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THE DECLINE IN ISCHEMIC HEART DISEASE MORTALITY: PROSPECTIVE EVIDENCE FROM THE ALAMEDA COUNTY STUDY

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Kaplan, G. A. (Human Population Laboratory, California Dept. of Health Services, Berkeley, CA 94704), B. A. Cohn, R. D. Cohen, and J. Guralnik. The decline in ischemic heart disease mortality: prospective evidence from the Alameda County Study. *Am J Epidemiol* 1988;127:1131–42.

The contribution of secular changes in the distribution of ischemic heart disease risk factors and medical care utilization to the decline in ischemic heart disease mortality was investigated using data collected on the nine-year ischemic heart disease mortality experience of two cohorts selected to be representative of Alameda County, California, in 1965 and 1974. With adjustment for age, sex, race, and baseline ischemic heart disease conditions and symptoms, there was a 45% decline in the nine-year odds of ischemic heart disease mortality between the two cohorts (1965/1974, odds ratio (OR) = 1.82, $p = 0.0001$). Further adjustment for cohort differences in the following ischemic heart disease risk factors did not explain the decline: smoking status, leisure-time physical activity, self-assessed physical activity, alcohol consumption, body mass index, or social network participation; neither did adjustment for measures of education, utilization of preventive medical care, availability of a regular physician or clinic, health insurance coverage, number of physician visits during the last 12 months, or occupation. There was no change in the estimated ischemic heart disease decline when all adjustment variables were included in a logistic model (1965/1974, OR = 1.81, $p = 0.0002$). These variables do not appear to explain the large decline in nine-year ischemic heart disease mortality between these two cohorts.

cardiovascular diseases; coronary disease; longitudinal studies, mortality

The recent, substantial decline in ischemic heart disease mortality observed in the United States and some other western countries has been widely noted and discussed (1–5). However, the causes of the decline are not well understood. It has been suggested that primary and secondary prevention, as well as improvements in acute care for myocardial infarction and long-term medical management of chronic heart disease, may have contributed to the decline (1–5). Unfortunately, adequate sources of data do not exist to distinguish between these alternative explanations. A recent analysis, bringing together the results of a number of studies, estimated that about 40 per cent of the decline in ischemic heart disease mortality between 1968 and 1974 could be due to secular improvements in hypertension control and other medical interventions, while 54 per cent of the decline could be due to changes in life-style

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(3). However, such estimates were based on a synthesis of data from many sources and not on observations within a defined population. As a result, it has not been possible to directly examine the contribution of changes in risk factor levels and other variables to the decline in mortality. The absence of data on risk factors in individuals has particularly hampered efforts aimed at assessing the role of primary prevention in the mortality decline. Instead, the role of risk factor change has had to be evaluated indirectly, using ecologic correlations between secular trends in risk factors and ischemic heart disease mortality rates (3, 4, 6–8). However, the difficulties in interpreting such analyses are well known (9).

In this report, we examine the nine-year ischemic heart disease mortality experience of two cohorts separated in time by nine years. Identical information on baseline values of a number of cardiovascular risk factors and measures of medical care utilization allows us to directly examine the contribution of secular changes in these factors in ischemic heart disease mortality to any differences observed between these two cohorts.

Materials and methods

Study population

In 1965 and 1974, cohorts representative of Alameda County, California, were selected by the Human Population Laboratory of the California Department of Health Services. All noninstitutionalized adults in the sampling frame were eligible respondents. The sampling methods are described in detail elsewhere (10). The response rates for both the 1965 and 1974 samples were high, 86 per cent for the 1965 cohort and 80 per cent for the 1974 cohort. The 1965 cohort consists of 6,928 people: 3,158 males and 3,770 females. The 1974 cohort consists of 3,119 people: 1,409 males and 1,710 females. The present analyses are restricted to white participants and black participants aged 40 years and over (n = 3,751 for the 1965 cohort, n = 1,551 for the 1974 cohort). For these participants, there were 218 ischemic heart disease deaths (5.8 per cent) in the 1965 cohort and 72 ischemic heart disease deaths in the 1974 cohort (4.6 per cent) during their respective nine-year follow-up periods.

