Mortality from coronary heart disease (CHD) has declined steadily over the past several decades in the US and in many other countries.1–4 Although in the US the rates of CHD death have been falling for 30 years, CHD remains the single largest killer of men and women, accounting for 459,841 deaths in 1998.5 The decline in CHD mortality has been attributed to improvements in primary and secondary prevention and improved medical care,6–8 although the exact impact of each is debated.8–12

Trends in CHD mortality rates result from a combination of factors that affect the rates of incident events (first events), recurrent events, disease severity and case-fatality. Accurate measures of these components can aid our understanding of contemporary trends in CHD mortality and can lead to public health strategies that may further lower mortality from CHD.

Recently we reported that, in four US communities in the Atherosclerosis Risk in Communities (ARIC) Study, improved case-fatality played a far greater role in the decline in CHD mortality than did reductions in incidence or recurrent events. For this paper, we report trends in all-cause mortality, rates of first and recurrent hospitalized myocardial infarction, and survival after myocardial infarction in the ARIC Study from 1987 through 1996.
mortality between 1987 and 1994 than did falling incident hospitalized myocardial infarction rates.\textsuperscript{13} Conversely, a recent report from the WHO-MONICA project\textsuperscript{3} indicated that although trends vary by population, a decrease in disease attack rates is the major determinant of declines in CHD mortality, with improvements in case-fatality having a less important role. The objective of the current report is to update trends in mortality due to CHD, rates of first and recurrent hospitalized myocardial infarction, and survival in the ARIC Study through 1996.

Methods

A detailed description of the methods used in ARIC community surveillance has been previously reported\textsuperscript{13,14} and is only briefly outlined here. The ARIC study used retrospective surveillance to monitor admissions to acute care hospitals and deaths due to CHD (both in- and out-of-hospital) among all residents 35–74 years of age. The surveillance areas included over 360,000 men and women in four communities: Forsyth County, North Carolina; the city of Jackson, Mississippi; eight northern suburbs of Minneapolis, Minnesota; and Washington County, Maryland.

Deaths and hospital discharges were validated and classified using standardized criteria.\textsuperscript{14} Eligibility for hospital surveillance was based on age, residence, date of discharge, and diagnosis code (ICD-9-CM codes 402, 410–414, 427, 428, and 518.4), with sampling of codes unlikely to be confirmed as myocardial infarction. Sampling was based on the ICD-9-CM code and the date of discharge. Details of this approach and the sampling probabilities used have been previously reported.\textsuperscript{13} T

Trained personnel reviewed death certificates that met criteria based on age, residence, and underlying cause of death (ICD-9 codes 250, 401, 402, 410–414, 427–429, 440, 518.4, 798, and 799). Deaths with an underlying cause of death unlikely to be confirmed as CHD were sampled. Sampling was based on ICD-9 code and day of death. For out-of-hospital deaths, additional information was sought from the next of kin and other informants, the certifying and family physicians, and coroners or medical examiners. The Mortality and Morbidity Classification Committee reviewed all out-of-hospital deaths and assigned a final diagnosis; the committee chairman adjudicated disagreements. In-hospital deaths were classified after a review of hospital records and death certificate information. Death due to CHD was defined as definite fatal myocardial infarction or definite fatal CHD. This category included deaths for which no probable cause other than atherosclerosis was known in patients with a history of hospitalization for myocardial infarction within 28 days before death, as well as deaths for which there was evidence of chest pain within 72 hours before death or a history of chronic ischaemic heart disease such as coronary insufficiency or angina pectoris, and no known non-atherosclerotic cause. This category excludes deaths classified as possible fatal CHD and those events that are unclassifiable due to missing data. Possible fatal CHD was defined as those without sufficient evidence to be diagnosed as definite, no known non-atherosclerotic or non-cardiac atherosclerotic process, and an underlying cause of death of 410–414, 427.4, 429.2, or 799. The unclassifiable category accounted for 5% of all eligible deaths investigated. Due to state law we were unable to use the same method to validate cause of death for out-of-hospital deaths in Washington County, Maryland and therefore these deaths are not included in the rates of mortality due to CHD.

