Increasing inequalities in all-cause and cardiovascular mortality among US adults aged 25–64 years by area socioeconomic status, 1969–1998

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Background This study examined the extent to which areal socio-economic gradients in all-cause and cardiovascular disease (CVD) mortality among US men and women aged 25–64 years increased between 1969 and 1998.

Methods Using factor analysis 17 census tract variables were used to develop an areal index of socio-economic status that was used to stratify all US counties into five socio-economic categories. By linking the index to county-level mortality data from 1969 to 1998, we calculated annual age-adjusted mortality rates for each area socio-economic group. Poisson regression models were fitted to estimate areal socio-economic gradients in mortality over time.

Results Areal socio-economic gradients in all-cause and cardiovascular mortality have increased substantially over the past three decades. Compared to men in the highest area socio-economic group, rates of all-cause and CVD mortality among men in the lowest area socio-economic group were 42% and 30% greater in 1969–1970 and 73% and 79% greater in 1997–1998, respectively. The gradients in mortality among women were steeper for CVD than for all causes. Compared to women in the highest area socio-economic group, rates of all-cause and CVD mortality among women in the lowest area socio-economic group were 29% and 49% greater in 1969–1970 and 53% and 94% greater in 1997–1998, respectively.

Conclusions Although US all-cause and cardiovascular mortality declined for all area socio-economic groups during 1969–1998, the gradient increased because of significantly larger mortality declines in the higher socio-economic groups. Increasing areal inequalities in mortality shown here may be related to increasing temporal differences in the material and social living conditions between areas.

Keywords Mortality, cardiovascular, area socio-economic status, social inequality, time trend, Poisson regression

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In the US, as well as in many other industrialized countries, geographical variations in health and mortality have long been

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associated with socio-economic conditions or characteristics of areas. Using linked census and vital statistics data from metropolitan Chicago for the 1930–1960 time period and for the US in 1960, Kitagawa and Hauser showed that census tracts or metropolitan areas with higher levels of social and economic disadvantage had substantially higher mortality rates than less disadvantaged areas.[1] A recent ecological study of census tracts for the city of Chicago utilizing the 1990 census data and 1989–1991 death records showed substantial positive effects of area socio-economic disadvantage on infant and working-age mortality.[2] A recent large scale prospective study of residents in 18 US cities showed a substantial gradient in all-cause mortality rates for white and black men by median family income of

postal zip code areas.[3,4] Other recent studies have shown significant effects of county-level education and poverty on US childhood mortality as well as areal indices of socio-economic disadvantage on county-level all-cause and cause-specific mortality rates.[5–7]

Despite an abundance of cross-sectional studies of areal socio-economic disparities in health, the temporal monitoring of disease and mortality trends by area socio-economic characteristics remains far less common in the US than in the UK and many other European countries.[2,5–11] Area-based socio-economic deprivation indices, in particular, have been widely used to analyse and monitor health differentials in Europe, Australia, and New Zealand.[12–23] The studies that do examine temporal trends in US health and mortality differentials by area-based deprivation or inequality measures have focused on single areal measures.[1,24–29] Although increasing inequalities in US mortality by individual socio-economic measures have been documented, the extent to which temporal mortality variations by composite area indices have changed is not known.[30–32]

In this study, we develop a comprehensive, composite area-based measure of socio-economic status (SES) for the US using census tract data. We then link the areal index to the national mortality data at the county level and examine the extent to which socio-economic differentials in all-cause and cardiovascular mortality among US men and women aged 25–64 years changed between 1969 and 1998. We view this composite area-based measure as denoting a hierarchical classification of areas with respect to key socio-economic conditions.

In this study, we focus on the 25–64 age group because (1) it represents the prime working age population in the US and (2) the health impact of social structure and socio-economic conditions are generally greater for this group than for those aged <25 and ≥65 years.[1,6,33–36] Death rates for those aged 25–64 are also taken to represent premature adult mortality. In addition to all-cause mortality, we analyse trends in US cardiovascular disease (CVD) mortality because (1) cardiovascular diseases were the most prominent cause of death for those aged 25–64, accounting for 34% of all deaths during 1969–1998 and (2) steep SES gradients in CVD mortality have been reported for the US.[1,3,4,6,7,34–38]

Methods

Constructing an index of area socio-economic status

At the individual level, there is little disagreement about measures of SES: educational attainment, occupation, income, wealth, social class, and social status or prestige.[1,6,7,39–43] On the other hand, there is no consensus on the specific variables that comprise area SES—a composite, multidimensional concept.[6,7,39,40,44–47] However, it has been suggested that indicators defining this composite should directly or indirectly reflect the normative value, social good, or social welfare in a given community.[6,48] Thus, if an indicator changes in a favourable direction, it can be interpreted as having brought about improvements in living conditions or declines in deprivation. Indicators for constructing an area socio-economic index may be drawn from the broad sub-domains of education, income and wealth, employment, housing, and transportation.[6,7,20,39,47,48,49]