Mortality ascertainment

Mortality was ascertained for both cohorts using a computer-matching linkage with the California Death Registry to obtain the death certificates of those persons who had died in California or who had died outside the state with notification to California. The description of the process used is given elsewhere (11, 12). Deaths ascertained in other ways are not included in these analyses. Those not known to be dead are considered alive. The procedure used in the ascertainment of the 1974–1983 deaths represents an improvement over the one used previously. The net result of this improvement should be an increase in the number of respondents positively identified as deceased and a higher mortality rate. Thus, the excess in ischemic heart disease mortality rates in the earlier cohort will be somewhat underestimated. Loss to follow-up has been estimated based on a 1974 follow-up of the 1965 cohort and is approximately 4 per cent over nine years. Ischemic heart disease mortality was coded according to the *International Classification of Diseases* (ICD) (Eighth Revision, codes 410–414) for both the 1965 and 1974 cohorts to ensure comparability.

Description of variables

Risk factor data were collected via a self-administered questionnaire; thus all information is self-reported. Variables chosen for this analysis were either known cardiovascular risk factors or had been shown by previous analyses of the mortality experience of the 1965 cohort to be significant as predictors of mortality from ischemic heart disease and/or all causes or were thought to be important as potential confounders. Table 1 describes the method of measurement and coding for the independent variables used in this study. Identical

TABLE 1

Independent variables: Alameda County Study, 1965 and 1974 cohorts

Variable	Coding
Age	Continuous
Sex	1 = males/0 = females
Race	1 = white/0 = black
High blood pressure	1 = yes/0 = no
Chest pain	1 = yes/0 = no
Heart trouble	1 = yes/0 = no
Smoking (2 dummies)	Current smoker/former smoker/never smoker (reference)
Leisure-time physical activity score	Range from 0 to 16 (least to most active)
Self-assessed physical activity	1 = much less active/0 = all other responses
Social contacts	
Marital status	1 = unmarried/0 = married
Church group	1 = nonmember/0 = member
Work, social group	1 = nonmember/0 = member
Social isolation	1 = isolated response in 2 of 3 of the following items: number of friends, number of relatives, frequency of contacts with friends and relatives/ 0 = not isolated
Body mass index (4 dummies)	Quintiles of Quetelet index (weight/height^2), 3rd quintile = reference
Alcohol (drinks/month) (4 dummies)	Abstainers/1–15/16–30 (reference)/31–60/61+
Physician visit within 12 months	1 = yes/0 = no
Utilization of preventive health care (2 dummies)	0 = never/1 = more than 2 years ago/2 = within last 2 years
Regular physician or clinic	1 = yes/0 = no
Health insurance	1 = no coverage/0 = coverage
Education (years) (3 dummies)	≤8/9–12 (reference)/13–16/17+
Income (3 dummies)	Inadequate/marginal/adequate/very adequate (reference)

information is available for both the 1965 and 1974 cohorts.

Prevalence of cardiovascular disease at baseline was measured by self-reports of heart trouble, chest pain, or high blood pressure during the preceding 12 months. These reports have been previously shown to be importantly associated with mortality from ischemic heart disease (13). Demographic variables (age, education, race) were measured as in table 1. Income was measured by total family income adjusted for family size and grouped into four categories (inadequate, marginal, adequate, very adequate) as compared with federal standards.

Smoking status was classified as current, former, or never. Two measures of leisure-time activity were utilized. The leisure-time activity score is a weighted index of activity type and frequency which has been shown to predict all-cause mortality in the 1965 cohort (14). The index items include sports, exercise, swimming, walking, hunting, fishing, and gardening, with the first four being weighted more heavily. A self-assessed physical activity item used responses to the question, "Are you more or less physically active than most people of your age?" The high-risk category was defined as those reporting that they were much less active; the low-risk category was all other responses. Body mass was measured using the Quetelet index (weight in pounds/height in inches^2). Cutpoints for quintiles were chosen separately for males and females based upon the joint distribution of Quetelet for the 1965 and 1974 cohorts. Alcohol consumption was measured by combining questions which assessed the usual frequency and amount of alcohol consumed converted to drinks per month. Social connections were assessed using individual components of the social network index (15). This index combines information about marital status, quantity and frequency of social contacts, and group membership, and has been previously shown to

predict all-cause and cardiovascular mortality in the 1965 cohort (15, 16).

Utilization of medical care was measured in four ways. Use of preventive health services was assessed using responses to the question, "When was the last time you went to a doctor for a general checkup—even though you were feeling well and had not been sick?" Respondents also reported if they had visited a physician in the last 12 months, if they had a regular physician or clinic, and if they had health insurance.

