DOI: 10.1161/CIRCULATIONAHA.115.015293

Coronary Heart Disease Mortality Declines in the United States From 1979 Through 2011: Evidence for Stagnation in Young Adults, Especially Women

Running title: *Wilmot et al.; CHD Mortality Decline Stagnation in Young Adults*

Kobina A. Wilmot, MD, (MSc candidate)[1]; Martin O'Flaherty, MD, PhD, MSc[2]; Simon Capewell, MD, DSc[2]; Earl S. Ford, MD, MPH[3]; Viola Vaccarino, MD PhD[4]

[1]Dept of Internal Medicine, Division of Cardiology, Emory University School of Medicine, Atlanta, GA; [2]Clinical Epidemiology, University of Liverpool, Dept of Public Health & Policy, Institute of Psychology, Health & Society, Liverpool, United Kingdom; [3]Centers for Disease Control and Prevention, Atlanta, GA; [4]Dept of Epidemiology, Rollins School of Public Health & Dept of Medicine, Emory University School of Medicine, Atlanta, GA

Address for Correspondence:
Viola Vaccarino, MD, PhD
Rollins School of Public Health
1518 Clifton Rd, Room 3011
Atlanta, GA 30322
Tel: 404-727-8710
Fax: 404-727-8737
E-mail: viola.vaccarino@emory.edu

Journal Subject Code: Etiology:[8] Epidemiology

Downloaded from http://circ.ahajournals.org/ by guest on August 24, 2015

DOI: 10.1161/CIRCULATIONAHA.115.015293

Abstract

Background—Coronary heart disease (CHD) mortality rates have fallen dramatically over the past four decades in the Western world. However, recent data from the US and elsewhere suggest a plateauing of CHD incidence and mortality among young women. We therefore examined recent trends in CHD mortality rates in the US according to age and sex.

Methods and Results—We analyzed mortality data between 1979 and 2011 for US adults ≥25 years. We calculated age-specific CHD mortality rates and compared annual percentage changes (EAPC) during three approximate decades of data (1979-1989, 1990-1999, and 2000-2011). We then used Joinpoint regression modeling to assess changes in trends over time, based on inflection points of the mortality rates. Adults aged 65+ years showed consistent mortality declines, which became even steeper after 2000 (women, -5.0% and men, -4.4%). In contrast, young men and women (aged <55 years) initially showed a clear decline in CHD mortality from 1979 until 1989 (EAPC -5.5% in men and -4.6% in women). However, the two subsequent decades saw stagnation with minimal improvement. Notably, young women demonstrated no improvements between 1990 and 1999 (EAPC +0.1%), and only -1% EAPC since 2000. Joinpoint analyses provided consistent results.

Conclusions—The dramatic decline in CHD mortality since 1979 conceals major heterogeneities. CHD death rates in older groups are now falling steeply. However, young adults have experienced frustratingly small decreases in CHD mortality rates since 1990. The drivers of these major differences in CHD mortality trends by age and sex merit urgent study.

Key words: coronary heart disease, mortality, epidemiology, sex, gender disparities

Downloaded from http://circ.ahajournals.org/ by guest on August 24, 2015

DOI: 10.1161/CIRCULATIONAHA.115.015293

Introduction

Despite a remarkable decline in cardiovascular deaths over several decades, coronary heart disease (CHD) remains the number one cause of death in the U.S. CHD mortality rates have fallen as much as 52% in men and 49% in women between 1980 and 2002.[1] However, these beneficial CHD mortality trends may not have been experienced by all demographic groups. In a previous analysis of U.S. mortality, there was a dramatic slowing in the average annual rate of decline of CHD mortality among younger adults (35-54 years of age), in women from -5.4% in 1980-1989 to +1.5% in 2000-2002, and in men from -6.2% to -0.5%.[1] These worrisome trends reflecting stagnation or even an increase in CHD mortality in young adults have also been mirrored by statistics outside the US.[2-5] In the United Kingdom, the CHD mortality decline in men and women aged 45-54 years slowed between the years 1984-2004. Also, in 2002, CHD mortality rates in men aged 35-44 years increased for the first time in two decades.[2] Likewise in Canada, younger individuals aged 55 years or younger demonstrated a +1.7% annual increase in incident rates of acute myocardial infarction (AMI) hospitalization per year from 2000 to 2009.[5] Similarly, in Australia an increase in the incidence of acute coronary syndromes (+2.3% per year) and AMI (+4.0% per year) was observed in women 35-54 years between 1996 and 2007.[4] The purpose of our study was therefore to examine US CHD mortality rates by age and sex from 1979 to 2011, and particularly to examine recent trends among young men and women.

Methods

We obtained mortality data for all individuals 25 years of age or older in the U.S. between 1979 and 2011 from the CDC WONDER online Compressed Mortality File of U.S. National Vital Statistics data.[6] This database includes mortality data and population counts for all U.S. counties

Downloaded from http://circ.ahajournals.org/ by guest on August 24, 2015

by sex, age, race, year and place of residence. The Compressed Mortality File is produced by the National Center for Health Statistics Office of Analysis and Epidemiology (OAE) at the Centers for Disease Control and Prevention. Mortality information is collected by state registries and provided to the National Vital Statistics System. Underlying cause of death and demographic descriptors are indicated on the death certificates. The underlying cause of CHD death was determined using the International Classification of Diseases (ICD)-9 codes 410-414 and 429.2 for 1979 to 1998 and ICD-10 codes I20-I25 for 1999-2011. There is greater than 98% similarity between the two coding systems for heart disease deaths classification,[7] resulting in only a small (1.5%) net decrease in the allocation of heart disease as the underlying cause of death under the ICD-10 coding system, due to differences in coding for cardiac arrest.[7] Population counts were based on U.S. census data for the years 1980, 1990, 2000, and 2010; intercensal estimates were used for the other years. CHD mortality was evaluated in three age groups, <55, 55-64, and 65+ years. Age-adjustment was performed using the direct method to the estimated U.S. population of the year 2000. For the period 1979-1998, CDC WONDER data are only available for whites, blacks, and others. Thus, in addition to age and gender, we stratified the analysis by the two main racial groups of blacks and whites.

