

Million Hearts: Description of the National Surveillance and Modeling Methodology Used to Monitor the Number of Cardiovascular Events Prevented During 2012–2016

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Background—This study describes the national surveillance and modeling methodology developed to monitor achievement of the Million Hearts initiative's aim of preventing 1 million acute myocardial infarctions, strokes, and other related cardiovascular events during 2012–2016.

Methods and Results—We calculate sex- and age-specific cardiovascular event rates (combination of emergency department, hospitalization, and death events) among US adults aged ≥ 18 from 2006 to 2011 and, based on log-linear models fitted to the rates, calculate their annual percent change. We describe 2 baseline strategies to be used to compare observed versus expected event totals during 2012–2016: (1) *stable baselines* assume no rate changes, with modeled 2011 rates held constant through 2016; and (2) *trend baselines* assume 2006–2011 rate trends will continue, with the annual percent changes applied to the modeled 2011 rates to calculate expected 2012–2016 rates. Events prevented estimates during 2012–2013 were calculated using available data: 115 210 (95% CI, 60 858, 169 562) events were prevented using stable baselines and an excess of 43 934 (95% CI, –14 264, 102 132) events occurred using trend baselines. Women aged ≥ 75 had the most events prevented (stable, 76 242 [42 067, 110 417]; trend, 39 049 [1901, 76 197]). Men aged 45 to 64 had the greatest number of excess events (stable, 22 912 [95% CI, 855, 44 969]; trend, 38 810 [95% CI, 15 567, 62 053]).

Conclusions—Around 115 000 events were prevented during the initiative's first 2 years compared with what would have occurred had 2011 rates remained stable. Recent flattening or reversals in some event rate trends were observed supporting intensifying national action to prevent cardiovascular events. (*J Am Heart Assoc.* 2017;6:e006021. DOI: 10.1161/JAHA.117.006021.)

Key Words: cardiovascular disease prevention • heart disease • hospitalization • Million Hearts • mortality • myocardial infarction • stroke

In the US, cardiovascular disease (CVD) accounts for more than \$300 billion in annual costs.¹ A major cause of disability² and leading cause of death, CVD accounts for nearly 30% of all deaths—more than 800 000 deaths each year.³ Many CVD-related events, including emergency

department (ED) visits, hospitalizations, and deaths, are avoidable, given that they can be attributed to a lack of healthy lifestyle behaviors, preventive health care, or timely and effective medical care.^{1,4–7} In recent decades, the United States has experienced continuous declines in cardiovascular event rates.^{1,8} However, because of an aging population⁹ and the high prevalence of CVD risk factors,¹ increased CVD prevalence and a slowing or reversal in previously declining overall cardiovascular event rate trends have been reported up through 2011 and forecast to continue if additional efforts are not taken.^{10–13} Some have suggested that the United States needs to establish and take action on achieving aggressive targets for CVD risk factor prevention and management and continue to improve adherence to evidence-based treatments to make substantial gains in decreasing the CVD burden.^{14–16}

In response, the US Department of Health and Human Services launched the Million Hearts initiative in 2012 to focus, coordinate, and enhance CVD prevention activities across the public and private sectors to prevent 1 million acute myocardial

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Accompanying Data S1, Tables S1 through S4 and Figures S1, S2 are available at <http://jaha.ahajournals.org/content/6/5/e006021/DC1/embed/inline-supplementary-material-1.pdf>

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infarctions (AMIs), strokes, and other related cardiovascular events by 2017.¹⁷ Million Hearts is working to meet this goal by focusing its efforts on the ABCS of clinical care—**a**spirin, when appropriate, for secondary CVD prevention; **b**lood pressure control; **c**holesterol management; and **s**moking cessation—and in the community setting by reducing overall tobacco use, reducing sodium consumption, and eliminating artificial trans fat from the diet. These intermediate measures have been tracked since Million Hearts began and will continue to be monitored.^{18,19} Population-level improvements in these risk factors have been demonstrated to lead to decreases in cardiovascular events.^{14,17,20–22}

A national surveillance system to collectively track nonfatal and fatal cardiovascular events in the United States is not available, limiting the ability to monitor the effects of the initiative on event totals.²³ The purpose of our study is to describe how Million Hearts is using a novel method to combine ED, hospitalization, and mortality data sets to overcome this limitation in national cardiovascular event surveillance and assess whether the initiative met the aim of preventing 1 million events. Using this methodology, we describe the burden of Million Hearts events before the initiative (2006–2011) and 2 strategies used to predict the expected number of events that would occur during the initiative (2012–2016) without additional intervention and estimate the number of events potentially prevented. We provide events prevented estimates for 2012 and 2013 using currently available data.

Methods

Description of Data Sources

We used encounter-level data from the Agency for Healthcare Research and Quality's Healthcare Cost and Utilization Project's Nationwide Emergency Department Sample²⁴ (NEDS) to capture ED events; annually, it contains 25 to 30 million unweighted ED visit records from over 950 sampled hospitals. We used the provided NEDS weights to calculate national ED estimates and SDs based on the survey's complex sampling design. We used encounter-level data from the Healthcare Cost and Utilization Project's Nationwide Inpatient Sample²⁵ to capture hospitalization events during 2006 to 2011; annually, it contains ≈8 million unweighted hospital stays from ≈1000 sampled hospitals. Beginning in 2012, the Nationwide Inpatient Sample was redesigned²⁶ as the National Inpatient Sample (collectively referred to throughout as the NIS), selecting a sample of discharges from all hospitals participating in the Healthcare Cost and Utilization Project's, which represents more than 95% of the US population and provides an almost population-level account of inpatient utilization. We used the Agency for Healthcare Research and Quality's NIS trend file²⁷ to establish

the hospitalization trend data for 2006–2011 to adjust for the sampling methodology change between 2011 and 2012.

We used mortality data from the Centers for Disease Control and Prevention's National Vital Statistics System (NVSS) Mortality Multiple Cause of Death Files to calculate national mortality estimates and SEs that account for non-sampling-related errors in the death reporting process.²⁸ The NVSS collects information reported on all death certificates filed in every US state and the District of Columbia.

Identification of Million Hearts Events

The events case definition was developed based on subject-matter expert input, literature findings, and past coding practices. Multiple decision points were considered in development of the definition (see Data S1), with the most important criterion for an event type's inclusion being that it could be expected to be prevented by current or planned Million Hearts efforts. This led to a definition that included a broader range of event types (eg, included heart failure) than only AMIs and strokes. Although effective from a communications standpoint, the name "Million Hearts" and the aim "to prevent 1 million heart attacks and strokes"¹⁷ are limited in conveying the full complement of the events targeted and assessed. We defined a Million Hearts event as a CVD-related ED encounter or hospitalization with a primary diagnosis International Classification of Diseases, Ninth Revision, Clinical Modification code²⁹ (specified in Table S1) or a death with an International Classification of Diseases, Tenth Revision underlying cause of death code³⁰ (specified in Table S1) among adults aged ≥18 years during 2006–2011. We then applied exclusion criteria to each data set to estimate the number of mutually exclusive acute events that were captured in each data set each year (Figure 1; additional details provided in Figure S1). This involved excluding ED visit events where the patients died in the ED, were transferred to another hospital, or were admitted to the same hospital and excluding hospitalization events that were reported as elective or where the patient died in the hospital or was transferred to another hospital. Million Hearts event totals were then summed across the data sets and SDs calculated (see Data S1). Events were assigned to 1 of 4 categories to describe their distribution—AMIs; strokes; symptomatic precursor conditions (eg, stable angina pectoris); or other CVD conditions (eg, heart failure). The combined totals represent the events tracked by the initiative.

Statistical Analysis

Calculation of event rates and assessment of trends

We calculated annual Million Hearts events rates, stratified by sex (men or women; the NEDS and NIS collects this