Analysis

Three methods were used to examine the difference in ischemic heart disease mortality for the 1965 and 1974 cohorts. The ratio of ischemic heart disease death rates for the 1965 cohort to the ischemic heart disease death rates for the 1974 cohort was tested for consistency across age, sex, and race subgroups using a chi-square test described by Gart (17). For those strata in which there was no evidence of inconsistency, the relative risk of ischemic heart disease death associated with cohort membership adjusted for age and sex was calculated using the Mantel-Haenszel method (18).

Secondly, in order to present adjusted survival curves for the nine-year follow-up for the two cohorts, a Cox proportional hazards model containing age, sex, race, and an indicator variable for cohort membership was utilized. A test of the effect of cohort membership on ischemic heart disease mortality, for example, whether or not there was a significant difference between the nine-year ischemic heart disease mortality experience of the two cohorts, was obtained from the coefficient for the cohort term in this model (19).

Evidence for a change in the decline over time was examined using the visual procedures suggested by Kalbfleisch and Prentice (19, pp. 88–95) for examining the proportional hazard assumption for the cohort term. Adjusted survival curves were estimated within each cohort, and plots of log(−log survival) versus time were examined for a constant difference between the cohorts.

The third objective of the analysis was to determine whether changes in the distribution of ischemic heart disease risk factors and medical care utilization between the 1965 and 1974 cohorts could account for any observed decline in nine-year ischemic heart disease mortality. This was accomplished by examining the effect of cohort membership on ischemic heart disease mortality before and after adjustment for cohort differences in baseline ischemic heart disease morbidity and other potential explanatory variables.

The effect of cohort membership was first estimated from a multiple logistic model containing terms for age, sex, race, and cohort membership using data for the 1965 and 1974 cohorts combined. Cohort membership was coded as a binary variable: 1 for membership in the 1965 cohort and 0 for membership in the 1974 cohort. The odds ratio (OR) for cohort membership (1965/1974) is an index of the decline in ischemic heart disease mortality between 1965 and 1974. A cohort odds ratio greater than one indicates that ischemic heart disease mortality rates were greater for the 1965 cohort.

Ischemic heart disease conditions and symptoms were added to the model as a group to determine the impact of cohort differences in baseline ischemic heart disease morbidity on the coefficient for cohort membership. Then a series of models was fit in which additional risk factors were added singly to the model containing age, sex, race, cohort membership, and baseline ischemic heart disease conditions and symptoms, thereby adjusting the coefficient for cohort membership for cohort differences in each individual risk factor. Next, the coefficient for cohort membership was estimated from a model containing all the risk factors which predicted ischemic heart disease mortality in any of the previous analyses. In the case of social connections, if any one was a risk factor predictor, all were included as adjustment variables.

All of these analyses are reported for the same set of individuals, none of whom had missing data on any of the predictors in the largest model ($n = 5,202$).

Finally, other potential confounders were added to the model, even if they were not significant predictors of ischemic heart disease mortality, to determine whether they had a role in confounding the association between cohort membership and ischemic heart disease mortality. This technique is consistent with the approach to identifying confounders recommended by Kleinbaum et al. (18).

In all analyses, sets of dummy variables were used to represent categorical risk factors with more than two categories. When a multicategorical risk factor was included in a logistic model, all of its dummy variables were entered together.

RESULTS

Decline in ischemic heart disease risk

Table 2 presents age- and sex-specific nine-year ischemic heart disease death rates for the 1965 and 1974 cohorts and cohort relative risks. A relative risk greater than one indicates that the nine-year risk of ischemic heart disease death was higher in 1965 than in 1974. With the exception of females aged 40–59 years, all age and sex groups experienced a decline in ischemic heart disease mortality. The differences in cohort relative risks by age and sex are not statistically significant ($p = 0.85$).

The age- and sex-adjusted cohort relative risk was 1.42 ($p = 0.006$, 95 per cent confidence interval (CI) = 1.11–1.81), indicating that the 1974 cohort experienced a 29.6 per cent decline [(1965–1974)/1965] in nine-year risk of ischemic heart disease death relative to the 1965 cohort.

The difference in nine-year ischemic heart disease rates between the 1965 and 1974 cohorts was also examined using a Cox proportional hazards model to fit age, sex-, and race-adjusted survival curves for the two cohorts (figure 1). Ischemic heart disease mortality in the 1974 cohort was significantly less than in the 1965 cohort ($p = 0.001$). Whites ($p = 0.004$), blacks ($p = 0.10$), males ($p = 0.004$), and females ($p = 0.09$) experienced better ischemic heart disease survival in 1974 (figure 2). Comparison of the survival curves for males and females suggests that women experienced a smaller decline in ischemic heart disease mortality, although this difference was not statistically significant ($p = 0.36$), possibly due to low statistical power.