First, we examined mortality rates based on pre-determined approximate decades (1979-1989, 1990-1999, and 2000-2011) to provide an initial descriptive assessment of mortality trends. Next, we performed Joinpoint regression modeling using Joinpoint version 3.0 software (National Cancer Institute, Bethesda, Maryland) to evaluate trends in the estimated annual percentage change (EAPC) in CHD mortality rates throughout the study period.[8] Joinpoint uses a Monte Carlo permutation test to detect years when significant changes in the trend of the rates occur; this method has been widely used to analyze trends in incidence and mortality rates.[1, 9]

Downloaded from http://circ.ahajournals.org/ by guest on August 24, 2015

Assuming a Poisson distribution, we specified a maximum number of 3 joinpoints. The software calculates the EAPC and its 95% confidence interval (CI) for each trend segment and tests whether the slope for each segment differs significantly from the prior segment using a *t* test.

Results

In the entire period from 1979 to 2011, the overall age-adjusted CHD mortality rate for adults aged ≥25 years declined in a similar fashion in men and women, from 703 to 225 deaths per 100,000 in men (68% decline), and from 395 to 125 deaths per 100,000 in women (68% reduction). However, these age-adjusted mortality rates obscured important differences by age and sex (**Figure 1**, **Table 1**, **Supplemental Figure 1**). The EAPC over this entire time period was lower in people <55 years than older groups, and was lower in young and middle-aged women (<65 years) than men in the same age group; women <55 years of age showed the lowest decline, with EAPC of -1.9% (**Table 1**).

After dividing the time period in three approximate decades, 1979-1989, 1990-1999, and 2000-2011, men and women <55 years of age showed a substantial decline in CHD mortality until 1990 (EAPC -5.5% in men and -4.6% in women), but there was stagnation and then minimal improvement in the two subsequent decades (**Table 2**). This was especially true for women, whose EAPC went from -4.6% between 1979 and 1989, to +0.1 between 1990 and 1999, and -1.0% between 2000 and 2011. In contrast, older people, particularly those age 65 years and older, had mediocre EAPC reduction prior to 2000 (EAPC -2.6% in men and -1.7% in women), but showed a much steeper decline in the most recent decade (EAPC -4.4% in men and -5.0% in women).

Next, we analyzed changes in CHD mortality trends using Joinpoint regression modeling,

Downloaded from http://circ.ahajournals.org/ by guest on August 24, 2015

which derives inflection points for trends for the mortality rates in a statistically robust and objective manner. This analysis confirmed that young individuals (age <55 years), especially women, showed less marked decline than older individuals since 1989 (**Table 3** and **Supplemental Figure 2**). However, in the most recent period, starting in 2004-2005, a slight improvement was observed in young women. While in the previous period, from 1989 to 2004/2005, women <55 years had a significantly lower yearly decline in mortality than men in the same age group, in the last period mortality trends between young men and women no longer differed significantly (-2.9% in men vs. -2.0% in women). After stratifying by race, the trends above were similar in the black and white population, showing a flattening in the <55 year age group followed by a recent decline in both black and white individuals (**Figure 2**). Joinpoint analysis revealed that the recent decline was most noticeable in the black population and least noticeable among white women (**Supplemental Tables 1 and 2**, **Supplemental Figure 3**).

Women aged 55-64 years also experienced a sustained slower rate of decline from 1992 up to 2011, in comparison to the period before 1992 (EAPC -2.0% vs -3.9% respectively) (**Table 3**). This was a significantly lower decline as compared to men of similar age. Finally, the Joinpoint analysis confirmed that steep declines in CHD mortality have been achieved in older women and men (age ≥65 years) since 2002, with an average annual percentage decline of 5.0% in men and 5.8% in women, approximately doubled compared to the previous period (**Table 3**). Stratification by race demonstrated an acceleration in both races in this last period, more marked in the black population (**Supplemental Table 1 & 2**, **Supplemental Figure 3**).

Discussion

Major reductions in CHD mortality have continued in the U.S. in recent years. However, these

Downloaded from http://circ.ahajournals.org/ by guest on August 24, 2015

favorable trends conceal large differences across demographic groups. In the last decade, the observed decline mainly reflects CHD mortality reductions among older adults. Young individuals, especially women, continue to show much slower reductions in CHD mortality, bordering on stagnation. Encouragingly, however, in the most recent decade, young women and men show a similar declining trend, albeit at a low EAPC. Thus, the previous disparities in CHD mortality decline between young women and men are narrowing.[1] In contrast, older men and women (aged ≥65 years) display large and continuing CHD mortality reductions since 2002, which seemingly appear to drive the overall recent reduction in CHD mortality in the US.

The causes of the sluggish improvements in CHD mortality among young adults in the U.S. in recent decades are unclear. The presentation, risk factors, and outcomes of CHD have been studied predominantly in older populations; young women have been especially underrepresented.[10] Contrary to common perception, however, young adults (<50 years) represent as many as 22% of acute coronary syndrome hospital admissions[11] and about 25% of all AMI hospitalizations under age 55 years occur in women,[12] accounting for approximately 30,000 AMI admissions each year. Compared with men, young women have more comorbidities, longer length of stay, and higher in-hospital mortality.[5, 12, 13] Furthermore, their 10-year risk of incident coronary events has not decreased at the same rate as men, and the Framingham risk scores for women of age 35-54 with MI has actually increased.[14] Understanding the mechanisms that contribute to the worse risk factor profiles in women is essential in improving their future morbidity and mortality.