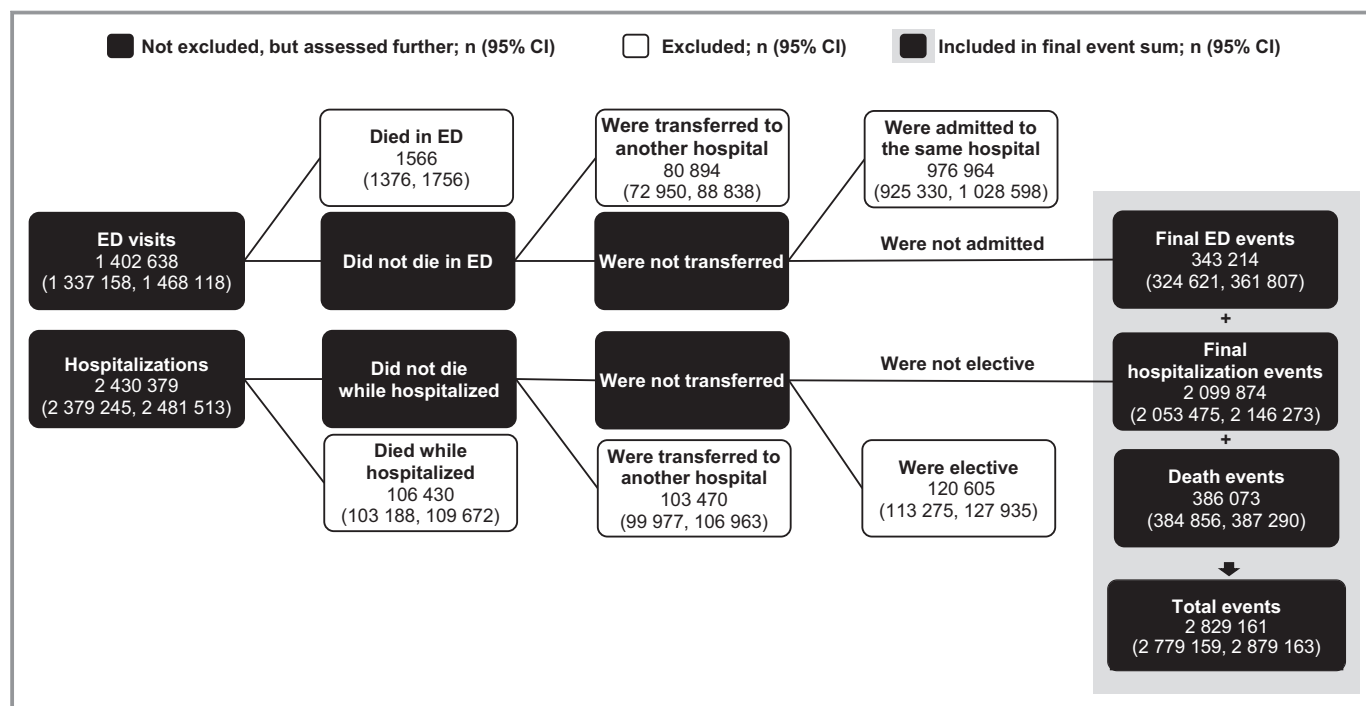


Figure 1. Million Hearts mutually exclusive event calculation methodology applied to the 2013 Nationwide Emergency Department Sample, National Inpatient Sample, and National Vital Statistics System data to determine the total number of mutually exclusive events. After applying the exclusion criteria, 343 214 ED visits, 2 099 874 hospitalizations, and 386 073 deaths were summed for a total of 2 829 161 mutually exclusive events that occurred in 2013. ED indicates emergency department. Additional details are included in Figure S1.

information as sex and the NVSS as gender) and age group (18–44, 45–64, 65–74, or ≥75 years). The ranges for the age groups align with those reported for Million Hearts’ risk factor measures.¹⁹ Race/ethnicity-specific rates were not calculated because race/ethnicity is not consistently included within the NEDS and NIS. We calculated rates and their SDs, using intercensal population estimates as the denominators,^{9,31} and age-standardized the overall and sex-specific rates to the 2010 US Decennial Census population,³¹ using the age categories listed above.

We characterized temporal trends in event rates during 2006–2011 by fitting log-linear regression models to the sex- and age-specific rates, weighted by the inverse of each rate’s variance. We used the log-transformed regression coefficients (slopes) of the event rate models to calculate the annual percent change (APC) for each rate and the associated SEs and 95% CIs.³² We tested the APCs within each sex and age group against the null hypothesis (slope=0); we interpreted models with APCs that were statistically different from 0 as having a change in event rate during the period ($P<0.05$). We compared APCs across age groups for each sex (referent, adults aged 18–44 years) and in each age group by sex (referent, men) to test for statistically significant differences ($P<0.05$). All statistical tests were 2-sided and conducted using SAS software (9.3; SAS Institute Inc, Raleigh, NC). This

study was exempt from institutional review board review because the data analyzed were from de-identified, public-use data sets made available for public health surveillance.

Development and use of two baseline strategies

Two parallel baseline strategies were developed to assess the association between the implementation of Million Hearts and decreases in event totals during 2012–2016. The first strategy (stable baselines) assumes there will be no change in event rates during 2012–2016 unless additional action is taken. To establish the stable baselines, we held the modeled sex- and age-specific 2011 rates constant during 2012–2016. The second strategy (trend baselines) assumes the event rate trends experienced during 2006–2011 will continue during 2012–2016. To establish the trend baselines, we applied the sex- and age-specific APCs to the modeled 2011 rates to calculate expected rates for 2012–2016 (see Data S1 and Figure S2 for an example). We applied the sex- and age-specific modeled 2011 rates and, for the trends baseline, the sex- and age-specific APCs and their associated SEs, to generate 1000 simulated expected rate estimates for each baseline strategy. We then applied the means and SDs of the simulated rates from both baseline strategies against the US Census population estimates^{9,31} to determine the mean

number of events, including the associated 95% CIs, expected to occur each year according to both strategies.

NIS, NEDS, and NVSS data were available for 2012 and 2013, so observed event rates and totals were calculated for those years. To estimate the number of events prevented during the first 2 years of the initiative, we subtracted the mean number of expected events obtained from the simulations from the number of actual events observed each year. These differences were then assessed annually and in combination for both years to see whether they were statistically significantly different than 0 (z -score $\geq |1.96|$). Events prevented estimates, including the use of revised population estimates, will be updated by Million Hearts as data become available for 2014 to 2016.

Results

Event Rates Preceding the Initiative

Prior to the beginning of the initiative, the age-standardized event rate (per 100 000) among all adults decreased 9.8% from 1296.8 (95% CI, 1265.9, 1327.8) in 2006 to 1170.3 (95% CI, 1144.7, 1195.9) in 2011 (Table 1), with similar relative percent decreases in the age-standardized event rates observed among men (9.8%) and women (9.9%; Figure 2). Every age group among both sexes experienced statistically significant declines in event rates during 2006 to 2011 ($P < 0.05$), except for men aged 45 to 64 years (Table 2). The annual event rate decreased at a statistically significant greater pace among women aged 65 to 74 years compared with women aged 18 to 44 years ($P = 0.002$); it decreased at a statistically significant slower pace among men aged 45 to 64 years compared with men aged 18 to 44 years ($P = 0.033$).

Event Rates by Age and Sex

Event rates increased considerably with age (Figure 2). Relative rate differences by sex were most striking among the younger age groups. For example, in 2013, the event rate among men aged 45 to 64 years was 64.7% higher than the rate among like-aged women. However, in the oldest age group (aged ≥ 75 years), the rate among men was only 5.9% higher than the rate among women. Women aged ≥ 75 years were the largest contributors to the event totals across the 8 sex/age groups in 2013, accounting for 26.5% of the events (Table S2).

Event Rates by Type and Condition

Of the 2 829 161 (95% CI, 2 779 159, 2 879 163) events that occurred in 2013, 74.2% were hospitalizations (2 099 874 [95% CI, 2 053 475, 2 146 273]; Figure 1;

Table S3); mortality contributed 13.6% of the events (386 073 [95% CI, 384 856, 387 290]) and ED encounters 12.1% of events (343 214 [95% CI, 324 621, 361 807]). The “other CVD conditions” category had the largest contribution to the overall event totals (47.9% of events; $N = 1\,274\,648$ [95% CI, 1 263 527, 1 285 769]), with the largest contributor being heart failure–related hospitalizations ($N = 831\,645$ [95% CI, 822 075, 841 215]). AMI- and stroke-related hospitalizations accounted for 45.8% ($N = 961\,925$ [95% CI, 952 127, 971 723]) of the hospitalization events, had the largest contribution (63.6%) to the death event totals ($N = 245\,456$ [95% CI, 244 485, 246 427]), and contributed 42.7% ($N = 1\,207\,381$ [95% CI, 1 197 535, 1 217 227]) to the overall event count in 2013. Comparing the overall age-standardized event rates in 2006 to 2013, by event category, the greatest relative overall reduction in rates occurred for the symptomatic precursor conditions (24.1% relative reduction); the smallest overall reduction occurred for stroke (0.3% relative reduction; Table 1). Moreover, despite considerable improvement in AMI event rates from 2006 to 2010, there was minimal improvement thereafter. Similarly, there was a slight increase in heart failure event rates in 2013 after experiencing declines during 2006 to 2012, which was driven by increases in the overall age-standardized heart failure ED and mortality rates (increased from 63.8 and 29.5 per 100 000, in 2012, to 69.4 and 31.1 per 100 000, in 2013, respectively) and minimal change in the hospitalization rate (334.8 per 100 000, in 2012, compared with 333.7 per 100 000, in 2013; data not shown).

Expected Event Rates and Events Prevented Estimates Using Both Baseline Strategies

The age-standardized modeled 2011 event rate (per 100 000) for all adults aged ≥ 18 years was 1165.4 (95% CI, 1153.1, 1177.7), with the sex- and age-specific event rates, which serve as the stable baselines, ranging from 106.3 (95% CI, 104.1, 108.5) among women aged 18 to 44 years to 7031.0 (95% CI, 6823.6, 7238.4) among men aged ≥ 75 years (Table 2). Using the trend baseline strategy and the simulation methodology, the overall age-standardized event rate (per 100 000) is projected to be 1063.1 (95% CI, 1040.2, 1086.0) by 2016, with sex- and age-specific rates ranging from 98.8 (95% CI, 94.7, 102.9) among women aged 18 to 44 years to 6439.8 (95% CI, 6068.8, 6810.8) among men aged ≥ 75 years. Overall, we estimate that 13.99 (trend baselines) to 14.81 (stable baselines) million events will occur during 2012–2016 without additional action, equating to an $\approx 820\,000$ event difference between the 2 baseline strategies over the 5 years.