Inspection of the log(−log survival) func-

TABLE 2

Nine-year risk of ischemic heart disease (IHD) mortality for 1965 and 1974 cohorts, Alameda County, CA

Sex and age (years)	Heart disease deaths*		Population at risk		IHD mortality risk/100		Relative risk of IHD death (1965/1974)
	1965	1974	1965	1974	1965	1974	
Males							
40–49	5	0	699	217	0.79	0.23†	3.43
50–59	27	9	474	235	5.70	3.83	1.49
60–69	36	10	313	135	11.50	7.41	1.55
70+	62	18	213	101	29.08	17.82	1.63
Females							
40–49	1	1	755	252	0.13	0.40	0.33
50–59	5	3	563	272	0.89	1.10	0.81
60–69	29	8	374	168	7.75	4.76	1.63
70+	53	23	213	101	15.59	13.45	1.16
Total	218	72	3,604	1,481	6.05	4.86	1.42‡

* *International Classification of Diseases* (8th Revision) codes 410–414.

† 0.5 added to all cells when there are no cases.

‡ Mantel-Haenszel age-, sex-adjusted relative risk for cohort membership (RR = 1.42, $p = 0.006$).

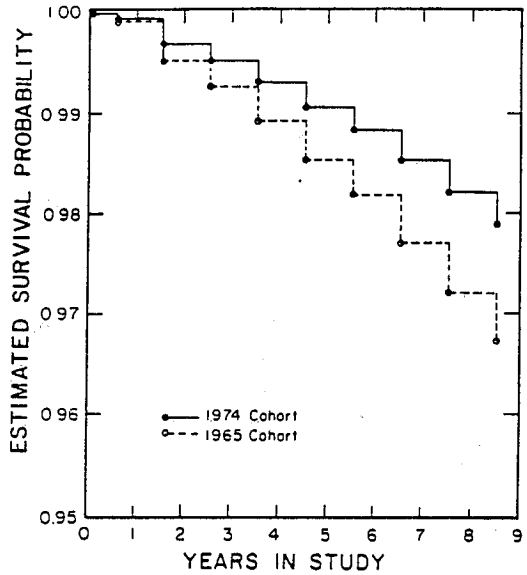

FIGURE 1. Estimated ischemic heart disease survival probabilities for 1965 and 1974 cohorts, Alameda County, California, adjusted for age, sex, and race.

tions for the two cohorts indicated that the curves were roughly parallel. This suggests that the proportional hazards assumption is valid. Further inspection of these curves did not indicate any convergence near the end of the follow-up period which would have suggested a diminution of the decline over time.

Predictors of ischemic heart disease risk

Cohort differences in the prevalence and means of risk factors are presented in table 3. There is a mixed pattern of differences, perhaps the most notable being the lower rates of current smoking and higher rates of past smoking in the 1974 cohort when compared with the 1965 cohort. On the other hand, the 1974 cohort members report higher rates of chest pain and heart trouble. Because the focus in these analyses is on the extent to which this pattern of risk factor differences between the two cohorts can account for differences in ischemic heart disease mortality risk, the next analyses consider the ability of these risk factors to predict this mortality outcome.

Table 4 presents the age-, sex-, and race-adjusted association between ischemic heart disease symptoms and conditions and nine-year ischemic heart disease mortality for the 1965 and 1974 cohorts combined. As expected, reports of heart trouble (OR = 1.63, $p = 0.01$), chest pain (OR = 2.01, $p = 0.0003$), and high blood pressure (OR = 1.72, $p = 0.0003$) were associated with increased risk.

Table 5 presents the association between ischemic heart disease risk factors and nine-year ischemic heart disease risk for the 1965 and 1974 cohorts combined, after adjustment for age, sex, race, and baseline ischemic heart disease symptoms and conditions. Odds ratios are presented for models which include age, sex, race, baseline ischemic heart disease morbidity, and each risk factor as well as for a model in which there is simultaneous adjustment for all risk factors. After adjustment for age, sex, race, and baseline ischemic heart disease conditions and symptoms, significant associations were found for smoking (current/never, OR = 2.04, $p = 0.0000$), leisure-time physical activity (lowest quartile/highest quartile, OR = 1.66, $p = 0.0002$), self-assessed physical activity (much less active/other, OR = 2.12, $p = 0.0002$), body mass index (1st quintile/3rd quintile, OR = 1.77, $p = 0.01$; 2nd quintile/3rd quintile, OR = 2.05, $p = 0.002$; and 5th quintile/3rd quintile, OR = 2.07, $p = 0.001$), social and work group membership (nonmember/member, OR = 1.34, $p = 0.03$), and social isolation (isolated/not isolated, OR = 1.63, $p = 0.0009$).