A hospitalized incident (first) myocardial infarction was defined as one in a patient for whom the medical record either stated that there was no history of myocardial infarction or did not contain any reference to a history of myocardial infarction. The numerator for the attack rate for hospitalized myocardial infarction included first or recurrent events.

Two definitions of case-fatality were used. First, case-fatality from myocardial infarction was defined as the per cent of hospitalized definite or probable myocardial infarction dying of any cause within 28 days of the event. Second, an estimate of the overall case fatality rate from CHD combines information on mortality at 28 days among patients hospitalized for myocardial infarction with information on deaths attributed to CHD that did not occur in conjunction with an event for which the patient was hospitalized.

Because hospital discharges and deaths were sampled, all analyses were weighted to reflect the sampling probabilities.\textsuperscript{14} Rates specific for sex and race were computed on the basis of dynamic population estimates derived by interpolation from US Census data. Poisson regression using the log of the weighted rates modelled as a linear function of year and age was used to determine the age-adjusted average annual per cent change in rates.\textsuperscript{13,14} Variances for the estimators of the coefficients in the model accounted for the additional variance due to the sampling of events. Change in the per cent of myocardial infarction events that did not survive 28 days (case-fatality per cent) was computed as the per cent change in the per cent case-fatality.
Results

Between 1987 and 1996 there were 14,842 hospitalized fatal or non-fatal definite or probable myocardial infarction events among residents 35–74 years old in the four study communities (Table 1). There were 4,225 deaths due to CHD. Sixty-five percent of the hospitalized myocardial infarctions and 49% of the fatal CHD events occurred in people without a history of myocardial infarction (data not shown). In 1996, the age-adjusted CHD mortality was highest in black men (2.7 per 1000), followed by white men (2.0 per 1000), black women (1.5 per 1000), and white women (0.6 per 1000). Averaged across all years in the areas where cause of death was validated, the death rate due to CHD was highest in Jackson (1.8 per 1000), followed by Forsyth County (1.5 per 1000) and suburban Minneapolis (1.0 per 1000). Similar to our previous report, death rates due to CHD defined solely on the basis of underlying cause recorded on the death certificate overestimated the rate of validated CHD death. However, the overall trends were similar between the two methods (data not shown).

Black men also had the highest age-adjusted hospitalized myocardial infarction incidence rate in 1996 (4.7 per 1000), followed by white men (3.9 per 1000), black women (2.2 per 1000), and white women (1.6 per 1000). For all men and women combined, averaged across all years, Forsyth County had the highest rate of incident hospitalized myocardial infarction (3.2 per 1000), followed by Jackson (3.0 per 1000), Washington County (2.8 per 1000), and suburban Minneapolis (2.4 per 1000).

Trends in mortality due to CHD

Age-adjusted CHD mortality fell 3.2% annually (95% CI: 2.0, 4.3) among men and 3.8% (95% CI: 1.9, 5.6) among women (Table 2). The greater part of the significant decline observed for men took place between 1987 and 1991, with relatively stable rates for 1992 through 1996 (Figure 1). While the trend was not perfectly linear, we did not have enough years of data to

Table 1 Events confirmed as due to coronary heart disease (CHD), 1987–1996

<table>
<thead>
<tr>
<th>Variable</th>
<th>Hospitalized for myocardial infarction</th>
<th>Death due to CHD</th>
<th>Population</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Men</td>
<td>Women</td>
<td>Total</td>
</tr>
<tr>
<td>Race</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Black</td>
<td>1475</td>
<td>1294</td>
<td>2769</td>
</tr>
<tr>
<td>White</td>
<td>8387</td>
<td>3686</td>
<td>12073</td>
</tr>
<tr>
<td>Total</td>
<td>9862</td>
<td>4980</td>
<td>14842</td>
</tr>
<tr>
<td>Community</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forsyth County, NC</td>
<td>3764</td>
<td>1947</td>
<td>5711</td>
</tr>
<tr>
<td>Jackson, MS</td>
<td>2168</td>
<td>1187</td>
<td>3355</td>
</tr>
<tr>
<td>Minneapolis suburbs</td>
<td>2066</td>
<td>905</td>
<td>2971</td>
</tr>
<tr>
<td>Washington County, MD</td>
<td>1795</td>
<td>898</td>
<td>2693</td>
</tr>
</tbody>
</table>