Using the stable baseline strategy and comparing the expected versus observed sex- and age-specific data, an

Table 1. Age-Standardized Rates* by Event Category and Event Type, 2006–2013

Event Category or Type	Age-Standardized Rate Per 100 000 (95% CI)									
	2006	2007	2008	2009	2010	2011	2012	2013		
Total	1296.8 (1265.9, 1327.8)	1228.6 (1200.4, 1256.8)	1239.5 (1210.1, 1268.9)	1220.9 (1191.5, 1250.2)	1174.5 (1146.7, 1202.3)	1170.3 (1144.7, 1195.9)	1147.6 (1134.6, 1160.6)	1137.6 (1125.0, 1150.2)		
AMI	264.8 (276.7, 292.8)	260.2 (253.3, 267.1)	269.0 (262.0, 275.9)	261.9 (254.8, 269.1)	244.6 (237.9, 251.4)	244.4 (238.3, 250.5)	249.3 (245.8, 252.8)	243.9 (240.6, 247.1)		
Stroke	242.1 (238.2, 246.1)	235.4 (231.7, 239.1)	243.2 (239.2, 247.3)	234.6 (230.6, 238.6)	241.3 (237.2, 245.4)	243.7 (239.5, 247.9)	241.4 (239.1, 243.7)	241.4 (239.1, 243.7)		
Acute ischemic cerebral infarction	157.0 (153.3, 160.7)	153.3 (149.8, 156.8)	161.8 (157.9, 165.7)	156.8 (152.9, 160.6)	161.5 (157.6, 165.4)	167.7 (163.7, 171.6)	166.9 (164.7, 169.0)	167.5 (165.4, 169.6)		
Acute hemorrhagic stroke	36.5 (35.3, 37.7)	34.5 (33.3, 35.6)	35.1 (33.9, 36.2)	34.2 (33.0, 35.3)	36.7 (35.4, 37.9)	33.7 (32.3, 35.0)	33.2 (32.5, 33.9)	33.2 (32.5, 33.9)		
Acute, but ill-defined, cerebrovascular disease	1.0 (0.9, 1.2)	0.8 (0.7, 0.9)	0.7 (0.6, 0.8)	0.5 (0.4, 0.7)	0.4 (0.3, 0.4)	0.3 (0.3, 0.4)	0.2 (0.2, 0.3)	0.2 (0.1, 0.2)		
Other cerebrovascular disease deaths	47.6 (47.3, 47.9)	46.9 (46.6, 47.2)	45.7 (45.4, 45.9)	43.1 (42.9, 43.4)	42.8 (42.5, 43.0)	42.0 (41.8, 42.3)	41.1 (40.9, 41.4)	40.5 (40.3, 40.8)		
Symptomatic precursor conditions	184.0 (180.9, 187.0)	171.4 (168.7, 174.1)	169.5 (166.6, 172.4)	161.0 (158.1, 164.0)	151.2 (148.6, 153.8)	150.4 (147.9, 152.9)	146.5 (144.6, 148.4)	139.7 (137.8, 141.6)		
Other acute and subacute ischemic heart disease	33.3 (32.1, 34.4)	29.1 (28.1, 30.1)	25.4 (24.6, 26.3)	24.1 (23.2, 24.9)	21.1 (20.3, 21.9)	20.3 (19.5, 21.2)	19.9 (19.3, 20.4)	19.7 (19.1, 20.3)		
Stable angina pectoris	24.6 (23.8, 25.3)	22.7 (22.0, 23.4)	21.1 (20.3, 21.8)	19.0 (18.4, 19.6)	17.8 (17.2, 18.4)	16.7 (16.1, 17.3)	16.2 (15.6, 16.7)	15.4 (14.9, 16.0)		
Transient ischemic attack	126.1 (123.3, 128.8)	119.6 (117.3, 122.0)	123.0 (120.3, 125.7)	117.9 (115.2, 120.7)	112.2 (109.8, 114.6)	113.4 (111.1, 115.7)	110.5 (108.8, 112.2)	104.5 (102.8, 106.3)		
Other CVD conditions	586.0 (575.5, 596.4)	561.6 (551.9, 571.4)	557.8 (548.1, 567.5)	563.3 (553.4, 573.1)	537.4 (527.9, 546.8)	531.8 (523.3, 540.3)	510.4 (505.9, 515.0)	512.6 (508.1, 517.1)		
Heart failure	512.8 (502.5, 523.1)	480.8 (471.2, 490.3)	477.0 (467.5, 486.5)	479.4 (469.7, 489.0)	453.4 (444.1, 462.6)	449.0 (440.7, 457.3)	428.1 (423.6, 432.5)	434.4 (430.0, 438.8)		
Abdominal aortic aneurysms	1.9 (1.7, 2.0)	1.7 (1.6, 1.9)	2.0 (1.8, 2.1)	1.7 (1.5, 1.8)	1.7 (1.5, 1.8)	1.5 (1.4, 1.7)	1.5 (1.4, 1.6)	1.5 (1.4, 1.6)		
Atheroembolism	0.5 (0.4, 0.5)	0.4 (0.3, 0.4)	0.4 (0.3, 0.4)	0.4 (0.3, 0.4)	0.4 (0.3, 0.4)	0.3 (0.3, 0.4)	0.4 (0.3, 0.4)	0.3 (0.3, 0.3)		

Continued

Table 1. Continued

Event Category or Type	Age-Standardized Rate Per 100 000 (95% CI)									
	2006	2007	2008	2009	2010	2011	2012	2013		
Atherosclerosis and peripheral artery disease	7.0 (6.9, 7.1)	6.6 (6.5, 6.7)	6.3 (6.2, 6.4)	6.0 (5.9, 6.1)	5.9 (5.8, 6.0)	5.6 (5.5, 5.7)	5.6 (5.5, 5.7)	5.5 (5.4, 5.6)		
Hypertension without heart failure	63.4 (61.5, 65.3)	71.6 (69.7, 73.6)	71.7 (69.7, 73.8)	75.5 (73.3, 77.6)	75.7 (73.8, 77.5)	75.0 (73.3, 76.8)	74.7 (73.7, 75.6)	70.7 (69.8, 71.6)		
Cardiac arrest	0.5 (0.4, 0.6)	0.5 (0.5, 0.6)	0.5 (0.4, 0.5)	0.4 (0.4, 0.5)	0.4 (0.4, 0.5)	0.3 (0.2, 0.3)	0.3 (0.2, 0.3)	0.3 (0.3, 0.4)		

*Standardized by age to the 2010 US Census Population distribution among adults aged ≥18 years. AMI indicates acute myocardial infarction; CVD, cardiovascular disease.

estimated 44 012 (95% CI, 5723, 82 301) and 71 198 (95% CI, 32 622, 109 774) fewer events occurred than were expected in 2012 and 2013, respectively, for a total of 115 210 (95% CI, 60 858, 169 562) events prevented during the first 2 years of the initiative (statistically significantly different than 0; $P<0.001$; (Figure 3; Table S2). In comparison, if the past trends experienced during 2006–2011 were continued and used as the baseline, 8380 (95% CI, –30 833, 47 593) and 35 554 (95% CI, –7450, 78 558) more events occurred than were expected in 2012 and 2013, respectively, for a total excess in events of 43 934 (95% CI, –14 264, 102 132; not statistically significantly different than 0; $P=0.139$). Women aged ≥75 years had the most events prevented using either baseline strategy during the combined years of 2012 and 2013; 76 242 (95% CI, 42 067, 110 417) using a stable baseline and 39 049 (95% CI, 1901, 76 197) using a baseline incorporating previous trends. During 2012–2013, men and women aged 45 to 64 years had 22 912 (95% CI, 855, 44 969) and 7975 (95% CI, –3281, 19 231; stable baseline) to 38 810 (95% CI, 15 567, 62 053) and 24 080 (95% CI, 12 604, 35 556; previous trend baseline) more events, respectively, than were expected.

Discussion

During the first 2 years of Million Hearts (2012–2013), improvement in event rates resulted in an estimated 115 000 events being prevented compared with what would have occurred had 2011 rates remained stable. However, there was no statistically significant change in the trajectory of the rates to demonstrate improvement beyond what would have happened had the trends observed during 2006–2011 continued. The choice to use 2 parallel baseline strategies—stable and trend baselines—to estimate the number of events prevented was made because the United States has to overcome several barriers, including an increasing prevalence of diabetes mellitus³³ and obesity³⁴ and an aging population,⁹ to continue making gains in event prevention. The effect these risk factors have on future event rates if they go unimpeded is uncertain; therefore, use of both strategies was considered a reasonable approach. We would consider attainment of the events prevented goal using either strategy a success. However, achieving the goal using the previous trends strategy would be ideal, given that an additional 820 000 events would be prevented if it was met using this strategy compared with only meeting it using the stable baseline strategy.

Although the events prevented during this period cannot be directly attributed to any single intervention or initiative, including Million Hearts, tracking these values is important because it demonstrates the collective progress the United States is making in reducing the burden of CVD and reveals