Decline in ischemic heart disease mortality after adjustment for risk factors

Table 6 presents the association between cohort membership and nine-year ischemic heart disease mortality before and after adjustment for cohort differences in baseline ischemic heart disease morbidity and predictors of ischemic heart disease mortality. A 41 per cent decline in the odds of ischemic heart disease mortality is seen

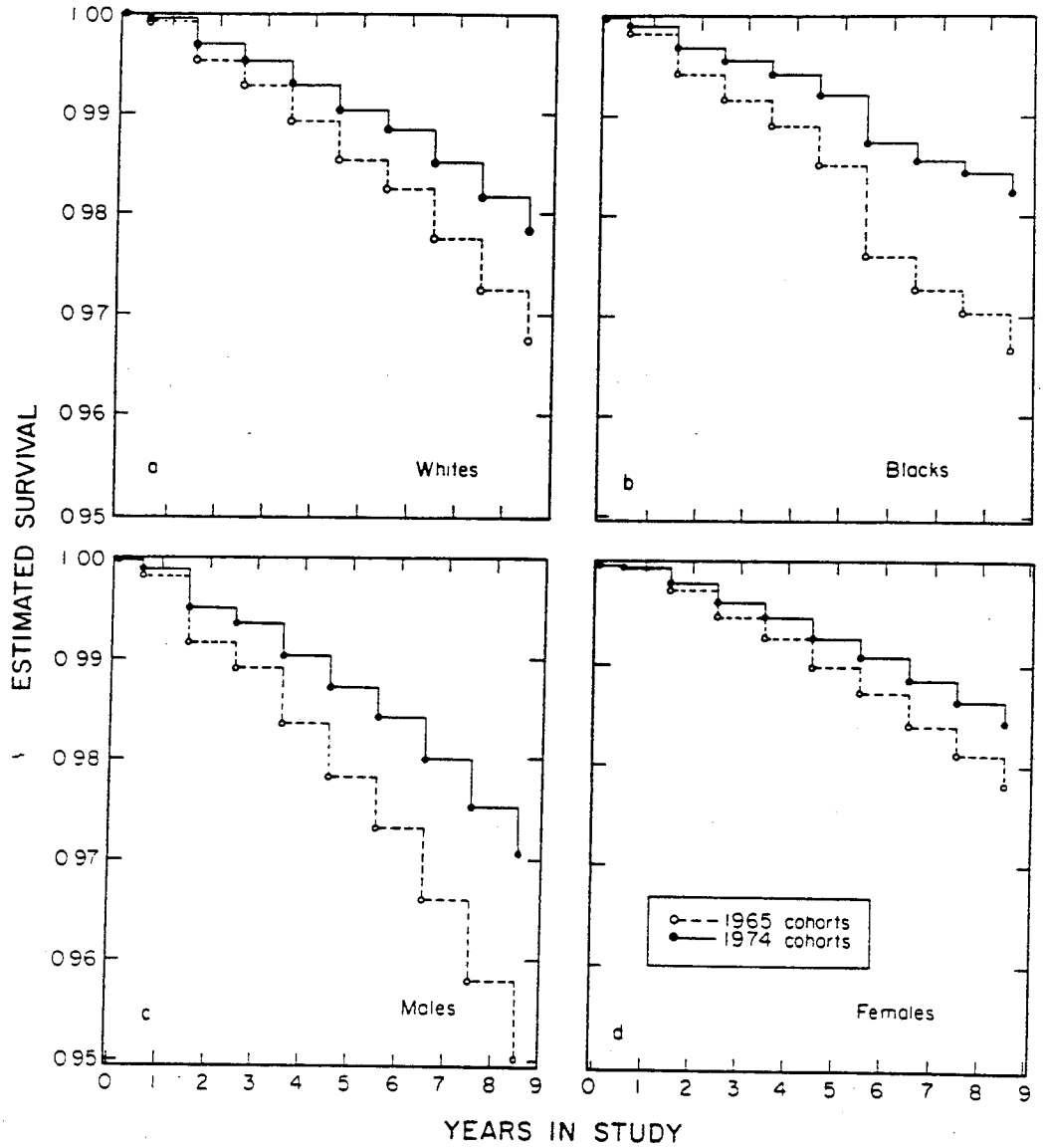

FIGURE 2. Estimated ischemic heart disease survival probabilities for males and females and blacks and whites in the 1965 and 1974 cohorts, Alameda County, California.

after adjustment for age, sex, and race (OR = 1.69, $p = 0.0006$). The coefficient for cohort membership is increased (OR = 1.82, $p = 0.0001$) after adjustment for baseline ischemic heart disease conditions and symptoms.