Table 2 Age-adjusted average annual per cent change (95% CI) in coronary heart disease (CHD) event rates or CHD case-fatality among men and women 35–74 years old, 1987–1996

<table>
<thead>
<tr>
<th>Variable</th>
<th>Men</th>
<th>Women</th>
<th>Total</th>
<th>Men</th>
<th>Women</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Death due to CHD</td>
<td>-2.2 (-4.7, 0.4)</td>
<td>-3.5 (-4.8, -2.3)</td>
<td>-3.2 (-4.3, -2.0)</td>
<td>-3.1 (-6.9, 0.8)</td>
<td>-3.9 (-5.7, -2.0)</td>
<td>-3.8 (-5.6, -1.9)</td>
</tr>
<tr>
<td>In-hospital</td>
<td>0.3 (-5.4, 5.0)</td>
<td>-4.7 (-6.5, -2.9)</td>
<td>-4.0 (-5.7, -2.3)</td>
<td>-5.7 (-12.9, 2.1)</td>
<td>-3.6 (-6.0, -1.1)</td>
<td>-4.9 (-7.7, -2.0)</td>
</tr>
<tr>
<td>Out-of-hospital</td>
<td>-3.0 (-6.1, 0.1)</td>
<td>-2.6 (-4.1, -1.0)</td>
<td>-2.7 (-4.1, -1.3)</td>
<td>-0.5 (-4.2, 3.3)</td>
<td>-3.4 (-6.4, -0.3)</td>
<td>-2.0 (-4.4, 0.4)</td>
</tr>
<tr>
<td>Incident MIα</td>
<td>4.1 (0.7, 7.5)</td>
<td>0.6 (-0.5, 1.7)</td>
<td>1.1 (0.0, 2.1)</td>
<td>4.9 (0.3, 9.6)</td>
<td>0.5 (-12.2, 2.2)</td>
<td>1.7 (-0.1, 3.4)</td>
</tr>
<tr>
<td>Incident MI (definite only)</td>
<td>1.7 (-2.1, 5.7)</td>
<td>-0.8 (-5.9, 0.5)</td>
<td>-0.6 (-1.7, 0.6)</td>
<td>4.7 (0.1, 9.6)</td>
<td>-1.1 (-3.1, 1.0)</td>
<td>0.3 (-1.5, 2.3)</td>
</tr>
<tr>
<td>Recurrent MI</td>
<td>1.2 (-2.2, 4.7)</td>
<td>-2.4 (-3.8, -1.1)</td>
<td>-1.9 (-3.1, 0.7)</td>
<td>2.0 (-2.3, 6.4)</td>
<td>-4.0 (-5.9, -2.1)</td>
<td>-2.1 (-3.9, -0.3)</td>
</tr>
<tr>
<td>Incident or recurrent MI</td>
<td>3.0 (0.6, 5.5)</td>
<td>-1.0 (-1.8, -0.1)</td>
<td>-0.4 (-1.2, 0.4)</td>
<td>3.8 (0.6, 7.0)</td>
<td>-1.5 (-2.8, -0.3)</td>
<td>0.0 (-1.2, 1.3)</td>
</tr>
<tr>
<td>Incident MI or fatal CHD</td>
<td>2.5 (-0.3, 5.3)</td>
<td>0.1 (1.2, 0.8)</td>
<td>0.6 (-0.5, 1.6)</td>
<td>3.6 (0.0, 7.4)</td>
<td>0.7 (-11.2, 2.5)</td>
<td>1.6 (-0.1, 3.4)</td>
</tr>
<tr>
<td>Incident or recurrent MI or fatal CHD</td>
<td>2.0 (0.1, 4.0)</td>
<td>-1.4 (-2.2, -0.6)</td>
<td>-0.8 (-1.5, -0.1)</td>
<td>2.3 (-0.3, 5.0)</td>
<td>-1.1 (-2.4, 0.2)</td>
<td>0.1 (-1.1, 1.4)</td>
</tr>
<tr>
<td>Case-fatality for MI</td>
<td>-8.0 (-17.0, 2.0)</td>
<td>-5.9 (-9.7, -1.9)</td>
<td>-6.1 (-9.7, -2.3)</td>
<td>-2.2 (-11.5, 8.1)</td>
<td>-8.2 (-13.5, -2.6)</td>
<td>-6.2 (-10.9, -1.2)</td>
</tr>
<tr>
<td>Case-fatality for CHD</td>
<td>-6.2 (-10.9, -1.3)</td>
<td>-1.3 (-3.5, 0.9)</td>
<td>-2.1 (-4.0, -0.1)</td>
<td>-3.1 (-9.0, 3.1)</td>
<td>-3.2 (-6.9, 0.6)</td>
<td>-2.7 (-5.8, 0.5)</td>
</tr>
</tbody>
</table>