Between 2001 and 2010 in the US, there was no significant reduction in AMI hospitalization rates among young people (<55 years),[12] a stark contrast to Medicare population studies which demonstrated >20% reduction in hospitalization rates in the same time period.[15]

Downloaded from http://circ.ahajournals.org/ by guest on August 24, 2015

Consistent with our findings, recent trends in AMI hospitalization rates in young individuals show a similarly discouraging picture across Westernized nations. In Western Australia, hospitalizations for AMI between 1996 and 2007 declined in older individuals, but did not significantly change in men younger than 55 years and significantly increased in women in this age group by 4% per year.[4] In British Columbia, Canada, while hospitalizations for AMI between 2000-2009 declined significantly in older individuals, there was no significant change (+0.3% per year) in young men ≤55 years old and a significant increase (+1.7%) in young women.[5] These unfavorable trends in AMI hospitalization rates in young adults, especially women, contrast with declining hospital mortality rates among young people. Young women, in particular, have shown especially pronounced case fatality declines.[12,16] Pre-hospital cardiac mortality is also declining in both men and women,[17] but there is evidence that women have had smaller improvements[18-20] and some studies even suggested that sudden cardiac death rates have increased particularly in younger women.[21] Thus, it is very likely that the disappointingly flat trends in CHD mortality recently observed in young individuals are driven not by CHD case fatality but by CHD incidence, reflecting adverse trends in cardiovascular risk factors.

Lower awareness and recognition of CHD in women has long been reported, although recent data show some improvement.[22] Socioeconomic status and ethnicity may also be important drivers, as young black Americans have higher AMI hospitalization rates, case fatality rates and CHD mortality than white Americans.[12, 23-25] Multiple studies have likewise demonstrated persistent CHD mortality inequalities for economically deprived groups in Western nations.[26-28] However, it is encouraging from our race-stratified results that black Americans appear to be experiencing recent moderate improvements in younger individuals and considerable improvements in older individuals, suggesting that disparities in CHD mortality

Downloaded from http://circ.ahajournals.org/ by guest on August 24, 2015

between races may be declining.

A possible reason for the slow decline in CHD mortality among young people in recent decades is that CHD prevention guidelines may disproportionately underestimate risk in the young population, undermining prevention efforts.[11,29] This problem may partly reflect the fact that the young population often possesses less traditional CHD risk factor patterns as compared to their older counterparts.[11, 30] Furthermore, the epidemic increases in obesity and overweight over the past 3-4 decades in individuals >20 years of age[31] is alarming, and diabetes is showing a parallel escalation.[9] These risk factor trends are especially relevant here given that individuals <44 years of age and women are experiencing the greatest increase in incidence of diabetes since the 1980s,[9] and young women show the largest increase in the prevalence of obesity and abdominal obesity in the same period.[32] Recent data also indicate that the risk of AMI associated with metabolic syndrome or incident diabetes is higher in younger women than any of the other groups, increasing their odds of AMI almost five-fold.[33] Likewise, diabetes is a powerful risk factor for CHD in young women. Kalyani et. al. analyzed data from multiple cohorts and found that young and middle-aged women with diabetes experience four to fivefold elevated risk of incident CHD as compared to their non-diabetic counterparts, which was a much higher risk than in men of similar age.[34]

Furthermore, non-traditional social and psychological risk factors, may play a disproportionate role, but are not routinely evaluated or managed.[35] For example, psychosocial factors such as depression and perceived stress[36] are more common in younger adults and especially in younger women,[37, 38] and increase the risk of CHD hospitalizations and mortality and delayed recovery after a cardiac event.[36, 39] As further demonstration of the importance of the psychosocial milieu for cardiovascular health among young women, mental stress-induced

Downloaded from http://circ.ahajournals.org/ by guest on August 24, 2015

myocardial ischemia, a phenomenon known to increase the risk of subsequent events and mortality in CHD patients, is more common in young women than in age-matched men.[40]

Our analysis reveals that the largest improvements in CHD mortality over the past decade have been experienced by adults 65+ years of age, with the yearly decline nearly doubling after 2002. This may primarily reflect primary prevention policies and interventions reducing CHD incidence in older adults. However, guideline-based secondary preventive medical care for CHD remains frustratingly low among elderly patients.[41] Secondly, statin use and intensity have modestly improved in older adults.[42] Nevertheless, elderly patients continue to have poorer statin adherence, poorer hypertensive control and a slower decline in smoking than younger patients.[43-45] Alternatively, the marked decline in CHD mortality among older adults may partly represent a cohort effect. For example, improved risk factor control or other preventive measures in middle age may have resulted in declining CHD mortality at older age. Most importantly, premature CHD mortality among young people may result in reduced CHD mortality at older ages as individuals at risk have already died in preceding years.

One strength of our study is the extensive time period examined, covering over 30 years, which allows a detailed historical comparison of mortality rates. Additionally, Joinpoint regression analysis supplies a non-biased estimation of significant changes of CHD mortality trends over time. One significant limitation is possible misclassification of CHD mortality due to miscoding of death certificate codes;[46-48] indeed, a proclivity for overestimation of CHD mortality by as much as 20% has been reported.[49] However, there are few high quality studies on whether misclassification varies by sex and age, or whether it has changed over time. An analysis of out-of-hospital deaths occurring in 1979 in Minneapolis-St Paul, Minnesota residents showed overall high validity of death certificates compared with physician review, with no

Downloaded from http://circ.ahajournals.org/ by guest on August 24, 2015

differences by age. Sensitivity, however, was lower among women (76%) than men (94%), suggesting that more "true" CHD deaths in women may be misclassified as non-CHD deaths.[50] Others have reported that the accuracy of cause of death classification is lowest in older populations, especially older women.[47] Taken together, these data suggest that miscoding of death certificates should not have caused an overestimation of CHD events among young individuals, especially young women, relative to older individuals.

In conclusion, US cardiovascular mortality has fallen steeply since 1979, but this overall decline has not been shared equally by all demographic groups. CHD death rates are falling rapidly in older groups, but not in younger adults, particularly young women. Although the reasons underlying these different trends urgently require further study, deteriorations in CHD treatment appear improbable. Attention thus points towards unfavorable trends in cardiovascular risk factors reflecting inadequate primary prevention strategies.