Table 6 also shows that adjustment for significant ischemic heart disease risk factors does not alter the coefficient for cohort membership. Adjustment for smoking status, physical activity, body mass index, and social contacts does not have an effect on the different pattern of ischemic heart disease mortality experienced by the two cohorts (OR = 1.81, $p = 0.0002$ for model containing all variables).

In addition to the ischemic heart disease risk factors discussed above, other possible confounders which might account for the cohort difference in mortality were exam-

TABLE 3

Ischemic heart disease risk factor prevalence in 1965 and 1974 Alameda County cohorts

Risk factor	1965	1974
Males	45.3	44.4
White	86.2	86.1
<9 years education	27.6	21.0
Inadequate income	14.3	15.9
High blood pressure	15.8	22.1
Chest pain	12.3	13.9
Heart trouble	6.9	11.6
Current smoker	40.6	34.2
Past smoker	17.6	23.8
Never smoked	41.8	42.0
Self-assessed activity (much less active than others)	5.6	7.4
Married	73.1	71.8
Church group	66.5	70.5
Other group	36.1	35.7
Socially isolated	23.2	17.8
Physician visit in last year	29.5	16.5
No preventive care	11.9	15.3
Regular physician or clinic	83.4	89.2
Health insurance	84.8	95.6
Means (Q1, Q4)*		
Age	57.3 (48.0, 65.0)	55.4 (45.0, 64.0)
Quetelet index ($\times 10^2$)	3.5 (3.1, 3.9)	3.1 (3.1, 3.8)
Alcohol consumption (drinks/month)	21.3 (0.0, 30.0)	19.4 (0.0, 24.8)
Leisure-time physical activity index	5.5 (3.0, 8.0)	5.4 (2.0, 8.0)

*Q1 = first quartile, Q4 = fourth quartile.

TABLE 4

Associations between baseline ischemic heart disease conditions and symptoms and nine-year ischemic heart disease mortality for the 1965 and 1974 cohorts in the Alameda County Study

Variable	Odds ratio*	95% confidence interval
Heart trouble	1.63	1.11–2.38
Chest pain	2.01	1.38–2.93
High blood pressure	1.72	1.28–2.30

* Each odds ratio adjusted for age, sex, race, and other ischemic heart disease conditions and symptoms using logistic model.

ined: alcohol consumption, use of preventive health services, physician visits within the last 12 months, use of a regular physician or clinic, health insurance coverage, education, and income adjusted for family size. These variables were not significant predictors of ischemic heart disease mortality in the combined 1965 and 1974 cohorts when adjusted for age, sex, race, and baseline conditions and symptoms. Because Kleinbaum et al. (18) have suggested that failure to predict an outcome is not a sufficient justification for ruling out individually examined variables as potential confounders, these variables were then included in models which contained the ischemic heart disease risk factors previously identified (table 4). Further adjustment for these variables had little effect. In the model which contained all of these additional variables plus other predictors, the 1974 cohort had a 46 per cent reduction in ischemic heart disease mortality risk (OR = 1.85, $p = 0.0005$). Similarly, changes in

TABLE 5

Predictors of nine-year ischemic heart disease (IHD) mortality for the 1965 and 1974 cohorts in the Alameda County Study