For the initial index construction, we considered 21 social and economic indicators that may be viewed as roughly approximating both absolute and distributive aspects of living conditions or socio-economic (dis)advantage in a community. These indicators, all drawn from the 1990 census, included educational distribution (2 variables: per cent population with <9 and >12 years of education), median family income, income disparity, occupational composition, unemployment rate, family poverty rate, 150% of the poverty rate, single-parent household rate, home ownership rate, median home value, median gross rent, median monthly mortgage, household crowding, per cent households without access to phone, plumbing, and motor vehicles, English language proficiency, divorce rate, per cent urban, and per cent immigrants.[50,51]

The above variables were selected on the basis of their theoretical relevance and prior empirical research.[1,2,6,7,12,20,21,39,41,45,52–54] Previous efforts to develop area socio-economic indices in the US have included such census variables as median household income, median home value, per cent households receiving interest, dividend or net rental income, per cent adults with at least a high school or college education and per cent employed in professional or managerial occupations. Additionally, other studies have included housing tenure, household crowding, unemployment rate, poverty rate, single-parent household rate, income disparity, monthly rent, automobile ownership, and immigration.[6,7,52–54]

The above variables were selected so as to broadly represent educational opportunities, labour force skills, and the economic and housing conditions prevailing in areas. Taken together, these variables may be viewed as reflecting key socio-economic resources available within a given population.[6,7] Areas with lower rates of educational achievement may have limited economic opportunities in terms of availability of jobs, reduced demand for skilled labour, and fewer resources like schools of higher education. Poverty rates measure extreme aspects of material deprivation in a community. The official poverty rate in the US is based on the absolute definition of poverty established in 1964, and is often criticized as a conservative measure of the extent of true poverty. A threshold level that is 150% above the poverty rate may better capture the level of extreme economic deprivation in an area.[6,7,43,47,55]

Besides poverty, income disparity measures the uneven distribution of economic resources. A higher percentage of single-parent households with young children is generally associated with greater economic deprivation. Similarly, divorce rate, generally an indicator of social disintegration, may reflect social disadvantage to the extent that it is associated with higher rates of poverty, unemployment and inadequate housing, and declines in social network relationships.[6] High values on median home value, mortgage, rent, home ownership, and median family income represent the relative affluence and wealth of communities. Lack of access to automobiles might often represent economic deprivation as well as transport difficulties, whereas household crowding, absence of telephones and adequate plumbing reflect substandard housing. Higher rates of unemployment lead to economic deprivation and poverty and shrinking labour market opportunities. The unemployment rate is also an indicator of social disintegration and is associated with higher divorce and suicide rates. White collar occupation includes those employed in professional, managerial, administrative, sales, and clerical occupations, and a higher concentration of such jobs may imply higher wage rates, more stable labour

markets, and a greater presence of large, profitable, high technology, and capital intensive industries.[6,56] Immigrant concentration and a higher proportion of population not proficient in English language are often associated with higher rates of poverty and economic hardship and lower wage rates, whereas a higher proportion of rural population in an area may be associated with higher rates of economic deprivation, substandard housing, increased transport difficulties, and fewer labour market opportunities and social amenities.[6]

The index construction was performed by applying factor and principal components analysis (PCA) methods.[57–59] The initial statistics from the factor analysis (not presented here) provided two factors (principal components) that respectively accounted for 43% and 17% of the variance in the data. Seventeen of the indicators clustered together and had considerably larger loadings (>0.45) on the first factor than on the second factor. However, three indicators, English language proficiency, per cent urban, and per cent immigrants had much smaller loadings (<0.25) on the first, but larger on the second factor. Divorce rate did not load highly on either factor. While the first factor clearly indicated a theoretically and empirically meaningful clustering of the given indicators, the second factor with only a few substantial loadings did not lend itself to any obvious theoretical interpretation. In the final phase of the index construction, we factor analysed 17 indicators with a single factor solution, the results of which are shown in Table 1.

The factor loadings (correlations of indicators with the index) for the tract SES index ranged from 0.92 for 150% of the poverty rate to 0.45 for household plumbing (Table 1). The 17 indicators comprising the index were weighted using the factor score coefficients. Poverty, income, and education had the largest relative weights in generating the index. The index accounted for 52% of the variance in the data. Since the original factor scale was a standard normal variate with a mean of 0 and a standard deviation of 1, the factor was transformed into a standardized index by arbitrarily setting the index mean and standard deviation to be 100 and 20, respectively. The index scores ranged from a low of 39.69 to a high of 129.78. The tract index scores were averaged to compute index scores for each of the 3097 US counties. Higher scores on the index denote higher levels of SES and lower levels of deprivation.

Using the PCA results, we computed the reliability coefficient, Cronbach's alpha, for the tract index to be 0.95, which indicates a high degree of internal consistency among the indicators comprising the index.[60] In order to further test the reliability of the tract index, we factor analysed 17 variables for different random subsamples of the US population (e.g. 5%, 10%, 25%, 50%, and 75% samples). The factor structure matrix containing the factor loadings for the different subsamples remained essentially unchanged, indicating a high degree of index reliability for different cross-sections of the 1990 population.