Funding Sources: This work was supported by grants 2K24 HL077506, R01 HL109413, R01HL109413-02S1, and P01 HL 101398.

Conflict of Interest Disclosures: None. 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.

References:

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

2. O'Flaherty M, Ford E, Allender S, Scarborough P, Capewell S. Coronary heart disease trends in England and Wales from 1984 to 2004: concealed levelling of mortality rates among young adults. *Heart*. 2008;94:178-181.

3. O'Flaherty M, Allender S, Taylor R, Stevenson C, Peeters A, Capewell S. The decline in

Downloaded from http://circ.ahajournals.org/ by guest on August 24, 2015

coronary heart disease mortality is slowing in young adults (Australia 1976-2006): a time trend analysis. *Int J Cardiol*. 2012;158:193-198.

4. Nedkoff LJ, Briffa TG, Preen DB, Sanfilippo FM, Hung J, Ridout SC, Knuiman M, Hobbs M. Age- and sex-specific trends in the incidence of hospitalized acute coronary syndromes in Western Australia. *Circ Cardiovasc Qual Outcomes*. 2011;4:557-564.

5. Izadnegahdar M, Singer J, Lee MK, Gao M, Thompson CR, Kopec J, Humphries KH. Do younger women fare worse? Sex differences in acute myocardial infarction hospitalization and early mortality rates over ten years. *J Womens Health (Larchmt)*. 2014;23:10-17

6. Center for Disease Control and Prevention. Compressed Mortality File. Underlying Cause-of-Death. Available at: http://wonder.cdc.gov/mortSQL.html. Accessed July 29,2014. 07/2014.

7. Anderson RN, Minino AM, Hoyert DL, Rosenberg HM. Comparability of cause of death between ICD-9 and ICD-10: preliminary estimates. *Natl Vital Stat Rep*. 2001;49:1-32.

8. Kim HJ, Fay MP, Feuer EJ, Midthune DN. Permutation tests for joinpoint regression with applications to cancer rates. *Stat Med*. 2000;19:335-351.

9. Geiss LS, Wang J, Cheng YJ, Thompson TJ, Barker L, Li Y, Albright AL, Gregg EW. Prevalence and incidence trends for diagnosed diabetes among adults aged 20 to 79 years, United States, 1980-2012. *JAMA*. 2014;312:1218-1226.

10. Kim ES, Carrigan TP, Menon V. Enrollment of women in National Heart, Lung, and Blood Institute-funded cardiovascular randomized controlled trials fails to meet current federal mandates for inclusion. *J Am Coll Cardiol*. 2008;52:672-673.

11. Akosah KO, Schaper A, Cogbill C, Schoenfeld P. Preventing myocardial infarction in the young adult in the first place: how do the national cholesterol education panel iii guidelines perform? *J Am Coll Cardiol*. 2003;41:1475-1479.

12. Gupta A, Wang Y, Spertus JA, Geda M, Lorenze N, Nkonde-Price C, D'Onofrio G, Lichtman JH, Krumholz HM. Trends in acute myocardial infarction in young patients and differences by sex and race, 2001 to 2010. *J Am Coll Cardiol*. 2014;64:337-345.

13. Vaccarino V, Parsons L, Every NR, Barron HV, Krumholz HM. Sex-based differences in early mortality after myocardial infarction. National Registry of Myocardial Infarction 2 Participants. *N Engl J Med*. 1999;341:217-225.

14. Towfighi A, Zheng L, Ovbiagele B. Sex-specific trends in midlife coronary heart disease risk and prevalence. *Arch Intern Med*. 2009;169:1762-1766.

15. Chen J, Normand SL, Wang Y, Drye EE, Schreiner GC, Krumholz HM. Recent declines in hospitalizations for acute myocardial infarction for Medicare fee-for-service beneficiaries: progress and continuing challenges. *Circulation*. 2010;121:1322-1328.

Downloaded from http://circ.ahajournals.org/ by guest on August 24, 2015

16. Vaccarino V, Parsons L, Peterson ED, Rogers WJ, Kiefe CI, Canto J. Sex differences in mortality after acute myocardial infarction: changes from 1994 to 2006. *Arch Intern Med*. 2009;169:1767-1774.

17. Salomaa V, Ketonen M, Koukkunen H, Immonen-Raiha P, Jerkkola T, Karja-Koskenkari P, Mahonen M, Niemela M, Kuulasmaa K, Palomaki P, Mustonen J, Arstila M, Vuorenmaa T, Lehtonen A, Lehto S, Miettinen H, Torppa J, Tuomilehto J, Kesaniemi YA, Pyorala K. Decline in out-of-hospital coronary heart disease deaths has contributed the main part to the overall decline in coronary heart disease mortality rates among persons 35 to 64 years of age in Finland: the FINAMI study. *Circulation*. 2003;108:691-696.

18. Capewell S, MacIntyre K, Stewart S, Chalmers JWT, Boyd J, Finlayson A, Redpath A, Pell JP, McMurray JJV. Age, sex, and social trends in out-of-hospital cardiac deaths in Scotland 1986–95: a retrospective cohort study. *The Lancet*. 2001;358:1213-1217.

19. Ni H, Coady S, Rosamond W, Folsom AR, Chambless L, Russell SD, Sorlie PD. Trends from 1987 to 2004 in sudden death due to coronary heart disease: the Atherosclerosis Risk in Communities (ARIC) study. *Am Heart J*. 2009;157:46-52.

20. Lehto HR, Lehto S, Havulinna AS, Ketonen M, Lehtonen A, Kesaniemi YA, Airaksinen KJ, Salomaa V. Sex differences in short- and long-term case-fatality of myocardial infarction. *Eur J Epidemiol*. 2011;26:851-861.

21. Zheng ZJ, Croft JB, Giles WH, Mensah GA. Sudden cardiac death in the United States, 1989 to 1998. *Circulation*. 2001;104:2158-2163.