α Myocardial infarction.

Coronary heart disease mortality includes deaths due to CHD regardless of history of myocardial infarction; out-of-hospital deaths include people who die in the emergency department or who are dead on arrival; first myocardial infarction includes definite plus probable hospitalized myocardial infarction events without prior history of myocardial infarction; attack rate for myocardial infarction includes people with or without a prior history of myocardial infarction; first myocardial infarction or fatal CHD excludes people with a prior history of myocardial infarction.

Case-fatality rates are at 28 days; the case-fatality for CHD includes patients hospitalized for myocardial infarction plus out-of-hospital deaths due to CHD.
adequately test for other shapes. Therefore we used a linear model to estimate the average annual per cent change. The greatest average annual decline in CHD mortality was seen among white women (3.9%) followed by white men (3.5%), black women (3.1%), and black men (2.2%). Although the fall in CHD mortality was statistically significant for men and women overall, the average annual per cent declines among black men and black women were not statistically significant. The lack of statistical significance among blacks is likely due to a smaller sample size.

The average annual rate of in-hospital fatal CHD events in the population fell 4.0% (95% CI: 2.3, 5.7) among all men. The decline among all women was somewhat greater, falling 4.9% per year (95% CI: 2.0, 7.7). A significant annual decline of 2.7% in out-of-hospital fatal CHD events was seen among men. The 3.4% annual decline in out-of-hospital fatal CHD seen among white women was also statistically significant.

To better compare trends in ARIC data with those reported by the WHO-MONICA Project, we further investigated trends after modifying our event definition. We broadened the standard ARIC definition of fatal CHD to include those events classified as 'possible fatal CHD' (Table 3). Furthermore, we restricted the analyses in Table 3 to residents 35–64 years old to be consistent with that used in the WHO-MONICA project. The addition of events classified as possible fatal CHD slightly reduced the downward trend in all gender-race groups.

Trends in the incidence of hospitalized myocardial infarction

Between 1987 and 1996 the age-adjusted rate of incident (first) hospitalized myocardial infarction remained relatively stable (Figure 1 and Table 2). The average annual per cent change was an increase of 1.1% (95% CI: 0.0, 2.1) among men. A similar flat trend was also observed for women.

Although the incidence of first hospitalized myocardial infarction was more variable among blacks due to fewer events, there was a suggestion of an increase in rates over time. The age-adjusted incidence rate of first hospitalized myocardial infarction increased 4.1% per year (95% CI: 0.7, 7.5) among black men and 4.9% per year (95% CI: 0.3, 9.6) among black women. The incidence rate of hospitalized myocardial infarction remained stable over the 10-year period among white men and women (Table 2).