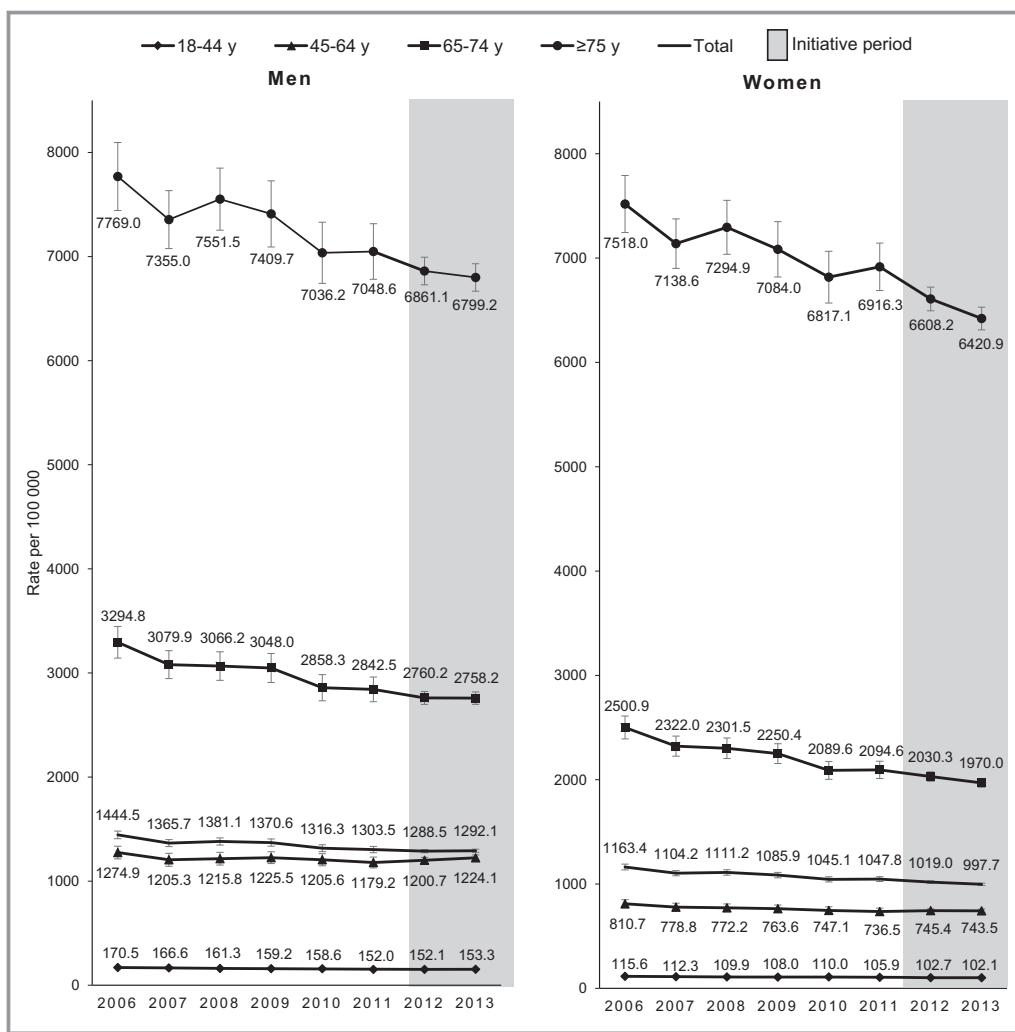


Figure 2. Million Hearts event rates before and during the Million Hearts initiative, by sex and age group, 2006–2013. Total rates were standardized by age to the 2010 US population. Bars denote 95% confidence intervals for the rates.

event trends for specific conditions and among various populations. For example, during 2012–2013, stroke rates remained stable as they had since 2006. AMI rates, which decreased considerably up to 2010, demonstrated no improvement from 2010 to 2013, and heart failure rates, which decreased considerably up to 2012, increased slightly in 2013. The majority of the improvement in overall event rates that did occur during 2012–2013 happened among those aged ≥ 65 years, especially among women aged ≥ 75 years. Continued gradual improvement in event rates, in particular among this age group, was likely driven by increased use of cholesterol-lowering medications,³⁵ including 3-hydroxy-3-methyl-glutaryl-coenzyme A reductase inhibitors (ie, statins), and moderate increases in blood pressure control.³⁶ Continued improvement in CVD risk factors among this group will likely lead to the largest number of events prevented during the current initiative, given that they have

the most events to prevent. In contrast, little to no improvement in event rates occurred among adults aged 45 to 64 years, with rates actually increasing among men aged 45 to 64. Although smoking prevalence continued to decrease among this age group,³⁷ they remained at greater risk for being unaware or untreated for conditions like hypertension and hypercholesterolemia and less likely to be using aspirin for secondary CVD prevention compared with older adults.^{19,38,39} Moreover, this age cohort was born around 1960 and likely has been the generation most affected by the rise of the obesity epidemic.⁴⁰ During their lifetime, the prevalence of obesity has more than doubled among adults,⁴⁰ possibly placing them at increased risk for developing CVD resulting from overweight status and its associated risk factors compared with previous generations. Therefore, additional focus on preventing or delaying the development of CVD risk factors,⁴¹ identifying and treating the ABCS,

Table 2. Changes in Sex- and Age-Specific Event Rates During 2006–2011 and Expected Rates Using Both Baseline Strategies

Sex	Age Group (y)	APC During 2006–2011 (95% CI)	Stable Baseline Rate for 2012–2016* (95% CI)	Trend Baseline Rates, Per 100 000, for 2012–2016 (95% CI) [†]					
				Rate Per 100 000 (95% CI)	2012	2013	2014	2015	2016
Men	18 to 44	-2.1 (-2.7, -1.5)	152.9 (150.9, 154.9)	149.7 (147.5, 151.9)	146.5 (144.1, 148.9)	143.4 (140.7, 146.1)	140.3 (137.2, 143.4)	137.3 (133.6, 141.0)	
	45 to 64	-1.1 [‡] (-2.2, 0.0)	1184.1 (1156.5, 1211.7)	1171.0 (1143.4, 1198.6)	1158.0 (1126.4, 1189.6)	1145.2 (1108.0, 1182.4)	1132.5 (1088.4, 1176.6)	1119.9 (1068.4, 1171.4)	
	65 to 74	-2.7 (-3.9, -1.4)	2827.4 (2753.1, 2901.7)	2752.1 (2676.2, 2828.0)	2677.9 (2592.8, 2763.0)	2605.8 (2507.0, 2704.6)	2535.7 (2421.2, 2650.2)	2467.5 (2336.4, 2598.6)	
	≥75	-1.7 (-3.1, -0.4)	7031.0 (6823.6, 7238.4)	6909.2 (6694.4, 7124)	6788.5 (6547.6, 7029.4)	6670.0 (6391.1, 6948.9)	6553.8 (6230.4, 6877.2)	6439.8 (6068.8, 6810.8)	
Women	18 to 44	-1.4 (-2.4, -0.5)	106.3 (104.1, 108.5)	104.8 (102.6, 107.0)	103.2 (100.7, 105.7)	101.7 (98.8, 104.6)	100.3 (96.8, 103.8)	98.8 (94.7, 102.9)	
	45 to 64	-1.7 (-2.2, -1.2)	735.1 (727.5, 742.7)	722.4 (714.4, 730.4)	709.9 (700.9, 718.9)	697.6 (687.0, 708.2)	685.5 (673.0, 698.0)	673.6 (659.1, 688.1)	
	65 to 74	-3.4 [§] (-4.7, -2.0)	2069.8 (2010.6, 2129.0)	1999.9 (1939.1, 2060.7)	1931.4 (1862.8, 2000.0)	1865.2 (1785.4, 1945.0)	1801.3 (1709.0, 1893.6)	1739.7 (1634.6, 1844.8)	
Total	≥75	-1.6 (-2.8, -0.3)	6842.6 (6666.4, 7018.8)	6735.6 (6551.4, 6919.8)	6629.6 (6420.3, 6838.9)	6525.3 (6280.5, 6770.1)	6422.8 (6136.8, 6708.8)	6322.1 (5992.2, 6652.0)	
	1165.4 (1153.1, 1177.7)	1144.1 (1131.2, 1157.0)	1123.2 (1108.5, 1137.9)	1102.7 (1085.6, 1119.8)	1082.6 (1062.6, 1102.6)	1063.1 (1040.2, 1086.0)	

APC indicates annual percent change.

*Based on the log-linear models that were fitted to the 2006–2011 sex- and age-specific rates and simulated 1000 times; used for stable baselines that are held constant during 2012–2016.

[†]Determined by subtracting the product of the preceding year's simulated rate multiplied by the 2006–2011 APC; used for the previous trend baselines during 2012–2016.

[‡]APC significantly less compared with men aged 18 to 44 years ($P=0.033$).

[§]APC significantly greater compared with women aged 18 to 44 years ($P=0.002$).

^{||}Rates are standardized by age to the 2010 US Census Population distribution among adults aged ≥18 years.