To determine whether the SES index was valid across different geographical units, we compared factor loadings for the same set of 17 indicators computed at the tract, zip code and county levels (Table 1). The factor loadings for the three geographical levels were generally similar in magnitude and relative importance. The per cent of variance explained and the reliability coefficient were almost identical for the tract and county indices.

We examined the predictive validity of the 1990 SES index by computing correlations of the index with a variety of county-level health outcomes, including infant mortality, low birthweight, all-cause mortality and mortality from various major

Table 1 Factor loadings and factor score coefficients for the census variables comprising the area socioeconomic index derived at census tract, zip code, and county levels: United States, 1990 (Principal components analysis of aggregate census data for 59 525 census tracts, 29 320 zip codes, and 3097 counties)

Census variable	Factor loadings tract index	Factor loadings zip code index	Factor loadings county index	Factor score coefficients tract index
% Population aged 25+ years with <9 years of education	−0.7498	−0.7383	−0.7885	−0.0849
% Population aged 25+ years with ⩾ high school diploma	0.8562	0.8089	0.8231	0.0970
% Employed aged 16+ in white collar occupations	0.7721	0.7118	0.6890	0.0874
Median family income ($)	0.8629	0.8690	0.9218	0.0977
Income disparity[a]	−0.8262	−0.7054	−0.8827	−0.0936
Median home value ($)	0.6074	0.6764	0.6740	0.0688
Median gross rent ($)	0.6896	0.7081	0.7876	0.0781
Median monthly mortgage ($)	0.6795	0.7362	0.7812	0.0770
% Owner-occupied housing units (home ownership rate)	0.5431	0.4688	0.4408	0.0615
Unemployment rate (% civilian labour force population aged 16+ unemployed)	−0.7117	−0.5231	−0.5679	−0.0806
% Families below poverty level	−0.8623	−0.7996	−0.8796	−0.0977
% Population below 150% of the poverty threshold	−0.9157	−0.8781	−0.9266	−0.1037
% Single-parent households with children aged <18 years	−0.6346	−0.3487	−0.3329	−0.0719
% Occupied housing units without a motor vehicle	−0.6126	−0.4335	−0.4549	−0.0694
% Occupied housing units without telephone	−0.7748	−0.6837	−0.7830	−0.0877
% Occupied housing units without complete plumbing (log)	−0.4505	−0.4863	−0.6392	−0.0510
% Occupied housing units with >1 person per room	−0.4910	−0.3963	−0.4018	−0.0556
Proportion of total variance explained by each factor	0.5195	0.4432	0.5140	
Cronbach's alpha (reliability coefficient)	0.9484	0.9311	0.9473	

[a] Income disparity was defined as the log of 100*ratio of no. of households with <$10 000 income to no. of households with $50 000+ income.

causes of death for the 1990–1996 period. All correlations were in the expected direction. The weighted correlation coefficients of the index with health outcomes were as follows: infant mortality rate (–0.48), low birthweight rate (–0.46), rates of mortality from all causes combined (–0.58), heart disease (–0.45), stroke (–0.24), all-cancers (–0.20), lung cancer (–0.27), breast cancer (0.19), cervical cancer (–0.51), melanoma (0.20), diabetes (–0.44), chronic obstructive pulmonary disease (COPD) (–0.14), cirrhosis (–0.25), unintentional injuries (–0.66), suicide (–0.27), and homicide (–0.39).

Computing annual age-sex-SES-specific rates and modelling areal socioeconomic gradients across time

To analyse mortality trends, we used the weighted population quintile distribution of the 1990 SES index that classified all US counties into five approximately equal population groups. The first (bottom) quintile represents the county group with the lowest SES scores; the second and third quintiles represent the second and third lowest area SES groups, respectively; the fourth quintile represents the second highest area SES group; and the fifth (top) quintile represents the highest area SES group. The five quintiles thus defined may also be viewed as ranging from being the most disadvantaged to the least disadvantaged areas.

Using national mortality data files, we obtained age-sex-county specific deaths from 1969 to 1998.[37,38] The mortality files, maintained by the National Center for Health Statistics, are based on information from death certificates of every death occurring in the US each year. In 1998, 2.34 million deaths occurred in the US.[38] The *US Standard Certificate of Death,* revised most recently in 1989, is the basis for the national mortality data. The *Standard Death Certificate* serves as the model for state death certificates in an effort to establish uniform certificates. Most state certificates conform closely to the standard, with modifications to meet particular state needs or legislation.[6,7,37,38] Although the principal responsibility for data collection, data processing, data quality maintenance and improvement rests with the states, the federal government is required to collect and publish national vital statistics data. The following variables on the death certificate are available: sex, race/ethnicity, age at death, place of birth and residence, educational attainment, occupation, industry, and marital status of decedent, cause of death, autopsy status, place of death, and injury at work.[6,7,37,38]

Age-sex-county specific population estimates from 1969 to 1998 prepared by the US Bureau of the Census served as denominators for computing rates.[51,61,62] Each of the 3097 counties in the mortality dataset was assigned one of the five areal socio-economic (deprivation) categories. For Alaska and Hawaii, state-specific rather than county-level data were used. We calculated annual age-adjusted and age-specific mortality rates for each socio-economic group. The rates were age-adjusted by the direct method using the age composition of the 1970 US population and 5-year age-specific death rates.