As shown in Table 2, restricting the ARIC data on incident hospitalized myocardial infarction to events classified as 'definite' had only a slight impact on the trend. The average annual incidence rate of definite hospitalized myocardial infarction fell less than one per cent per year (0.6%) in men, and was not statistically significant. Trends in incident definite hospitalized myocardial infarction further restricted to residents 35–64 years of age are shown in Table 3. The trends were similar to those seen for the full ARIC age range except there was a significant decline in incident definite myocardial infarction among white women aged 35–64 years.

Trends in recurrent myocardial infarction attack rate and case-fatality

The age-adjusted rate of recurrent hospitalized myocardial infarction fell 1.9% per year among men and 2.1% per year among women (Table 2). Overall, declines in recurrent hospitalized myocardial infarction were primarily due the significant reductions observed for whites.

Hospitalized myocardial infarction event attack rate (first or recurrent) changed little in either men or women. The combination of the attack rate of hospitalized myocardial infarction plus deaths due to CHD (in- or out-of-hospital) is a measure of the total event rate in the population. The average rate of such events fell a statistically significant 0.8% per year (95% CI: 0.1, 1.5) for men. There was no evidence of an annual decrease in this combined endpoint among women.

Between 1987 and 1996 there was a significant decline in 28-day case-fatality among hospitalized myocardial infarction

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**Table 3** Age-adjusted average annual per cent change (95% CI) in MODIFIED coronary heart disease (CHD) event\(^a\) rates among men and women, 35–64 years old, 1987–1996

| Variable | Men | | | Women | | |
| --- | --- | --- | --- | --- | --- |
| | Black | White | Total | Black | White | Total |
| Death due to CHD (includes possible fatal CHD) | -2.2 (-4.9, 0.7) | -2.0 (-5.5, 1.5) | -1.8 (-4.6, 1.1) | -2.7 (-6.6, 1.4) | -2.4 (-5.6, 0.9) | -2.2 (-5.4, 1.1) |
| First MI\(^b\) (definite MI only) | 4.3 (-2.3, 11.4) | -1.1 (-2.9, 0.7) | -0.4 (-2.3, 1.4) | 2.2 (-2.1, 6.7) | -3.6 (-6.9, -0.2) | -1.8 (-4.4, 0.8) |

\(^a\) Definition of death due to CHD includes cases classified as possible fatal CHD in addition to definite fatal myocardial infarction and definite fatal CHD.

\(^b\) Definition of hospitalized myocardial infarction restricted to definite myocardial infarction only. Age range restricted to 35–64 years.
events for men (~6.1% per year) and women (~6.2% per year) (Table 2). Declines were also seen for total CHD case-fatality (includes patients hospitalized for myocardial infarction plus out-of-hospital deaths due to CHD).

Discussion

Between 1987 and 1996 CHD mortality in the ARIC communities declined 32% in men and 38% in women. The fall in CHD mortality was evident among blacks and whites. Most of the decline, however, occurred in the first half of the study period with more stable rates in the latter half. We also observed modest declines in attack rates of hospitalized myocardial infarction (first and recurrent events combined). However, most of the decline in hospitalized myocardial infarction attack rates was due to a fall in recurrent events. This is in agreement with data from Finland that showed that a decreased occurrence of recurrent coronary events played a prominent role in the decline of CHD mortality. The data suggest that secondary prevention and treatment of chronic symptomatic CHD have a substantial impact.16