22. Mosca L, Hammond G, Mochari-Greenberger H, Towfighi A, Albert MA, American Heart Association Cardiovascular D, Stroke in W, Special Populations Committee of the Council on Clinical Cardiology CoE, Prevention CoCNCoHB. Fifteen-year trends in awareness of heart disease in women: results of a 2012 American Heart Association national survey. *Circulation*. 2013;127:1254-1263, e1-29.

23. Ho JE, Paultre F, Mosca L. The gender gap in coronary heart disease mortality: is there a difference between blacks and whites? *J Womens Health (Larchmt)*. 2005;14:117-127.

24. Manhapra A, Canto JG, Vaccarino V, Parsons L, Kiefe CI, Barron HV, Rogers WJ, Weaver WD, Borzak S. Relation of age and race with hospital death after acute myocardial infarction. *Am Heart J*. 2004;148:92-98.

25. Jolly S, Vittinghoff E, Chattopadhyay A, Bibbins-Domingo K. Higher cardiovascular disease prevalence and mortality among younger blacks compared to whites. *Am J Med*. 2010;123:811-818.

26. Kaplan GA, Keil JE. Socioeconomic factors and cardiovascular disease: a review of the literature. *Circulation*. 1993;88:1973-1998.

Downloaded from http://circ.ahajournals.org/ by guest on August 24, 2015

27. Capewell S, MacIntyre K, Stewart S, Chalmers JW, Boyd J, Finlayson A, Redpath A, Pell JP, McMurray JJ. Age, sex, and social trends in out-of-hospital cardiac deaths in Scotland 1986-95: a retrospective cohort study. *Lancet*. 2001;358:1213-1217.

28. Davies CA, Dundas R, Leyland AH. Increasing socioeconomic inequalities in first acute myocardial infarction in Scotland, 1990-92 and 2000-02. *BMC Public Health*. 2009;9:134.

29. Nasir K, Michos ED, Blumenthal RS, Raggi P. Detection of high-risk young adults and women by coronary calcium and National Cholesterol Education Program Panel III guidelines. *J Am Coll Cardiol*. 2005;46:1931-1936.

30. Akosah KO, Gower E, Groon L, Rooney BL, Schaper A. mild hypercholestermia and premature heart disease: Do the National Criteria Underestimate Disease Risk? *J Am Coll Cardiol*. 2000;35:5.

31. Flegal KM, Carroll MD, Kuczmarski RJ, Johnson CL. Overweight and obesity in the United States: prevalence and trends, 1960-1994. *Int J Obes Relat Metab Disord*. 1998;22:39-47.

32. Ladabaum U, Mannalithara A, Myer PA, Singh G. Obesity, abdominal obesity, physical activity, and caloric intake in US adults: 1988 to 2010. *Am J Med*. 2014;127:717-727 e12.

33. Mente A, Yusuf S, Islam S, McQueen MJ, Tanomsup S, Onen CL, Rangarajan S, Gerstein HC, Anand SS, Investigators I. Metabolic syndrome and risk of acute myocardial infarction a case-control study of 26,903 subjects from 52 countries. *J Am Coll Cardiol*. 2010;55:2390-2398.

34. Kalyani RR, Lazo M, Ouyang P, Turkbey E, Chevalier K, Brancati F, Becker D, Vaidya D. Sex differences in diabetes and risk of incident coronary artery disease in healthy young and middle-aged adults. *Diabetes Care*. 2014;37:830-838.

35. Shah AJ, Veledar E, Hong Y, Bremner JD, Vaccarino V. Depression and history of attempted suicide as risk factors for heart disease mortality in young individuals. *Arch Gen Psychiatry*. 2011;68:1135-1142.

36. Xu X, Bao H, Strait K, Spertus JA, Lichtman JH, D'Onofrio G, Spatz E, Bucholz EM, Geda M, Lorenze NP, Bueno H, Beltrame JF, Krumholz HM. Sex differences in perceived stress and early recovery in young and middle-aged patients with acute myocardial infarction. *Circulation*. 2015;131:614-623.

37. Narrow WE, Rae DS, Robins LN, Regier DA. Revised prevalence estimates of mental disorders in the United States: using a clinical significance criterion to reconcile 2 surveys' estimates. *Arch Gen Psychiatry*. 2002;59:115-123.

38. Mallik S, Spertus JA, Reid KJ, Krumholz HM, Rumsfeld JS, Weintraub WS, Agarwal P, Santra M, Bidyasar S, Lichtman JH, Wenger NK, Vaccarino V, Investigators PR. Depressive symptoms after acute myocardial infarction: evidence for highest rates in younger women. *Arch Intern Med*. 2006;166:876-883.

Downloaded from http://circ.ahajournals.org/ by guest on August 24, 2015

39. Shah AJ, Veledar E, Hong Y, Bremner JD, Vaccarino V. Depression and history of attempted suicide as risk factors for heart disease mortality in young individuals. *Arch Gen Psychiatry*. 2011;68:1135-1142.

40. Vaccarino V, Shah AJ, Rooks C, Ibeanu I, Nye JA, Pimple P, Salerno A, D'Marco L, Karohl C, Bremner JD, Raggi P. Sex differences in mental stress-induced myocardial ischemia in young survivors of an acute myocardial infarction. *Psychosom Med*. 2014;76:171-180.

41. Timoteo AT, Ramos R, Toste A, Lousinha A, Oliveira JA, Ferreira ML, Cruz Ferreira R. [Impact of age on treatment and outcomes after acute myocardial infarction, particularly in very elderly patients]. *Rev Port Cardiol*. 2011;30:897-903.

42. Carroll MD, Kit BK, Lacher DA, Shero ST, Mussolino ME. Trends in lipids and lipoproteins in US adults, 1988-2010. *JAMA*. 2012;308:1545-1554.

43. Lloyd-Jones DM, Evans JC, Levy D. Hypertension in adults across the age spectrum: current outcomes and control in the community. *JAMA*. 2005;294:466-472.