Log-linear models were used to estimate annual exponential rates of mortality decline.[32] Poisson regression models were fitted to age-sex-county-specific deaths and populations to estimate area socio-economic gradients in mortality for 15 2-year time periods as shown in Figure 3.[63] Socio-economic gradients (relative mortality risks) were estimated for men and

women separately, after adjusting for age. In all Poisson models, the highest area SES group was selected as the reference category. All models, estimated by the SAS Generalized Linear Models procedure, showed reasonable fit as determined by the likelihood ratio statistic or deviance.[64] In all models, 95% CI were adjusted for overdispersion. Trend tests were conducted by the χ^2 statistic derived through Poisson models that included age and area SES coded as a continuous variable. Additionally, a sensitivity analysis was conducted to assess the impact of large counties on mortality trends and to compare SES mortality trends based on the areal index defined for the three decennial time points, 1990, 1980, and 1970.

Results

Descriptive sociodemographic data in Table 2 indicate the relative stability and robustness of the county SES groupings between 1970 and 1990. Although all area SES groups experienced improved levels of educational attainment, their relative educational standing remained fairly similar during 1970–1990. Compared to the highest area SES group, the proportion of high school graduates in the lowest area SES group was 23%, 29%, and 36% lower in 1990, 1980, and 1970, respectively. The proportion of adults with less than 5 years of education was over three times greater in the lowest than in the highest area SES group in 1970. Similarly, the proportion of adults with <9 years of education was 2.4 to 2.8 times greater in the lowest than in the highest area SES group in 1980 and 1990.

Median family income was 66–92% greater in the highest than in the lowest area SES group during 1970–1990. Similarly, median home value was more than two times higher in the highest than in the lowest SES group in 1970, 1980, and 1990. The proportion of population in white collar occupations was 37% to 40% greater in the highest than in the lowest area SES group. Moreover, the poverty rate was at least three times higher in the lowest than in the highest area SES group.

Figure 1 shows increasing areal socio-economic gradients in all-cause mortality for both men and women over the past three decades. Not only did lower area SES groups have higher mortality than higher area SES groups in each calendar year, but the inverse gradient increased consistently across time. Although mortality rates for all area SES groups declined during the 1969–1998 period, the higher SES groups experienced larger mortality declines. The mortality rate for men in the lowest, the second lowest, the third lowest, the second highest, and the highest area SES groups declined, respectively, at an average annual rate of 1.27%, 1.56%, 1.69%, 1.65%, and 1.97% during 1969–1998. The corresponding average annual rates of decline for women were 0.97%, 1.19%, 1.25%, 1.45%, and 1.58%.

Figure 2 presents trends in CVD mortality. Like all-cause mortality, men and women in lower area SES groups had higher CVD mortality than those in higher area SES groups. The inverse SES gradient generally widened during 1969–1998 as men and women in higher area SES groups experienced larger reductions in CVD mortality than their counterparts in lower area SES groups. Cardiovascular mortality for men in the lowest, the second lowest, the third lowest, the second highest, and the highest area SES groups declined, respectively, at an average annual rate of 2.47%, 2.96%, 3.14%, 3.26%, and 3.66%

Table 2 Selected social and demographic characteristics of five area (county) socio-economic status (SES) groups (quintiles): United States, 1970–1990