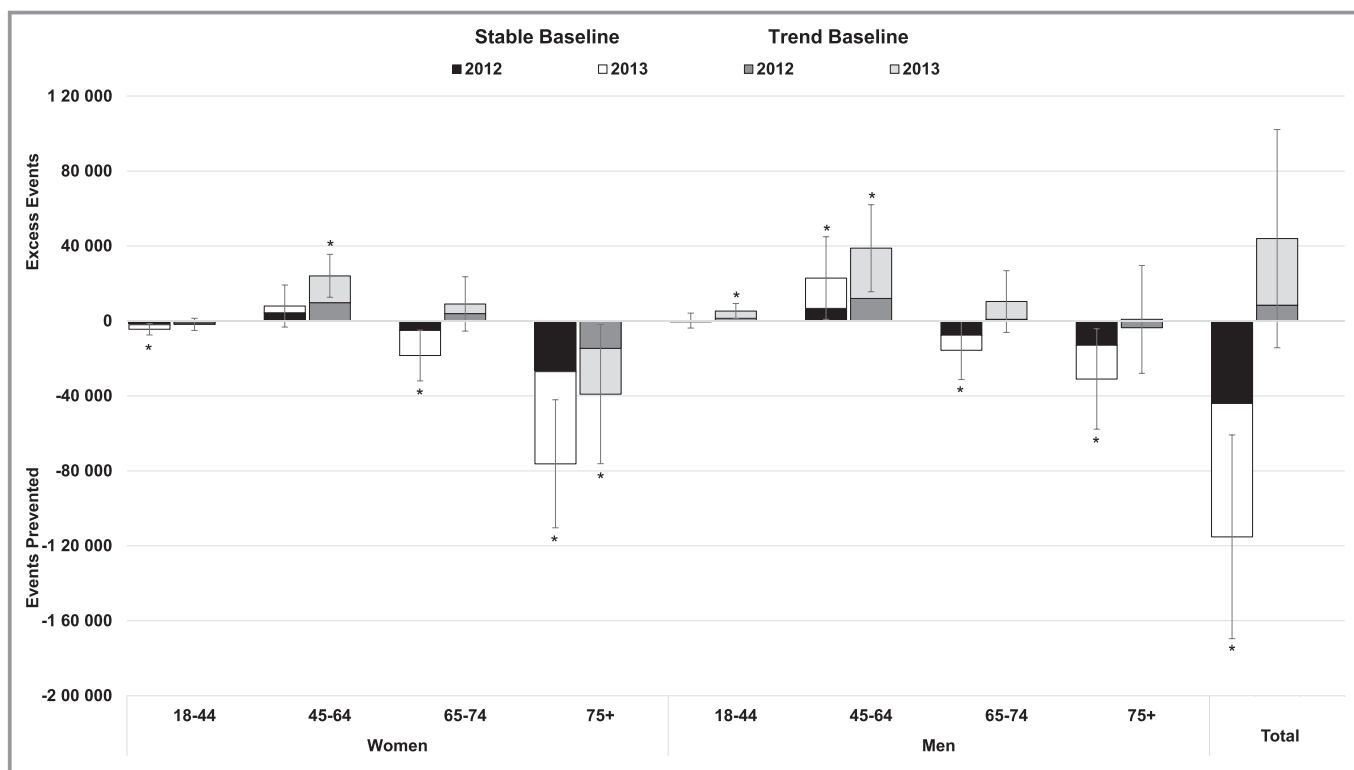


Figure 3. Estimated number of mutually exclusive Million Hearts events prevented in 2012 and 2013, by baseline strategy, sex, and age group. Determined by combining the observed event totals from the 2012 and 2013 and subtracting the expected number of events calculated by multiplying the 2011 modeled sex- and age-specific rates (stable baselines) or by applying the annual percent change to the modeled 2011 rate for each sex- and age-specific group to generate expected 2012 and 2013 rates (trend baselines) and multiplying those rates by the US Census mid-year population estimates for 2012 and 2013, respectively. During 2012–2013, 115 210 (95% CI, 60 858, 169 562) events were prevented using the stable baseline; an excess of 43 934 (95% CI, –14 264, 102 132) events occurred using the trend baseline. Bars denote the 95% confidence intervals. Values denoted with an asterisk (“*”) are statistically significantly different than 0 (z-score $\geq |1.96|$). Table S2 includes the sex- and age-specific values for each year and for 2012 and 2013 combined.

implementing effective weight management interventions, and calculating and managing lifetime CVD risk,⁴² instead of just acute risk, is likely required to decrease event rates among this age group now and better position the United States for improved CVD outcomes in future decades.

There are potential limitations to this study. One potential limitation is that the event definition is based on mutually exclusive events, not the number of unique persons affected. Although this methodology tries to achieve mutual exclusivity among event totals, there is potential for survivor bias and over- or undercounting events. Moreover, changes in health-care utilization practices (eg, use of urgent care services instead of ED services) might affect rates rather than changes in disease burden. However, we have attempted to account for this in several ways. First, we excluded all hospitalizations characterized as elective, because how these cases are managed (eg, within acute care hospitals or in outpatient surgical centers) might change over time. Second, by including ED event data, we address potential changes in practice patterns where cases that were previously hospitalized are now managed in the ED setting, including through

observation. Finally, the definition relies on use of administrative data; thus, reductions in the number of “silent” events, which account for upward of 20% of all AMIs and strokes^{1,43,44} and are likely affected by the focused attention on the leading risk factors, are not captured in monitoring systems and cannot be accounted for. Despite these limitations, the current definition uses the best available data sources to understand the number of unique Million Hearts–related fatal and nonfatal events prevented at a national level and across all adult age groups and health insurance coverage types, including people without health insurance. The use of this novel methodology helps address the need for improved comprehensive national cardiovascular event surveillance.²³

The NIS was selected to describe the hospitalization burden because it is a robust data set that can be weighted to produce national estimates. While the NIS was redesigned in 2012, use of the Agency for Healthcare Research and Quality’s trend weights alleviates differences attributed to sampling rather than changes in utilization during the observation period and the new design is expected to provide more-precise results.²⁶ The benefits of using the NEDS for ED

surveillance has been described previously.⁴⁵ Although the NEDS does not contain all of the same hospitals as the NIS sample, it is structured similarly; therefore, it better lends itself to the application of the exclusion criteria used to determine mutually exclusive events compared with data sets that are structured differently from the NIS. The biggest potential limitations with use of the NEDS are that the ability to assess trends is somewhat limited because it only provides data since 2006, and, depending on the year, the weighted national estimates are based on discharge data from only 24 to 31 states. However, NEDS allows considerable flexibility in analyses because of its large sample size.

The NVSS was selected to describe the death burden because it is the national standard for describing national death rates and has been used for tracking purposes in scientific publications¹ and by various national and international projects, including the Healthy People initiative. A potential limitation of using the NVSS, as well as the Healthcare Cost and Utilization Project databases, is that they are nonvalidated administrative databases. Use of administrative claims data for surveillance can be affected by reporting or coding changes and has been found to sometimes overestimate cardiovascular event rates, especially deaths.⁴⁶ However, the analysis of these data to assess cardiovascular event rate trends are recommended for national surveillance and, when combined across communities, appears valid given that the overestimation likely will not vary greatly at the macro level and over this short period.^{46–48}

Because of the current lag time in data release for each of the data assets used for event surveillance, methodologies and strategies are being explored to forecast and/or calculate more-timely preliminary estimates. In addition, the United States switched from the International Classification of Diseases, Ninth Revision, Clinical Modification–based claims system to the International Classification of Diseases, Tenth Revision, Clinical Modification–based system in October 2015. Crosswalks from the old to the new coding systems have been developed (Table S4); assessment of the effects of applying these new definitions on event totals is underway.

The United States will experience an $\approx 6.8\%$ reduction in the total number of events that would have occurred during 2012–2016 by meeting the 1 million events prevented goal using the stable baseline strategy. Whereas only 12% of this goal was achieved in the first 2 years of the initiative through the prevention of an estimated 115 000 events, we expect that the implementation, and therefore the effects, of Million Hearts' focused strategies on overall event totals will increase over time. However, the recent flattening observed in the overall event rate trend is concerning and supports intensifying national action in implementing community-focused policy and systems changes and evidence-based clinical

treatment strategies to meet the aggressive, but achievable, targets of Million Hearts.¹⁹ In particular, the increase in event rates observed among those aged 45 to 64 years should serve as a warning that we need to better address the cardiovascular health of this cohort or a reversal in event rate trends may occur. Use of the novel methodology described in this study will allow for Million Hearts and its partners to understand the progress they are making toward their goal of preventing 1 million AMIs, strokes, and other related cardiovascular events through 2016 and beyond.

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Disclosures

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SUPPLEMENTAL MATERIAL

Data S1.

SUPPLEMENTAL METHODS

Decision Points When Developing the Million Hearts Event Definition

Multiple decision points were discussed during the development of the Million Hearts events case definition. Inclusion of each *International Classification of Disease, Ninth Revision, Clinical Modification* (ICD-9-CM) or *International Classification of Diseases, Tenth Revision* (ICD-10) component was driven by: 1) administrative codes that can be adequately used to describe the condition of interest; 2) codes that typically signal events that are acute in nature; 3) events that are most likely not elective hospital encounters; 4) alignment with current HHS agencies' definitions; and, 5) events that could be expected to be prevented by current or planned Million Hearts efforts. Many of the other decision points are discussed here:

1) Should the “symptomatic precursor conditions” be included in the Million Hearts events definition and at what level should they be tracked? Yes, stable angina, other acute ischemic heart disease (e.g., unstable angina), transient ischemic attacks, and hypertension should be included in the definition, because they are conditions that: can cause overt symptoms that would potentially lead patients to seek emergency care; are typically non-fatal, especially when treated early; and are usually highly preventable.^{1,2} The first three event types remain in the definition across all settings, because they are acute cardiovascular conditions that are often managed in emergency departments (EDs) and during hospitalizations and are highly preventable by Million Hearts activities. Deaths attributable to these conditions are rare, but they were still included in the definition. Hypertension is discussed further below.

2) Should hypertension be included and at what level? Overall, Million Hearts activities should positively affect hypertension-related ED, hospitalization, and death events via its blood pressure control activities. However, hypertension-related ED encounters were excluded from the definition because ED services can often be used for hypertension management and not necessarily to treat acute events. With improvements in health insurance coverage through the enactment of the Patient Protection and Affordable Care Act, greater access to primary care services may alter how hypertension is being

managed (e.g., clinic-based versus ED-based) for certain groups and changes in event rates may be more indicative of changes in patient access rather than burden.³⁻⁵ Hypertension-related hospitalizations and deaths are included in the definition, because current Million Hearts efforts to improve blood pressure control should prevent these acute events from occurring.⁶

3) Should heart failure be included in the definition? Or, should only acute heart failure be included? Heart failure events can be prevented by Million Hearts activities. Specifically, improvements in medication adherence⁷⁻⁹, a decreased incidence of heart attacks¹⁰, and improved hypertension control¹⁰ should prevent heart failure-related ED encounters, hospitalizations, and deaths. Originally, we attempted to only include acute heart failure events in the case definition. However, despite the availability of specific codes to identify acute heart failure ED and hospitalization events (ICD-9-CM: 428.21, 428.23, 428.31, 428.33, 428.41, and 428.43) it was found that changes in coding practices during the observation period demonstrated that these codes might not accurately describe the acuity of the event (data not shown). Therefore, all heart failure event codes (ICD-9-CM: 428.XX) were included in definition.

4) Should acute myocardial infarctions, strokes, and other highly acute ED events be included? A considerable number of higher acuity events (e.g., AMIs and strokes) occurred in the ED. While the vast majority of patients experiencing these events were later hospitalized or died in the ED or hospital and, therefore, were theoretically captured in one of the other two surveillance systems, multiple cases were treated and then released from the hospital. Because of the acuity of these event types, it is expected all patients should have been admitted, transferred, or died. Therefore, we excluded all of the higher acuity ED cases, because they should be captured in the other data sets; those who were not likely had advance directives, were coded incorrectly, or left against medical advice.

5) Should all stroke deaths be included? We included hospitalization and mortality codes that were acute and directly related to ischemic or hemorrhagic strokes, because it was determined that Million Hearts activities can directly impact those conditions. While there is a link between Million Hearts activities (e.g., improving blood pressure control) and decreasing the burden of other types of strokes (e.g., non-traumatic subarachnoid hemorrhages¹¹), those effects are more distal and may not greatly impact

hospitalizations; therefore, strokes other than ischemic or hemorrhagic strokes were only included in the mortality definition.