44. Benner JS, Glynn RJ, Mogun H, Neumann PJ, Weinstein MC, Avorn J. Long-term persistence in use of statin therapy in elderly patients. *JAMA*. 2002;288:455-461.

45. Jackevicius CA, Mamdani M, Tu JV. Adherence with statin therapy in elderly patients with and without acute coronary syndromes. *JAMA*. 2002;288:462-467.

46. Burnand B, Feinstein AR. The role of diagnostic inconsistency in changing rates of occurrence for coronary heart disease. *J Clin Epidemiol*. 1992;45:929-940.

47. Lloyd-Jones DM, Martin DO, Larson MG, Levy D. Accuracy of death certificates for coding coronary heart disease as the cause of death. *Ann Intern Med*. 1998;129:1020-1026.

48. Smith CJ, Scott SM, Wagner BM. The necessary role of the autopsy in cardiovascular epidemiology. *Hum Pathol*. 1998;29:1469-1479.

49. Coady SA, Sorlie PD, Cooper LS, Folsom AR, Rosamond WD, Conwill DE. Validation of death certificate diagnosis for coronary heart disease: the Atherosclerosis Risk in Communities (ARIC) Study. *J Clin Epidemiol*. 2001;54:40-50.

50. Folsom AR, Gomez-Marin O, Gillum RF, Kottke TE, Lohman W, Jacobs DR, Jr. Out-of-hospital coronary death in an urban population--validation of death certificate diagnosis. The Minnesota Heart Survey. *Am J Epidemiol*. 1987;125:1012-1018.

Downloaded from http://circ.ahajournals.org/ by guest on August 24, 2015

DOI: 10.1161/CIRCULATIONAHA.115.015293

Table 1. Estimated annual percentage change (EAPC) in CHD mortality among US adults age ≥ 25 years, 1979-2011

	1979-2011			
	EAPC	95% CI	Number of CHD Deaths	Number of Individuals at Risk
Age <55				
Men	-2.8	[-2.9, -2.7]	871,057	1,827,934,040
Women	-1.9	[-2.1, -1.6]	249,723	1,859,066,839
Age 55-64				
Men	-3.9	[-4.0, -3.8]	1,400,006	395,725,909
Women	-2.8	[-3.0, -2.6]	550,786	434,616,765
Age 65+				
Men	-3.3	[-3.4, -3.1]	6,800,823	448,791,635
Women	-3.1	[-3.2,- 2.9]	7,523,832	640,776,232

American Heart Association.
Circulation

Downloaded from http://circ.ahajournals.org/ by guest on August 24, 2015

DOI: 10.1161/CIRCULATIONAHA.115.015293

Table 2. CHD mortality rates and estimated annual percentage change (EAPC) per decade among US adults ≥ 25 years, 1979-2011

	1979-1989			1990-1999			2000-2011		
	Mean Rate	EAPC	95% CI	Mean Rate	EAPC	95% CI	Mean Rate	EAPC	95% CI
Age <55									
Men	64.2	-5.5	[-6.4, -4.6]	45.4	-1.2	[-2.3, -0.2]	39.1	-1.8	[-2.8, -0.7]
Women	16.1	-4.6	[-5.5, -3.7]	12.6	0.1	[-1.7, 1.9]	12.3	-1.0	[-3.1, 1.0]
Age 55-64									
Men	540.7	-3.7	[-4.1, -3.2]	366.7	-4.0	[-5.0, -2.9]	232.3	-3.9	[-4.8, -3.0]
Women	187.6	-2.5	[-3.6, -1.4]	135.3	-3.3	[-4.4, -2.1]	85.3	-4.5	[-5.9, -3.2]
Age 65+									
Men	2113.3	-2.6	[-4.0, -1.3]	1589.8	-2.1	[-3.0, -1.3]	1121.2	-4.4	[-5.5, -3.4]
Women	1539.3	-1.7	[-3.3,- 0.2]	1242.9	-1.6	[-2.7, 0.4]	898.0	-5.0	[-6.3, -3.7]

Table 3. Estimated annual percentage change (EAPC) in age-specific CHD mortality rates among US adults age ≥ 25 years, 1979-2011.

	Period 1			Period 2			Period 3		
	Years	EAPC	[95% CI]	Years	EAPC	[95% CI]	Years	EAPC	[95% CI]
Age <55									
Men	1979-1989	-5.6	[-5.9, -5.4]	1989-2005	-0.9	[-1.1, -0.8]	2005-2011	-2.9	[-3.5, -2.3]
Women	1979-1989	-4.7	[-5.1, -4.3]	1989-2004	0.2	[-0.1, 0.4]	2004-2011	-2.0	[-2.7, -1.3]
Age 55-64									
Men	1979-1996	-3.7	[-3.8,-3.6]	1996-2005	-4.7	[-5.0, -4.3]	2005-2011	-3.2	[-3.8, -2.7]
Women	1979-1992	-3.9	[-4.2, -3.6]	1992-2011	-2.0	[-2.2, -1.9]			
Age 65+									
Men	1979-2002	-2.6	[-2.7, -2.5]	2002-2011	-5.0	[-5.4, -4.5]			
Women	1979-2002	-2.0	[-2.1, -1.9]	2002-2011	-5.8	[-6.3, -5.4]			

*EAPC results from joinpoint analysis.