Characteristic	Ist Quintile (Lowest SES)	2nd Quintile	3rd Quintile	4th Quintile	5th Quintile (Highest SES)
Mean index score	83.28	94.71	100.01	106.07	116.04
Range (index score)	39.69–91.97	91.98–97.48	97.49–103.03	103.04–110.55	110.56–129.78
Median county population size, 1990	15 709	20 844	41 588	86 793	225 338
Min. county population size, 1990	460	107	1025	2526	6012
Max. county population size, 1990	2 300 664	5 102 993	1 852 810	8 863 164	2 498 016
No. of counties, 1990	1484	760	486	226	141
% With education 12+ years, 1990	64.2	72.6	76.9	78.4	83.5
% With education 12+ years, 1980	54.0	63.5	68.1	71.6	76.4
% With education 12+ years, 1970	40.3	49.5	53.8	58.6	62.9
% With education <9 years, 1990	17.2	11.5	8.8	8.8	6.2
% With education <9 years, 1980	27.9	19.9	16.4	14.6	11.5
% With education <5 years, 1970	10.4	5.5	4.1	3.8	3.1
Median family income ($), 1990	23 774	28 231	32 025	36 853	45 754
Median family income ($), 1980	14 442	17 141	19 085	20 715	24 034
Median family income ($), 1970	6129	7760	8686	9553	11 006
Median home value ($), 1990	39 500	45 500	58 000	77 700	125 650
Median home value ($), 1980	26 650	33 500	39 900	47 550	63 600
Median home value ($), 1970	8642	11 322	13 742	16 390	21 215
% White collar occupation, 1990	48.8	54.5	56.3	60.8	66.7
% White collar occupation, 1980	44.4	49.7	51.4	56.2	61.3
% White collar occupation, 1970	40.4	45.0	46.8	52.1	56.7
% Families below poverty level, 1990	17.8	11.5	8.8	7.8	4.4
% Families below poverty level, 1980	16.0	10.3	8.2	7.8	5.1
% White families below poverty level, 1970	14.5	8.6	7.4	6.5	4.7
Unemployment rate, 1990	8.8	7.1	5.8	5.7	4.4
Unemployment rate, 1980	7.4	6.5	6.1	5.4	4.7
Unemployment rate, 1970	5.1	4.3	4.3	4.5	4.7
% Employed in manufacturing sector, 1990	19.0	18.2	18.1	16.7	16.5
% Employed in manufacturing sector, 1970	24.1	27.0	27.0	24.4	25.3
% Employed in agricultural sector, 1990	4.8	3.1	2.8	1.9	1.6
% Employed in agricultural sector, 1970	6.1	3.8	3.1	1.7	1.1
% Urban population, 1990	56.6	72.8	74.2	84.3	87.9
Income disparity, 1990	210.6	104.4	77.7	45.5	21.6
Income disparity, 1970	143.9	79.0	69.1	55.4	34.2
% Female-headed households, 1990	20.5	18.0	16.0	15.9	13.8
% Female-headed households, 1970	13.2	11.4	10.3	10.5	8.7
Female labour force participate rate (%), 1990	45.2	50.4	53.0	55.2	58.5
Female labour force participate rate (%), 1970	36.7	40.3	40.7	42.6	41.3
No. of doctors/10 000 population, 1990	17.3	21.4	21.3	22.2	25.1
No. of doctors/10 000 population, 1970	12.7	13.6	13.3	15.3	14.2
No. of nurses/10 000 population, 1990	55.3	71.8	79.5	80.4	92.0
No. of nurses/10 000 population, 1972	26.7	34.6	41.1	38.7	36.9
% Living in a different metro area, 1985–1990 (migration rate)	63.2	43.0	41.6	32.5	26.7
Work-related disability rate/1000 population, 1990	102.5	65.3	55.3	44.8	33.4
Violent crime rate/100 000 population, 1991	934.4	843.5	645.5	787.6	431.7
Age-adjusted homicide rate/100 000 population, 1990[a]	14.8	11.1	7.6	8.8	4.4
Age-adjusted suicide rate/100 000 population, 1990[a]	11.9	11.5	11.8	11.2	9.5
Population/square mile (pop. density), 1990	4349	1781	703	1866	1302
Population/square mile (pop. density), 1970	6440	2404	868	2115	1261

Source: 1990 Census and 1996 Area Resource File.