	Adjusted for age, sex, race, baseline IHD conditions and symptoms*		Adjusted for age, sex, race, baseline IHD conditions and symptoms* and all other predictors in this table	
	Odds ratio	95% confidence interval	Odds ratio	95% confidence interval
Current smoking vs. never smoking	2.04	1.46–2.85	1.91	1.35–2.70
Former smoking vs. never smoking	1.25	0.87–1.80	1.27	0.88–1.83
Leisure-time physical activity index (lowest quartile vs. highest quartile)	1.66	1.27–2.16	1.35	1.02–1.79
Self-assessed physical activity (much less active vs. other)	2.12	1.42–3.16	1.61	1.06–2.44
Social contacts				
Marital status (unmarried vs. married)	1.08	0.80–1.46	1.00	0.73–1.36
Church group membership (nonmember vs. member)	1.19	0.89–1.59	0.97	0.72–1.32
Social, work group membership (nonmember vs. member)	1.34	1.03–1.76	1.18	0.90–1.55
Social isolation (few contacts vs. many)	1.63	1.22–2.17	1.41	1.05–1.89
Body mass (Quetelet index)				
1st quartile vs. 3rd	1.77	1.14–2.75	1.49	0.95–2.34
2nd quartile vs. 3rd	2.05	1.30–3.21	1.95	1.24–3.07
4th quartile vs. 3rd	1.18	0.72–1.93	1.21	0.74–2.00
5th quartile vs. 3rd	2.07	1.32–3.22	1.98	1.26–3.10

* Chest pain, high blood pressure, heart trouble.

TABLE 6

Estimated decline in nine-year ischemic heart disease (IHD) mortality between the 1965 and 1974 cohorts in the Alameda County Study before and after adjustment for cohort differences in baseline and IHD morbidity and IHD predictions

Adjustment level	Odds ratio for cohort membership: 1965/1974	95% confidence interval
Age, race, sex only	1.69	1.25–2.27
Age, race, sex, and baseline IHD conditions and symptoms*	1.82	1.34–2.46
Age, race, sex, baseline IHD conditions and symptoms and IHD predictors†	1.81	1.33–2.47

* Heart trouble, chest pain, high blood pressure.

† Current smoking, former smoking, leisure-time physical activity index, self-assessed physical activity, social contacts, body mass index.

the distribution of occupational status had little effect on the cohort difference when examined in sex-specific models.

DISCUSSION

These results indicate that secular changes in the distribution of the risk factors and medical utilization characteristics examined in this study do not explain the decline in ischemic heart disease mortality observed between the 1965 and 1974 cohorts representative of Alameda County. It is possible that secular changes in other risk factors not measured in this study could explain the decline. We do not have information on either lipoprotein concentrations or blood pressure readings. Although it is likely that there have been changes in lipoprotein concentrations during the period studied in these analyses, we cannot, in the present study, assess the contribution of such changes to the observed decline. However, based on information from other sources (20, 21), it is

unlikely that these changes are large enough to account for the entire 45 per cent decline in the odds of ischemic heart disease death which we observed.

Although we do not have systolic and diastolic readings for study participants, or information on treatment for hypertension, the self-report of "high blood pressure during the last 12 months" is a highly significant predictor in these analyses and others (13). It is worth noting in this regard that for the 1974 cohort, where data are available, 97 per cent and 99 per cent of the men and women who reported "high blood pressure" reported that they had seen a physician about it.

A further limitation of the present study is that it is unable to consider differences in the incidence of ischemic heart disease in the two cohorts. As noted in many reports (1–4), this is a serious limitation which has made interpretation of the secular changes in mortality difficult. The present study's strengths lie in the prospective observation of the mortality experience of two representative cohorts for whom some information on important risk factors is available.

It is possible that the failure of identified ischemic heart disease risk factors to account for the decline in mortality might be due to inaccurate measurement of these variables. However, the associations between ischemic heart disease mortality and smoking, physical activity, body mass index, baseline morbidity, and social isolation are strong and consistent in direction and magnitude with other reports. If there were significant misclassification, one would not expect these variables to have as good predictive validity.

We have also explored the possibility of imprecise measurement or coding of variables directly in a series of analyses. To check the possibility that smoking status was not adequately measured by never, current, and former categories, we substituted pack-years of exposure as an adjustment variable. Pack-years was a significant predictor of ischemic heart disease risk in a model adjusted for age, sex, race, and baseline ischemic heart disease conditions and symptoms, as expected. However, adjustment for pack-years led to virtually identical results for the association between cohort membership and ischemic heart disease mortality (OR = 1.79, $p = 0.002$; see table 6 for comparison). Similar results were obtained if pack-years for current smokers were distinguished from pack-years for former smokers.

Alternative methods for coding alcohol consumption, e.g., quadratically, were considered, although Camacho et al. (22) did not find evidence for such a relation in the 1965 cohort. These changes, as well as alternative methods for coding body mass index and physical activity, did not appreciably change the coefficient for cohort membership. In short, it is unlikely that the failure of ischemic heart disease risk factors to explain the decline in these data is due to measurement or coding problems.