Downloaded from http://circ.ahajournals.org/ by guest on August 24, 2015

DOI: 10.1161/CIRCULATIONAHA.115.015293

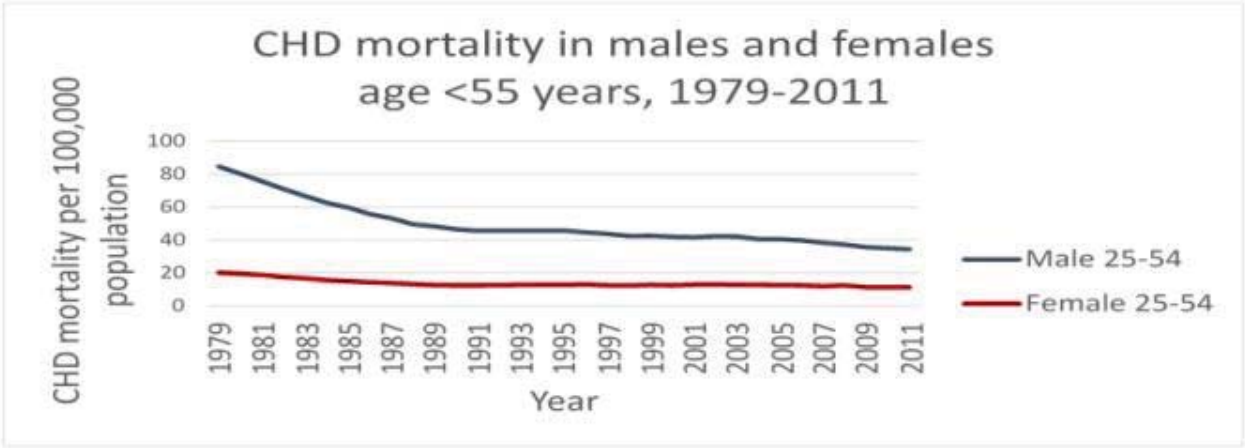
Figure Legends:

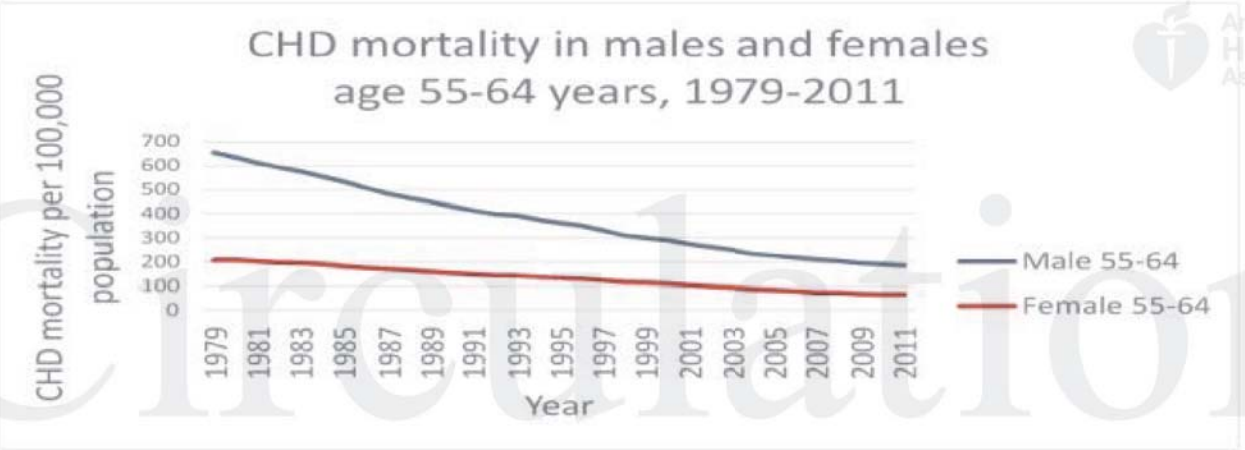
Figure 1. Trends in Age-Specific CHD Mortality Rates in Age Groups <55, 55-64, and 65+ Years, United States, 1979-2011.

Figure 2. Trends in CHD Mortality Rates Stratified by Age, Sex, and Race, United States, 1979-2011.