Calculation of Standard Errors for the Mortality Data and Combination of Estimates Across Datasets

Mortality data represent complete counts of all deaths, therefore, they are not subject to sampling error. However, these data are subject to non-sampling error resulting from potential errors in the death reporting process, therefore, we calculated and report the estimates and standard errors for the mortality counts per the methodology used by the National Center for Health Statistics.¹² The mortality estimates and standard errors were then combined with the weighted estimates and standard deviations derived from the Nationwide Emergency Department Sample and Nationwide/National Inpatient Sample analyses (using the SAS PROC SURVEYFREQ procedure) for the ED visits and hospitalizations, respectively, to report the combined overall event counts and standard deviations. The choice to use the mortality estimates' standard errors for combination, instead of converting the standard errors to standard deviations, was made for two reasons: 1) mortality estimates are not subject to sampling error, therefore, it was determined inappropriate to attempt to calculate standard deviations; and 2) converting the standard errors to standard deviations using the equation: $\text{standard deviation} = \text{standard error} * \sqrt{\text{population } n}$ would greatly overestimate error in the mortality estimates.

Additional Information about Log-linear Model Development and Use to Establish Stable and Previous Trend Baselines and Interpret Progress

The sex- and age-specific rates from 2006–2011 were each fit with a log-linear regression model. The log-transformed beta obtained from each model was then applied within this equation $[\exp(\beta)-1]$ to describe the annual percent change (APC) in the rates. Because we only had access to 6 years of historical data there wasn't enough available data to appropriately assess for statistically significant breaks in the rate trend using Joinpoint methods or piecewise linear Poisson models. However, during our preliminary analyses we assessed the rates in Joinpoint,^{13,14} and no significant trend breaks were identified ($P > .05$).

Here is how we established the two baselines (stable and previous trends) for each sex- and age-specific group, using men aged 65–74 years as an example (Figure S2). To establish their stable baseline rate, we held their modeled 2011 rate (2827.4 per 100000; Table 2) constant during 2012–2016. To establish their previous trend baseline, we applied their APC (-2.7%; Table 2) to the modeled 2011 rate to get their estimated 2012 rate (2752.1 per 100000). This was then repeated for each year through 2016. Each baseline strategy was simulated 1000 times using the sex- and age-specific modeled 2011 rates and, for the previous trends baseline, the sex- and age-specific APCs with their associated standard errors. The means and associated standard deviations of these simulated rates, in combination with US Census population estimates, were then used to compare to the events observed during 2012 and 2013. Overall, we consider it a success if the observed rate for each/all of the sex- and age-specific groups falls within one of the two green sections (Figure S2). Ideally, it would fall in the darkest green section meaning the event rate decrease was accelerated above and beyond what had occurred previously. However, in this example, the observed rates falls in the light green section, meaning that events were prevented compared with what would have occurred had the 2011 rates remained stable.

Table S1. Million Hearts case definition codes by event category and type

Event Category or Type	Emergency Department	Acute Care Hospitalization	Underlying Cause
	Primary ICD-9-CM	Primary ICD-9-CM	of Death ICD-10
	Codes*	Codes*	Codes*
Acute myocardial infarction	—	410.X0, 410.X1	I21
Stroke			
Acute ischemic cerebral infarction	—	433.X1, 434.X1	I63
Acute hemorrhagic stroke	—	430, 431	I60, I61
Acute, but ill-defined, cerebrovascular disease	—	436	— †
Other cerebrovascular disease deaths	—	—	I62, I64, I67, I69
Symptomatic precursor conditions			
Other acute and subacute ischemic heart disease	411	411	I20.0‡, I24
Stable angina pectoris	413	413	I20.1, I20.8, I20.9
Transient ischemic attack	435	435	G45.0, G45.1, G45.2, G45.8, G45.9
Other cardiovascular disease conditions			
Heart failure	[402.X1, 404.X1]§, 428	[402.X1, 404.X1]§, 428	[I11.0, I13.0] , I50
Abdominal aortic aneurysms	—	441.02, 441.3#	I71.3, I71.4**
Atheroembolism	—	445	— ††

Atherosclerosis and peripheral artery disease	—	—	[I70, I73.9 ^{††}] ^{§§}
Hypertension without heart failure	—	[401, 402.X0, 403.X0, 404.X0] [§]	[I10, I11.9, I12.9, I13.9]
Cardiac arrest	—	427.5	I46

Abbreviations: ICD-9-CM, International Classification of Diseases, 9th Revision, Clinical Modification codes; ICD-10, International Classification of Diseases, 10th Revision

* Excludes all cases involving women with any pregnancy-related ICD-9-CM codes (630–677, V22, V23, or V28) or contributing cause of death ICD-10 codes (O00–O99).

† ICD-9-CM code 436 does not accurately map to an ICD-10 death code (closest code: I64, which is included as “Other cerebrovascular disease deaths”).

‡ “Unstable angina” (i.e. intermediate coronary syndrome, ICD-9-CM 411.1) does not map to an I24 ICD-10 code, but to I20.0.

§ Excludes people with a chronic kidney disease, stage 5, or end-stage renal disease ICD-9-CM code of 585.5, 585.6, V42.0, V45.1, or V56.

|| Excludes people with a chronic kidney disease, stage 5 ICD-10 contributing cause of death code of N18.5.

Includes only acute abdominal aortic dissection and rupture (not asymptomatic or elective admissions for surgery).

** “Abdominal aortic aneurysm without mention of rupture” is included because—although not explicitly mentioned—deaths from abdominal aortic aneurysm almost always occur as the result of rupture.

†† ICD-10 mortality codes for embolism/thrombosis (I74) do not specify the cause of the embolism/thrombosis like ICD-9-CM codes do, therefore they were excluded.

‡‡ “Peripheral vascular disease, unspecified” is included (I73.9), because it best represents deaths attributable to “peripheral artery disease.”

§§ Only deaths attributable to atherosclerosis or peripheral artery disease were included because Million Hearts activities will directly impact mortality related to these types of cases, but not necessarily emergency department visits or hospitalizations.

||| Cardiac events were only included if they had a secondary diagnosis/contributing cause of death described using a Million Hearts ICD-9-CM diagnosis or ICD-10 death code.

Table S2. Number of expected, observed, and estimated prevented Million Hearts events, by baseline strategy, in 2012 (a), 2013 (b), and 2012–2013 combined (c), by sex and age group

a. Year: 2012

Sex and Age Group (y)	Expected Events: Stable Baseline	Expected Events: Trend Baseline	Observed Events	Events Prevented: Stable Baseline				Events Prevented: Trend Baseline			
	Number	Number	Number	Number	Lower 95% CI	Upper 95% CI	z-score	Number	Lower 95% CI	Upper 95% CI	z-score
Men, 18-44	88,048	86,190	87,563	-485	-3321	2351	0.34	1373	-1484	4230	-0.94
Men, 45-64	478,861	473,561	485,544	6683	-8960	22,326	-0.84	11,983	-3910	27,876	-1.48
Men, 65-74	317,035	308,599	309,505	-7530	-18,384	3324	1.36	906	-10,088	11,900	-0.16
Men, 75+	535,507	526,226	522,562	-12,945	-31,698	5808	1.35	-3664	-22,890	15,562	0.37
Women, 18-44	60,287	59,416	58,261	-2026	-4252	200	1.78	-1155	-3418	1108	1.00
Women, 45-64	312,351	306,978	316,737	4386	-3636	12,408	-1.07	9759	1686	17,832	-2.37
Women, 65-74	264,853	255,921	259,806	-5047	-14,556	4462	1.04	3885	-5788	13,558	-0.79
Women, 75+	789,325	776,984	762,277	-27,048	-51,215	-2881	2.19	-14,707	-39,659	10,245	1.16
Total	2,846,267	2,793,875	2,802,255	-44,012	-82,301	-5723	2.25	8380	-30,833	47,593	-0.42

b. Year: 2013

Sex and Age Group (y)	Expected Events: Stable Baseline	Expected Events: Trend Baseline	Observed Events	Events Prevented: Stable Baseline				Events Prevented: Trend Baseline			
	Number	Number	Number	Number	Lower 95% CI	Upper 95% CI	z-score	Number	Lower 95% CI	Upper 95% CI	z-score
Men, 18-44	88,622	84,902	88,827	205	-2,576	2986	-0.14	3925	1051	6799	-2.68
Men, 45-64	480,354	469,756	496,583	16,229	679	31,779	-2.05	26,827	9866	43,788	-3.10
Men, 65-74	333,444	315,821	325,284	-8160	-19,403	3083	1.42	9463	-2793	21,719	-1.51
Men, 75+	547,911	529,009	529,847	-18,064	-37,218	1090	1.85	838	-20,560	22,236	-0.08
Women, 18-44	60,601	58,857	58,192	-2409	-4555	-263	2.20	-665	-2960	1630	0.57
Women, 45-64	313,290	302,558	316,879	3589	-4307	11,485	-0.89	14,321	6164	22,478	-3.44
Women, 65-74	277,915	259,334	264,521	-13,394	-23,115	-3673	2.70	5187	-5589	15,963	-0.94
Women, 75+	798,222	773,370	749,028	-49,194	-73,357	-25,031	3.99	-24,342	-51,863	3179	1.73
Total	2,900,359	2,793,607	2,829,161	-71,198	-109,774	-32,622	3.62	35,554	-7450	78,558	-1.62

c. Years: 2012 and 2013 combined

Sex and Age Group (y)	Expected Events: Stable Baseline	Expected Events: Trend Baseline	Observed Events	Events Prevented: Stable Baseline				Events Prevented: Trend Baseline			
	Number	Number	Number	Number	Lower 95% CI	Upper 95% CI	z-score	Number	Lower 95% CI	Upper 95% CI	z-score
Men, 18-44	176,670	171,092	176,390	-280	-4252	3692	0.14	5298	1246	9350	-2.56
Men, 45-64	959,215	943,317	982,127	22,912	855	44,969	-2.04	38,810	15,567	62,053	-3.27
Men, 65-74	650,479	624,420	634,789	-15,690	-31,318	-62	1.97	10,369	-6095	26,833	-1.23
Men, 75+	1,083,418	1,055,235	1,052,409	-31,009	-57,815	-4203	2.27	-2826	-31,593	25,941	0.19
Women, 18-44	120,888	118,273	116,453	-4435	-7527	-1343	2.81	-1820	-5043	1403	1.11
Women, 45-64	625,641	609,536	633,616	7975	-3281	19,231	-1.39	24,080	12,604	35,556	-4.11
Women, 65-74	542,768	515,255	524,327	-18,441	-32,039	-4843	2.66	9072	-5409	23,553	-1.23
Women, 75+	1,587,547	1,550,354	1,511,305	-76,242	-110,417	-42,067	4.37	-39,049	-76,197	-1901	2.06
Total	5,746,626	5,587,482	5,631,416	-115,210	-169,562	-60,858	4.15	43,934	-14,264	102,132	-1.48