[a] Age-adjusted by the direct method using the 1970 US population composition as standard.
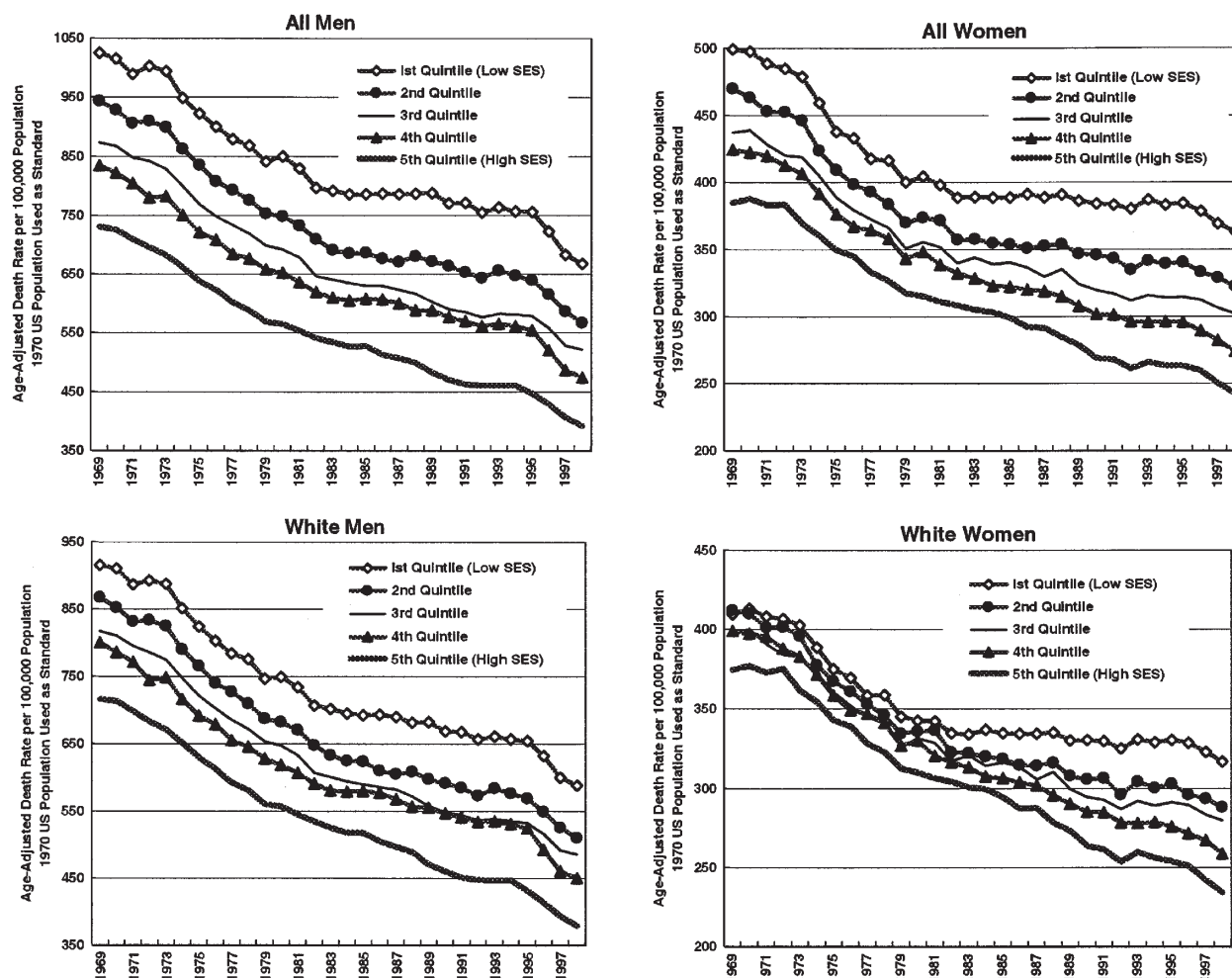
Figure 1 All-cause mortality among US men and women aged 25–64 years by the 1990 area socio-economic status (SES) index, 1969–1998

during 1969–1998. The corresponding annual rates of decline in CVD mortality for women were 2.01%, 2.43%, 2.56%, 2.66%, and 3.04%. All area SES groups experienced faster declines in CVD than in all-cause mortality.

Figures 1 and 2 also contain annual trends in age-adjusted all-cause and cardiovascular mortality rates for US white men and women. Although SES differentials in mortality among whites were somewhat smaller than those for the total population, the similar increasing gradient was observed for the white population.

Poisson regression models confirm the patterns observed in Figures 1 and 2. Figure 3 presents relative risks of all-cause and CVD mortality among men and women in five area SES groups after adjusting for age. Throughout the study period, there was an inverse and increasing socio-economic gradient in mortality risks among men and women. In 1969–1970 the risk of all-cause mortality was 42% greater among men in the lowest than in the highest area SES group. In 1985–1986, the risks of all-cause mortality for men in the two lowest area SES groups, respectively, were 53% and 32% greater than the risk for the highest area SES group. In 1997–1998, the differential widened even more, with all-cause mortality being 73% greater for men

in the lowest than in the highest area SES group. Areal socio-economic gradients in all-cause mortality were less steep for women than for men. Compared to women in the highest area SES group, all-cause mortality among women in the lowest area SES group was 29% greater in 1969–1970, 33% greater in 1985–1986, and 53% greater in 1997–1998.

Areal SES gradients in CVD mortality were generally similar to those for all-cause mortality for men but were larger and increased more rapidly than those in all-cause mortality for women (Figure 3). Compared to those in the highest area SES group, men in the lowest area SES group had a 30% higher risk of CVD mortality in 1969–1970, a 45% higher risk in 1985–1986, and a 79% higher risk in 1997–1998. The gradients in CVD mortality for women were steeper, with those in the lowest area SES group having a 49% higher risk than their counterparts in the highest area SES group in 1969–1970, 64% higher in 1985–1986, and 94% higher in 1997–1998.