American Heart Association.
Circulation

Downloaded from http://circ.ahajournals.org/ by guest on August 24, 2015





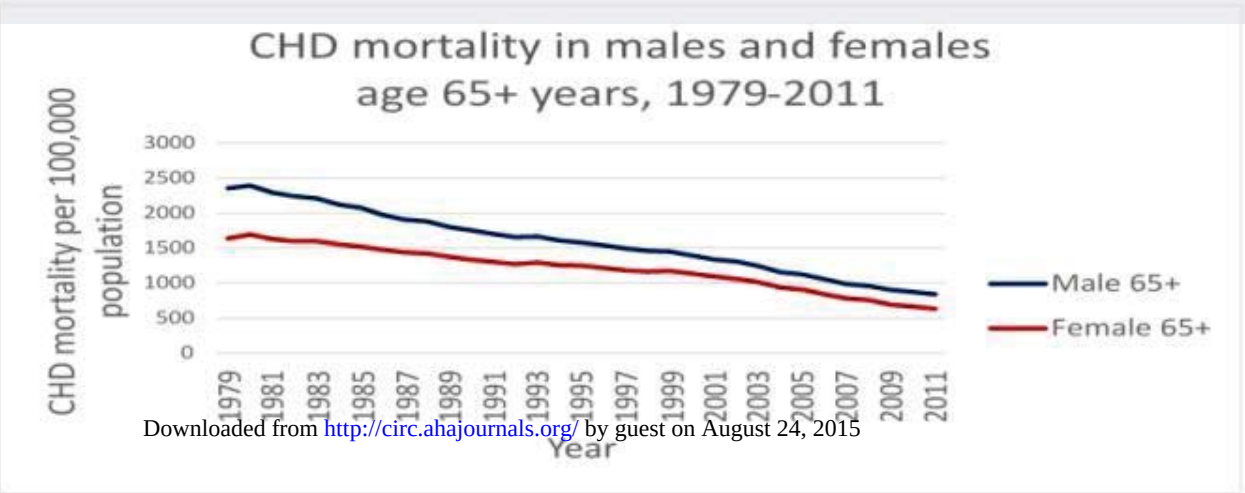
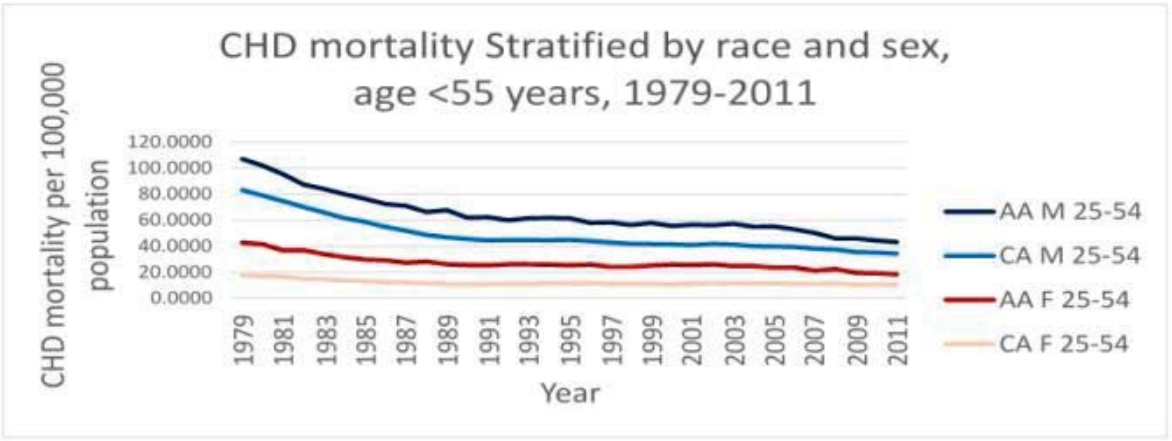
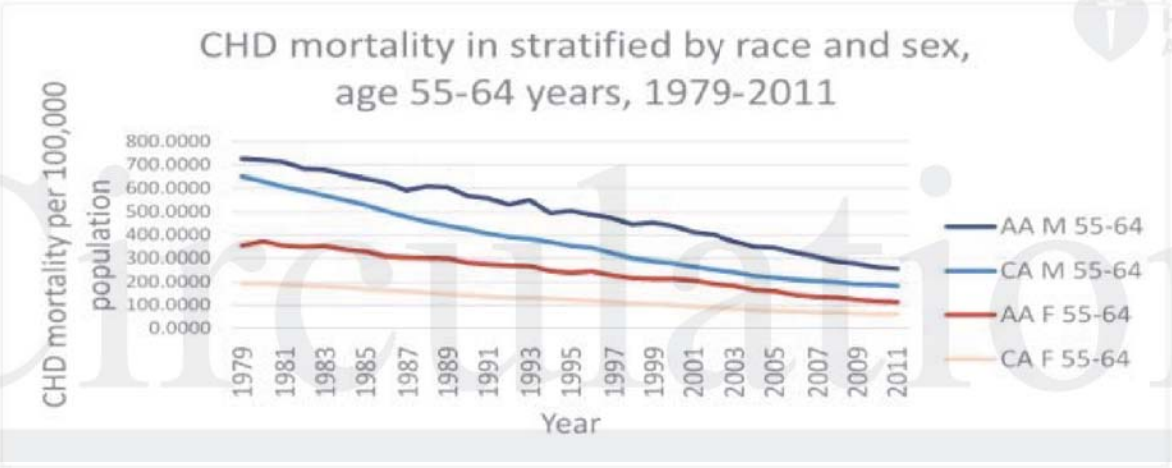


Figure 1

Downloaded from http://circ.ahajournals.org/ by guest on August 24, 2015





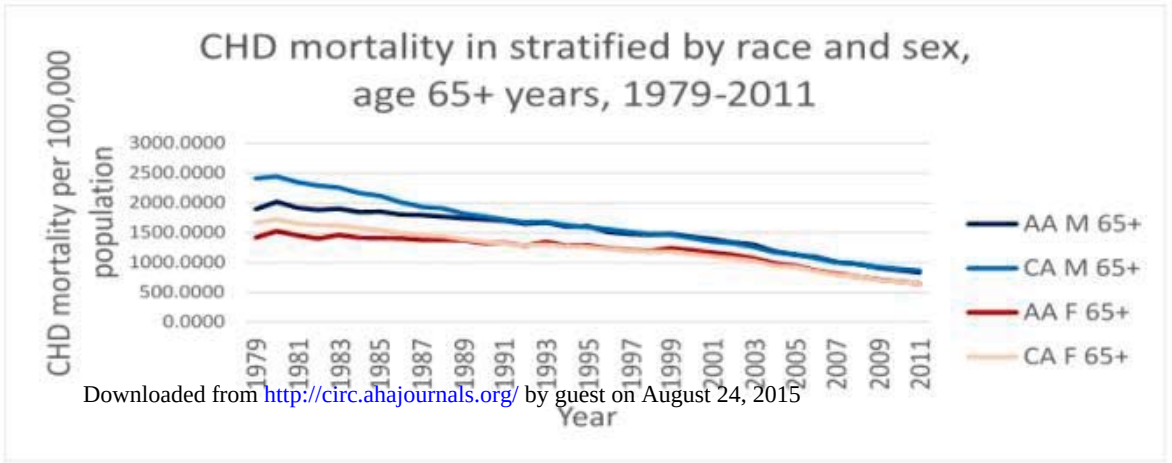


Figure 2

Downloaded from http://circ.ahajournals.org/ by guest on August 24, 2015

Circulation
JOURNAL OF THE AMERICAN HEART ASSOCIATION

American Heart Association®

Coronary Heart Disease Mortality Declines in the United States From 1979 Through 2011: Evidence for Stagnation in Young Adults, Especially Women

Kobina A. Wilmot, Martin O'Flaherty, Simon Capewell, Earl S. Ford and Viola Vaccarino

Circulation. published online August 24, 2015;
Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 2015 American Heart Association, Inc. All rights reserved.
Print ISSN: 0009-7322. Online ISSN: 1524-4539

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://circ.ahajournals.org/content/early/2015/08/05/CIRCULATIONAHA.115.015293

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in *Circulation* can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to *Circulation* is online at:
http://circ.ahajournals.org//subscriptions/

Downloaded from http://circ.ahajournals.org/ by guest on August 24, 2015