We found that in ARIC the trend in incidence of hospitalized myocardial infarction (first events) was stable. As expected, these more current morbidity data agree with our previous report that showed, between 1987 and 1994, the CHD mortality decline occurred in the context of stable or slightly increasing trends in the incidence of hospitalized myocardial infarction and improving survival after myocardial infarction.13 The updated trends reported here support the conclusion that into the mid 1990s the fall in death rates due to CHD in these communities was primarily a consequence of improvements in case-fatality and declines in recurrent hospitalized myocardial infarction. Declines in incident myocardial infarction and declining out-of-hospital CHD death rates played a lesser role. It is possible that myocardial infarction events have become milder. However, recent reports from the ARIC study provide only mixed support for decreases in severity of hospitalized myocardial infarctions.17

In contrast, recent reports from the WHO-MONICA project suggested that decreases in disease occurrence accounts for two-thirds of declines in CHD mortality with improvements in case-fatality having a less important role.18 Although differences in the respective role of event rates and survival in determining mortality rates are expected between studies, some of the difference may reflect important methodological issues.18 The definition used in the main analysis of the WHO-MONICA project was a composite of non-fatal events classified as definite myocardial infarction, and fatal events classified as definite, possible, and unclassifiable coronary deaths (URL:www.ktl.fi/publications/monica/manual/part4).

The ARIC study defined total CHD as definite or probable myocardial infarction, plus definite fatal CHD. Although the terminology is not identical between the two studies, in general the WHO-MONICA project definition included a broader spectrum of fatal CHD and the ARIC definition includes a broader spectrum of non-fatal myocardial infarction. After modifying the ARIC definition of fatal CHD to include cases defined as ‘possible fatal CHD’ and restricted to the same age group as the WHO-MONICA project, the downward trend in CHD mortality was attenuated compared to the more specific ARIC definition. When considering only definite incident hospitalized myocardial infarctions, there was a suggestion of a downward trend in such events in ARIC. No downward trend was observed when the broader ARIC definition that included probable cases was considered. In ARIC, the per cent age declines in hospitalized event rates and out-of-hospital deaths were less than that for case-fatality rates. However, in terms of absolute number of events, the decline in out-of-hospital fatal CHD represents a larger contribution to the decline in number of fatal CHD events over time than does case-fatality. A sustained underlying risk in the population may have stimulated increasing or stable rates of events classified as probable myocardial infarction thus flattening the overall trend in total hospitalized myocardial infarction event rates. However, more direct measures of trends in severity are needed to better characterize this picture.

Because a complex of factors that vary by time and place determines trends in mortality rates there is every reason to expect inconsistencies across studies. Indeed, estimating the relative contribution of preventive factors and treatment factors has been the focus of recent debate.9,10,19 Recent reports from the WHO-MONICA project that estimated the contribution of classic risk factors11 and coronary care12 to mortality trends suggest that while changes in treatments and secondary prevention were strongly linked with declining coronary endpoints, risk factors explained less of the variability of trends in event rates than anticipated.

The update of trends in the ARIC communities presented in the current paper is in contrast to the downward trend in hospitalized myocardial infarction incidence seen in the 1980s in several population-based studies in the US,7,20–22 but is in agreement with surveillance studies conducted in the 1990s23,24 Although none of these studies is representative of the entire US and therefore free of bias, they offer the best available data on incident myocardial infarction in the community. Factors associated with the occurrence of recurrent myocardial infarction, as well as those creating a better chance of survival after an event, were likely the prominent components in the decline in CHD mortality observed over this period in the US.

KEY MESSAGES

- The average annual age-adjusted mortality rate of CHD declined about 3% per year between 1987 and 1996 for all gender-ethnic groups in the four ARIC Communities, although most of the decline took place in the first half of this period.
- Although rates of recurrent hospitalized myocardial infarction fell during this period, the trend in rates of incidence (first) events was stable.
- Case-fatality (28-day) after myocardial infarction improved significantly during this period.
Acknowledgements

The authors thank the staff and participants in the ARIC study for their important contributions. The ARIC study was supported by contracts N01-HC-55015, N01-HC-55016, N01-HC-55018, N01-HC-55019, N01-HC-55020, N01-HC-55021, and N01-HC-55022 from the US National Heart, Lung, and Blood Institute.

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