The medical care variables used in this study are not adequate to evaluate the effects of improved medical management of either acute or chronic ischemic heart disease. However, these variables are crude estimates of access to and utilization of these services. None of these variables explained cohort differences in ischemic heart disease mortality.

The present analyses have, by necessity, utilized cause-of-death information obtained from death certificates, a procedure which is not without its problems. A number of validation studies have been carried out in which death certificate information is compared with autopsy findings or hospital records, with sensitivities in the general area of 70–80 per cent (23–26). A recent study which examined out-of-hospital coronary deaths found the sensitivity of ICD Ninth Revision codes 410–414 and 427 listings on the death certificate to be 90.3 per cent (27). These validation studies cover the period in which mortality was monitored in the present study, and there is no reason to believe that sensitivity or specificity has changed during this period. Furthermore, all causes of death which were coded to the Ninth Revision of the ICD

were back-coded to the Eighth Revision to eliminate problems of comparability. It is unlikely, then, that the decline in ischemic heart disease mortality demonstrated in the current analyses is an artifact of coding biases or changes in convention.

Finally, it should be pointed out that the procedures used in designating the sample from which the 1974 cohort was chosen resulted in a duplication of some persons in the two cohorts. Specifically, the 1974 designated sample consisted of a 50 per cent random subsample of the housing units used in the 1965 designated sample, supplemented by a stratified probability sample of Alameda County housing units newly constructed or converted between July 1965 and June 1973. This process results in a strict probability sample of Alameda County housing units in 1974, as in 1965. However, because there was a duplication of some housing units, and because some people who were respondents in the 1965 cohort had not moved, 844 persons (8.4 per cent) were represented in both cohorts. The analytic issues involved in ascertaining the impact of this overlap on the obtained results are complex. In order to estimate this impact, we repeated the analyses reported in table 5, excluding these persons from the 1974 cohort. The odds ratio for cohort membership with adjustment for age, race, sex, baseline ischemic heart disease conditions and symptoms and ischemic heart disease predictors was 1.78 (95 per cent CI = 1.20–2.64) compared with the previously obtained 1.81 (95 per cent CI = 1.33–2.47). Because exclusion of the duplicated persons makes so little difference in the results, and inclusion maintains the representative nature of the two cohorts, we have chosen to include them in all analyses.

This study is one of the first direct examinations, using prospective data from two population-based samples, of the hypothesis that the decline in ischemic heart disease mortality is due to secular changes in the distribution of risk factors and medical care utilization. The analyses reported here do not support a role for these variables in the decline in ischemic heart disease mortality observed in the Alameda County Study.

A recent report from Gothenburg, Sweden, which examined factors responsible for a secular *increase* in ischemic heart disease mortality recorded for two cohorts separated by 10 years (1963 and 1973) reached a similar conclusion. Secular changes in risk factor distributions did not account for the observed increase in seven-year incidence of fatal and nonfatal myocardial infarction (28). These results are consistent with our findings that secular changes in ischemic heart disease mortality rates may not be explained by changes in the distribution of many known ischemic heart disease risk factors.

A common feature of the current study and the Gothenberg study is a lack of information concerning changes in risk factor status during the follow-up period. Substantial changes may occur during long follow-up periods. A nine-year reinterview of those members of the 1965 cohort who survived to 1974 indicated that 25.7 per cent of baseline smokers had quit smoking during the nine-year period. Analyses of mortality risk following quitting indicated that those who quit between 1965 and the 1974 follow-up were at decreased risk compared with those who continued to smoke. Thus, if substantially greater quitting occurred following baseline measurement in the later cohort, the role of smoking in the decline in ischemic heart disease mortality could be underestimated. However, higher rates of quitting in the second cohort would lead to a weaker association between smoking status and ischemic heart disease mortality, and such a result was not found.

Thus, it would appear that, in addition to the need for information on cardiovascular incidence and risk factors, solving the puzzle of the decline in cardiovascular disease mortality will require prospective, multiwave, population-based studies. Lacking these types of studies, it would be premature to conclude, based on the current analyses, that risk factors and medical care utilization have no role whatsoever in the decline in ischemic heart disease mortality.

It is possible that further analyses will identify a role for the factors utilized in these analyses in the mortality decline within particular subgroups. Work currently under way at the Human Population Laboratory is aimed at examining whether subgroups such as women smokers or those with prevalent disease have experienced lesser or greater declines.

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