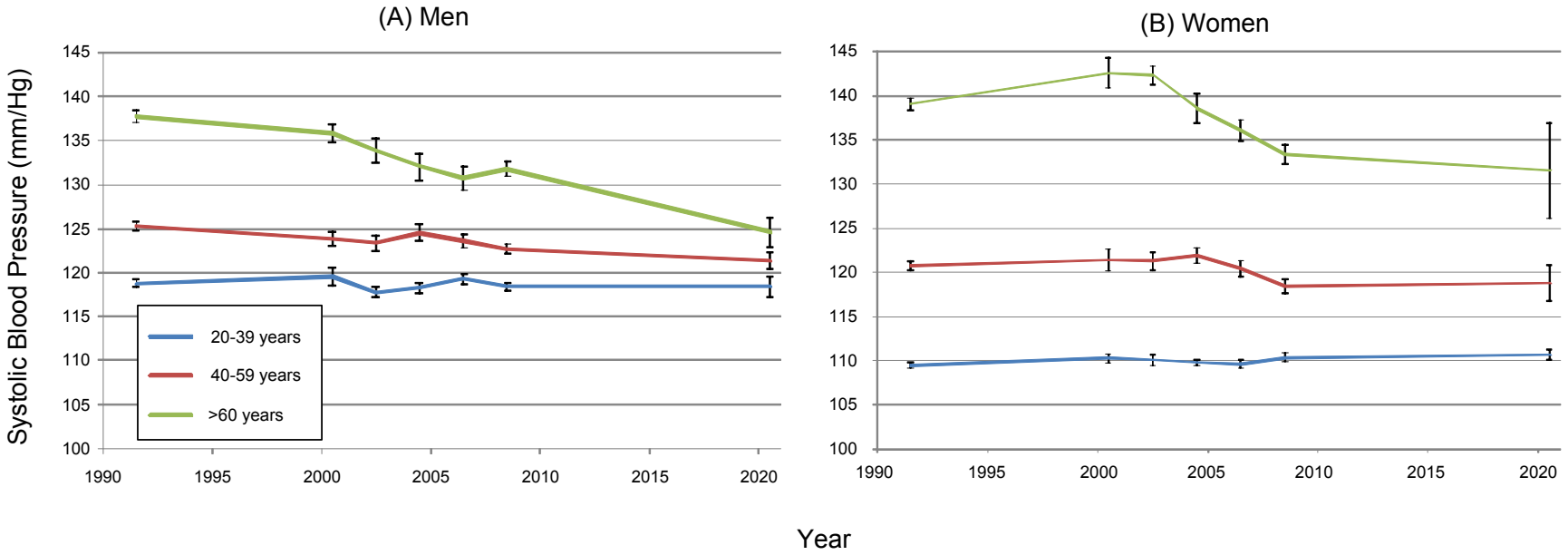
Supplemental Figure 9. Trends for mean (SE) total cholesterol in UNTREATED U.S. adults (≥20 years) from 1991 to 2008 and projected estimates for 2020 by sex and age group: National Health and Examination Surveys.



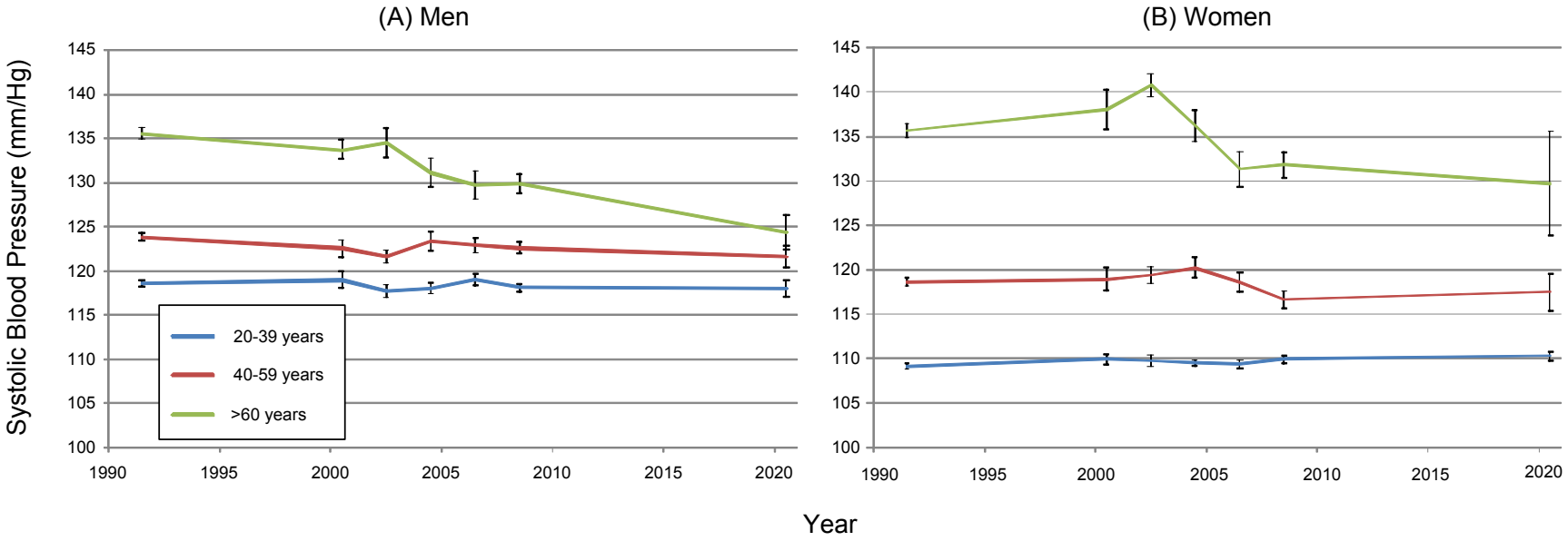
Supplemental Figure 10. Trends for mean (SE) total cholesterol in TREATED U.S. adults (≥20 years) from 1991 to 2008 and projected estimates for 2020 by sex and age group: National Health and Examination Surveys.



Supplemental Figure 11. Trends for systolic blood pressure in U.S. adults (≥20 years) from 1991 to 2008 and projected estimates for 2020 by sex and age group: National Health and Examination Surveys.



Supplemental Figure 12. Trends for mean (SE) systolic blood pressure in UNTREATED U.S. adults (≥20 years) from 1991 to 2008 and projected estimates for 2020 by sex and age group: National Health and Examination Surveys.



Supplemental Figure 13. Trends for mean (SE) systolic blood pressure in TREATED U.S. adults (≥20 years) from 1991 to 2008 and projected estimates for 2020 by sex and age group: National Health and Examination Surveys.