Abbreviation: CI, confidence interval

Table S3. Event counts and age-standardized rates* by event category and event type and data source, 2013

Event Category or Type	ED visits		Hospitalizations		Deaths		Total events	
	Events	Rate	Events	Rate	Events	Rate	Events	Rate
	n (95% CI)	(95% CI)	n (95% CI)	(95% CI)	n (95% CI)†	(95% CI)†	n (95% CI)	(95% CI)
Total	343214	138.1	2099874	844.1	386073	155.4	2829161	1137.6
	(324621, 361807)	(133.3, 142.9)	(2053475, 2146273)	(832.4, 855.8)	(384855, 387291)	(154.9, 155.8)	(2779160, 2879162)	(1125, 1150.2)
Acute myocardial infarction	—	—	489715	197.1	116749	46.8	606464	243.9
			(481666, 497764)	(193.8, 200.3)	(116079, 117419)	(46.6, 47.1)	(598388, 614540)	(240.6, 247.2)
Stroke	—	—	472210	189.6	128707	51.8	600917	241.3
			(466622, 477798)	(187.3, 191.8)	(128004, 129410)	(51.5, 52.0)	(595285, 606549)	(239.1, 243.6)
Acute ischemic cerebral infarction	—	—	410830	164.8	6694	2.7	417524	167.5
			(405527, 416133)	(162.6, 166.9)	(6534, 6854)	(2.6, 2.8)	(412219, 422829)	(165.3, 169.6)
Acute hemorrhagic stroke	—	—	60910	24.6	21285	8.6	82195	33.2
			(59151, 62669)	(23.9, 25.3)	(20999, 21571)	(8.5, 8.7)	(80413, 83977)	(32.5, 33.9)
Acute, but ill-defined, cerebrovascular disease	—	—	470	0.2	—	—	470	0.2
			(370, 570)	(0.1, 0.2)			(370, 570)	(0.1, 0.2)
Other cerebrovascular disease deaths	—	—	—	—	100728	40.5	100728	40.5
					(100106, 101350)	(40.2, 40.7)	(100106, 101350)	(40.2, 40.7)
Symptomatic precursor conditions	170571	68.7	172345	69.3	4216	1.7	347132	139.7
	(166586, 174555)	(67.1, 70.3)	(169815, 174875)	(68.3, 70.3)	(4089, 4343)	(1.6, 1.7)	(342410, 351854)	(137.8, 141.6)

Other acute and subacute ischemic heart disease	26062 (24694, 27430)	10.6 (10.0, 11.1)	18710 (17996, 19424)	7.6 (7.3, 7.9)	3954 (3831, 4077)	1.6 (1.5, 1.6)	48726 (47178, 50274)	19.7 (19.1, 20.3)
Stable angina pectoris	28073 (26847, 29299)	11.4 (10.9, 11.9)	9840 (9318, 10362)	4.0 (3.8, 4.2)	157 (132, 182)	0.1 (0.1, 0.1)	38070 (36737, 39403)	15.4 (14.9, 16.0)
Transient ischemic attack	116436 (112900, 119972)	46.8 (45.3, 48.2)	143795 (141424, 146166)	57.7 (56.8, 58.7)	105 (85, 125)	<0.1 (<0.1, 0.1)	260336 (256079, 264593)	104.5 (102.8, 106.2)
Other cardiovascular disease conditions	172642 (167469, 177815)	69.4 (67.3, 71.5)	965605 (955787, 975423)	388.1 (384.1, 392.1)	136401 (135677, 137125)	55.0 (54.7, 55.3)	1274648 (1263527, 1285769)	512.5 (508.0, 517.0)
Heart failure	172642 (167469, 177815)	69.4 (67.3, 71.5)	831645 (822075, 841215)	333.7 (329.8, 337.6)	77177 (76632, 77722)	31.1 (30.9, 31.3)	1081464 (1070572, 1092356)	434.2 (429.8, 438.6)
Abdominal aortic aneurysms	—	—	3665 (3391, 3939)	1.5 (1.4, 1.6)	—	—	3665 (3391, 3939)	1.5 (1.4, 1.6)
Atheroembolism	—	—	740 (620, 860)	0.3 (0.3, 0.3)	—	—	740 (620, 860)	0.3 (0.3, 0.3)
Atherosclerosis and peripheral artery disease	—	—	—	—	13631 (13402, 13860)	5.5 (5.4, 5.6)	13631 (13402, 13860)	5.5
Hypertension without heart failure	—	—	128775 (126609, 130941)	52.3 (51.4, 53.2)	45542 (45124, 45960)	18.4 (18.2, 18.6)	174317 (172111, 176523)	70.7 (69.8, 71.6)
Cardiac arrest	—	—	780 (658, 902)	0.3 (0.3, 0.4)	51 (37, 65)	<0.1 (<0.1, <0.1)	831 (708, 954)	0.3 (0.3, 0.4)

Abbreviations: ED, emergency department; CI, confidence interval

* Counts and rates represent mutually exclusive terminus events as outlined in Figure S1. Rates are standardized by age to the 2010 U.S.

Census Population distribution among adults aged ≥ 18 years.

† Mortality data represent complete counts of all deaths, therefore, they are not subject to sampling error. However, these data are subject to non-sampling error resulting from potential errors in the death reporting process, therefore, we calculated and report the estimates and standard errors for the mortality counts (See Data S1 for additional information).

Table S4. Post ICD-10-CM transition Million Hearts case definition codes by event category and type

Event Category or Type	Emergency Department	Acute Care Hospitalization	Underlying Cause of
	Primary ICD-10-CM	Primary ICD-10-CM	Death ICD-10
	Codes*	Codes*	Codes*
Acute myocardial infarction	—	I21	I21
Stroke			
Acute ischemic cerebral infarction	—	I63	I63
Acute hemorrhagic stroke	—	I60, I61	I60, I61
Acute, but ill-defined, cerebrovascular disease	—	I67.89 [†]	— [‡]
Other cerebrovascular disease deaths	—	—	I62, I64, I67, I69
Symptomatic precursor conditions			
Other acute and subacute ischemic heart disease	I20.0 [§] , I24	I20.0 [§] , I24	I20.0 [§] , I24
Stable angina pectoris	I20.1, I20.8, I20.9	I20.1, I20.8, I20.9	I20.1, I20.8, I20.9
Transient ischemic attack	G45.0, G45.1, G45.2, G45.8, G45.9, G46.0, G46.1, G46.2, I67.841, I67.848	G45.0, G45.1, G45.2, G45.8, G45.9, G46.0, G46.1, G46.2, I67.841, I67.848	G45.0, G45.1, G45.2, G45.8, G45.9
Other cardiovascular disease conditions			
Heart failure	[I11.0, I13.0] , I50	[I11.0, I13.0] , I50	[I11.0, I13.0] [#] , I50
Abdominal aortic aneurysms	—	I71.02, I71.3 ^{**}	I71.3, I71.4 ^{††}
Atheroembolism	—	I75	— ^{‡‡}

Atherosclerosis and peripheral artery disease	—	—	[170, 173.9 ^{§§,}]
Hypertension without heart failure	—	[110, 111.9, 112.9, 113.10]	[110, 111.9, 112.9, 113.9] [#]
Cardiac arrest	—	I46 ^{##}	I46 ^{##}

Abbreviations: ICD-10-CM, International Classification of Diseases, 9th Revision, Clinical Modification codes; ICD-10, International Classification of Diseases, 10th Revision

* Excludes all cases involving women with any pregnancy-related ICD-10-CM/PCS codes (O00–O9A , Z34, or Z36) or contributing cause of death codes (O00–O99).

† ICD-9-CM code 436 only partially maps to ICD-10-CM/PCS code I67.89. However, the Centers for Medicare and Medicaid Services plans on using I67.89 for tracking purposes relating to acute stroke patient management, so the code was included. ICD-9-CM code 436 is currently rarely used, as coders now use more appropriate specific cerebrovascular disease codes.

‡ ICD-9-CM code 436 does not accurately map to an ICD-10 mortality code (closest code: I64, which is included as “Other cerebrovascular disease deaths”).

§ “Unstable angina” (i.e. intermediate coronary syndrome, ICD-9-CM 411.1) does not map to an I24 ICD-10-CM/PCS code, but to I20.0.

|| Excludes people with any chronic kidney disease, stage 5, or end-stage renal disease ICD-10-CM/PCS code of N18.5, N18.6, Z49, Z94.0, Z99.2, or Z91.15.

Excludes people with any chronic kidney disease, stage 5, ICD-10 contributing cause of death code of N18.5.

** Includes only acute abdominal aortic dissection and rupture (not asymptomatic or elective admissions for surgery).

†† “Abdominal aortic aneurysm without mention of rupture” is included because—although not explicitly mentioned—deaths from abdominal aortic aneurysm almost always occurs as the result of rupture.