Sensitivity analysis

We examined the extent to which mortality trends were affected by the inclusion of larger and potentially more heterogeneous counties. Figure 4 presents the results of this analysis after
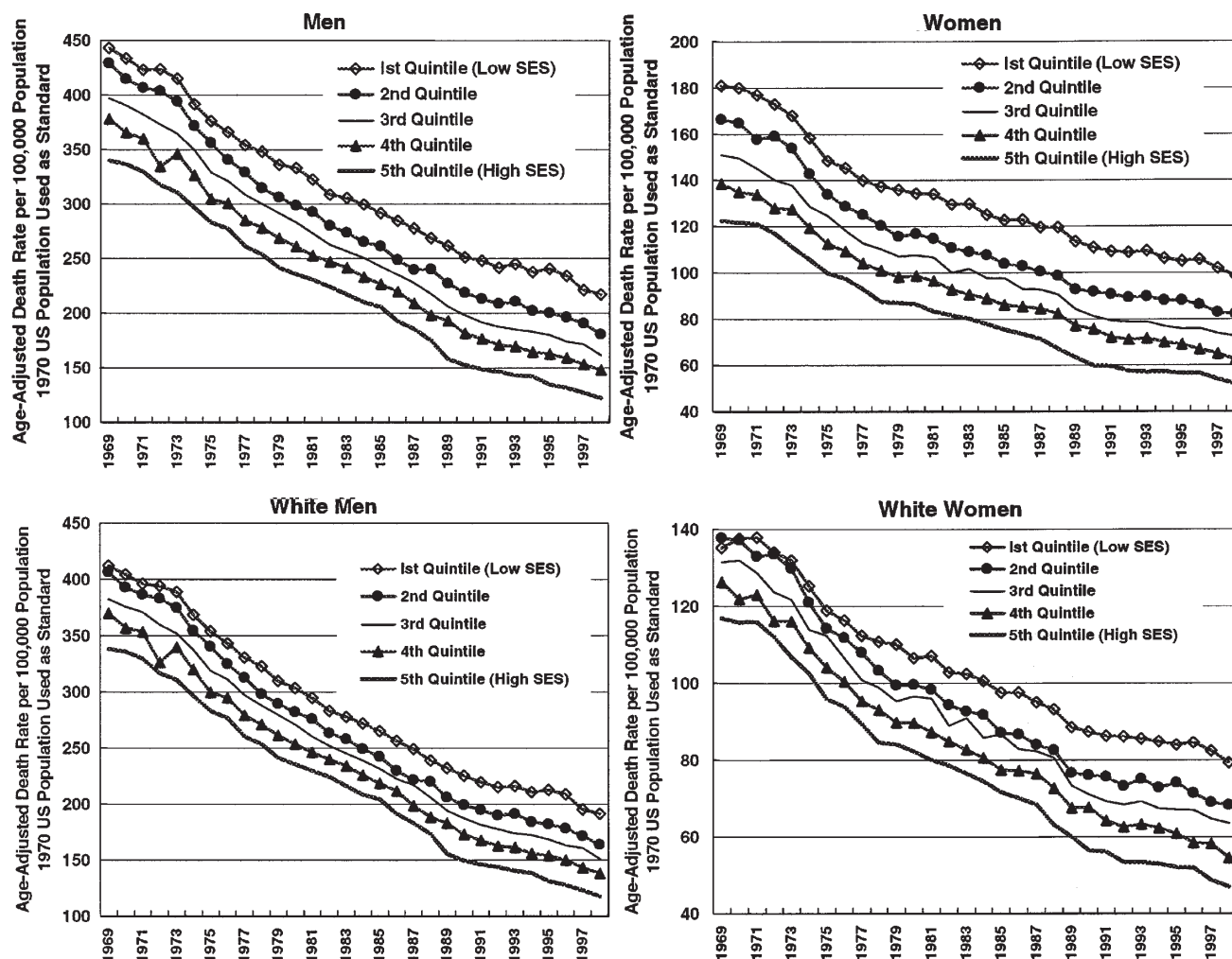
Figure 2 Cardiovascular disease (CVD) mortality among US men and women aged 25–64 years by the 1990 area socio-economic status (SES) index, 1969–1998

excluding counties with populations of 250 000 and 1 million or 56.7% and 23.6% of the total US population, respectively. As can be seen, the exclusion of these counties did not alter the general pattern of increasing areal SES inequalities in all-cause and CVD mortality.

Since census tract data were not available to us for the 1980 and 1970 censuses, we could not construct a similar area SES index for 1980 and 1970. However, county-level data were available for 1980 for 11 of the 17 variables used to construct the 1990 SES index.[51] These variables included per cent population with <9 years and ≥12 years of education, per cent white collar occupation, median family income, income disparity, median home value, median gross rent, unemployment rate, family poverty rate, per cent households without telephones and plumbing. For 1970, we had all of the 1980 variables except median rent.[51] Using the truncated set of variables, we created factor indices for 1980 and 1970. The 1980 and 1970 indices were highly correlated with the 1990 index, the correlation coefficients being 0.91 and 0.86, respectively. Similar associations were observed when the quintile classifications of the

1990, 1980, and 1970 indices were compared. The gamma (γ) statistic was 0.91 between 1990 and 1980 and 0.87 between 1990 and 1970.

Figure 5 presents mortality trends based on the 1970 and 1980 areal SES indices. Temporal trends in areal SES differentials in all-cause and CVD mortality based on the 1970 and 1980 indices were generally similar to those based on the 1990 index, although the magnitude of the SES differentials differed somewhat and the gradients based on the 1970 and 1980 indices were not as consistent as those derived from the 1990 index.