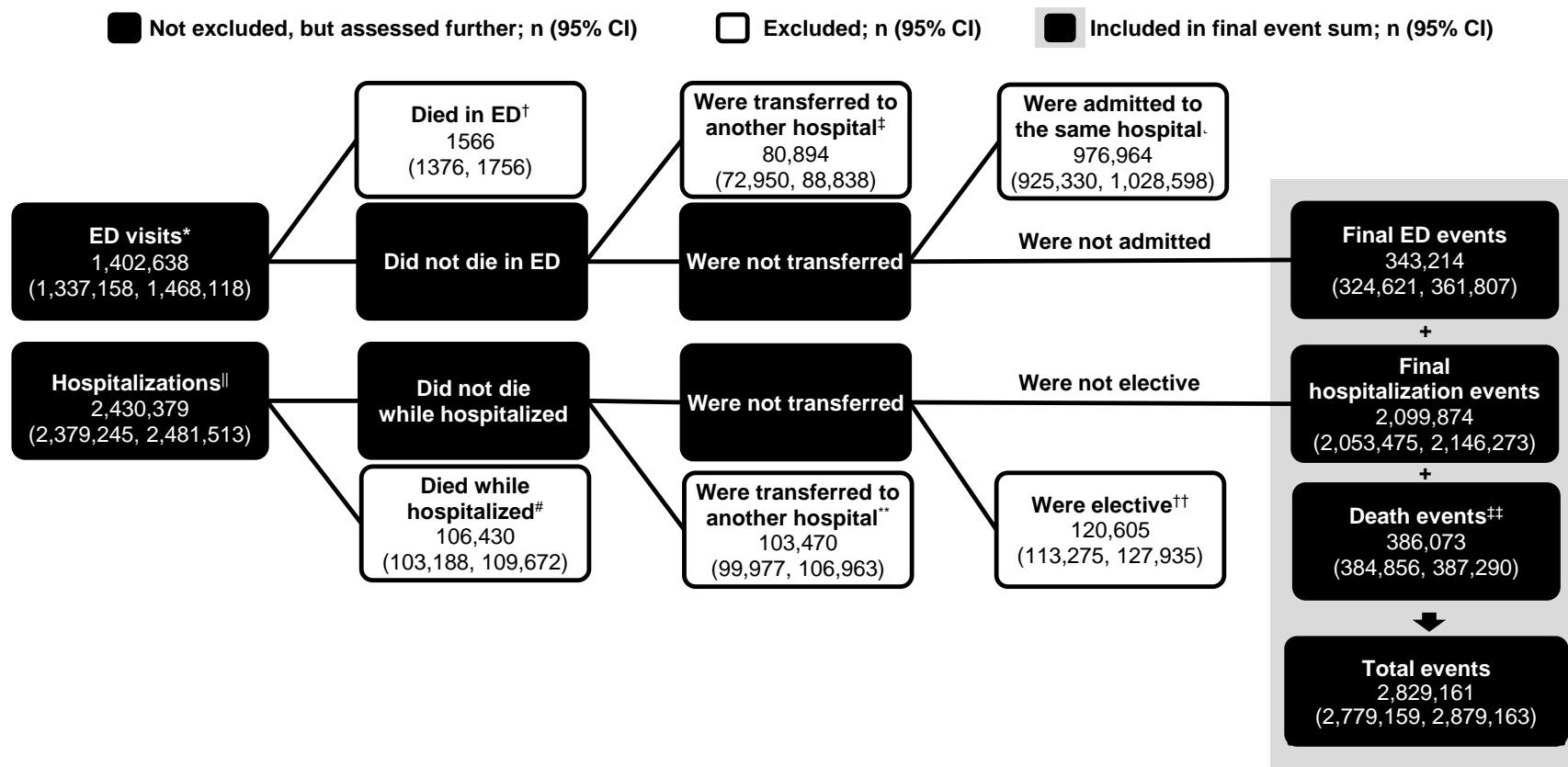
‡‡ ICD-10 mortality codes for embolism/thrombosis (I74) do not specify the cause of the embolism/thrombosis like ICD-10-CM/PCS codes do, therefore they were excluded.

§§ “Peripheral vascular disease, unspecified” is included, because it best represents deaths attributable to “peripheral artery disease.”

||| Only deaths attributable to atherosclerosis or peripheral artery disease were included because Million Hearts® activities will directly impact mortality related to these types of cases, but not necessarily ED visits or hospitalizations.

Cardiac events were only included if they had a secondary diagnosis/contributing cause of death described using a Million Hearts® ICD-10-CM/PCS or ICD-10 mortality code.

Figure S1. Detailed Million Hearts Mutually Exclusive Event Calculation Methodology Applied to the 2013 NEDS, NIS and NVSS Data



Abbreviations: NEDS, Nationwide Emergency Department Sample; NIS, National Inpatient Sample; NVSS, National Vital Statistics System; CI, confidence interval; ED, emergency department; ICD-9-CM, International Classification of Diseases, 9th Revision, Clinical Modification codes; ICD-10, International Classification of Diseases, 10th Revision

* Measured using the NEDS. Primary ICD-9-CM diagnosis code of: 411, 413, 428, 435, or (402.X1 or 404.X1, excluding 585.5, 585.6, V42.0, V45.1, or V56). Excludes all cases involving women with any pregnancy-related ICD-9-CM codes (630–677, V22, V23, or V28).

† NEDS variable “died_visit” = 1 (Died in ED).

‡ NEDS variable “disp_ed” = 2 (Transfer to short-term hospital).

§ NEDS variable “disp_ed” = 9 (Admitted as an inpatient to this hospital).

|| Measured using the NIS. Primary ICD-9-CM diagnosis code of: 410.X0, 410.X1, 411, 413, 428, 433.X1, 434.X1, 435, 436, 441.02, 441.3, 445, (401, 402, 403.X0, 404.X0, or 404.X1, excluding 585.5, 585.6, V42.0, V45.1, or V56), or (427.5 with another previously mentioned code listed as a secondary diagnosis). Excludes all cases involving women with any pregnancy-related ICD-9-CM codes (630–677, V22, V23, or V28).

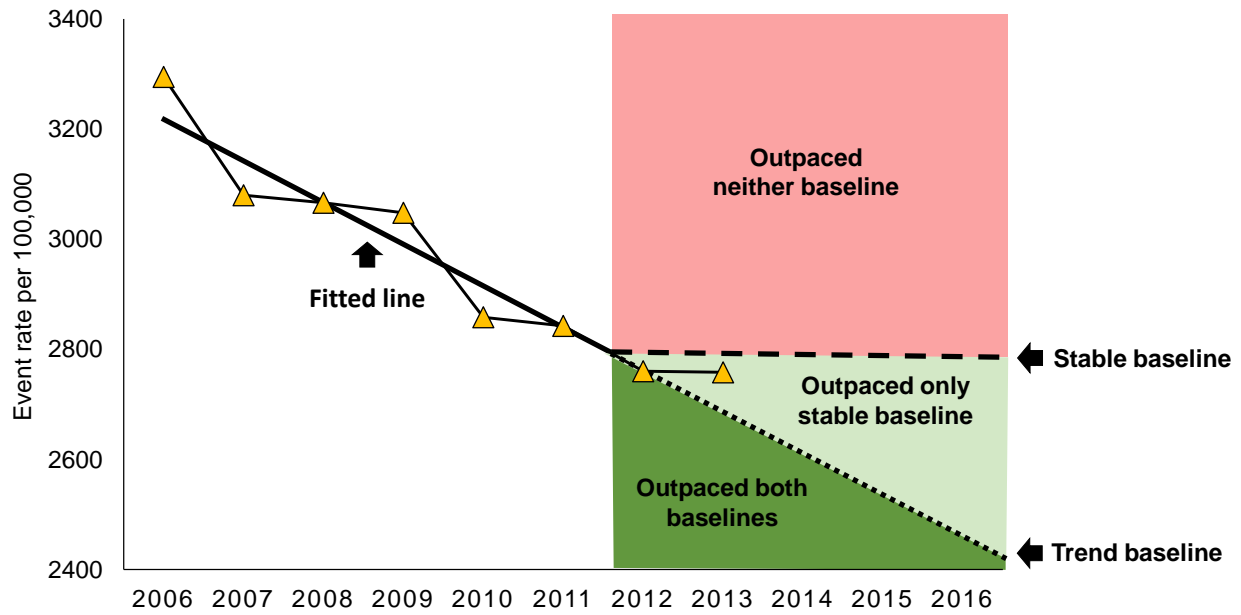
NIS variable “died” = 1 (Died)

** NIS variable “dispuniform” = 2, except when “dispub04” = 43 (Discharged/transferred to a Federal Health Care Facility); other “dispub04” categories included when “dispuniform” = 2 are: 2 (Discharged/transferred to a Short-Term Hospital for Inpatient Care), 5 (Discharged/transferred to a Designated Cancer Center or Children's Hospital), or 66 (Discharged/transferred to a Critical Access Hospital); Note: Effective prior to 10/1/07, “dispub04” 5 = Discharged/transferred to another type of institution not defined elsewhere

†† NIS variable “Elective” = 1 (Elective admission)

‡‡ Measured using National Vital Statistics death certificate data. Underlying cause of death ICD-10 code of: I20, I21, I24, I50, I60–I69, I71, I71.3, I73.9, I74, (G45, excluding G45.3 and G45.4), (I10, I11, I12.9, I13.0, and I13.9, excluding a contributing cause code of N18.5) or (I46 with another previously mentioned code listed as an contributing cause. Excludes all cases involving women with any contributing cause of death ICD-10 codes (O00–O99).

Figure S2. Example of how the stable and previous trend baselines were established for each sex and age group, men aged 65–74 years



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