Discussion

In this study, we used a composite area measure to show increasing socio-economic gradients in all-cause and cardiovascular mortality among US adults aged 25–64 during the past three decades. Although previous studies have examined temporal inequalities in US mortality using single area SES measures, the present study uses a comprehensive area-based index to examine temporal socio-economic inequalities in mortality.
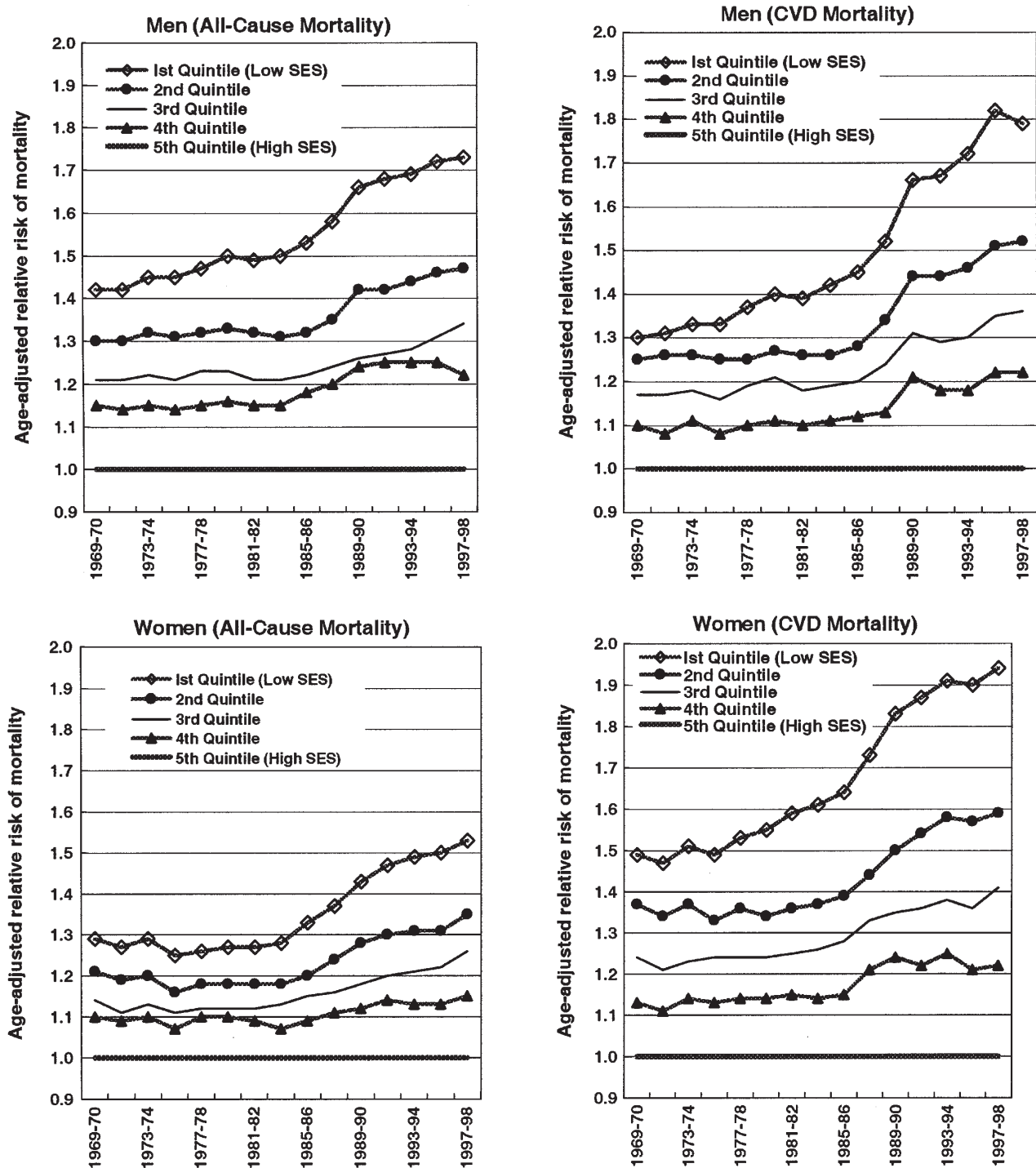
Figure 3 Age-adjusted relative risks of all-cause and cardiovascular (CVD) mortality among US men and women aged 25–64 years by 1990 area socio-economic status (SES) derived from Poisson regression models, 1969–1998

Notes. All relative risks of CVD mortality for men and women were statistically significant at $P < 0.0001$. All-cause relative mortality risks for men in all SES quintiles and for women in 1st and 2nd SES quintiles were significant at $P < 0.05$.

All-cause relative mortality risks for women in 3rd SES quintile was significant at $P < 0.05$ for all years except during 1969–1976 and for women in 4th SES quintile significant at $P < 0.05$ only for 1997–1998. All trend tests were significant at $P < 0.0001$.
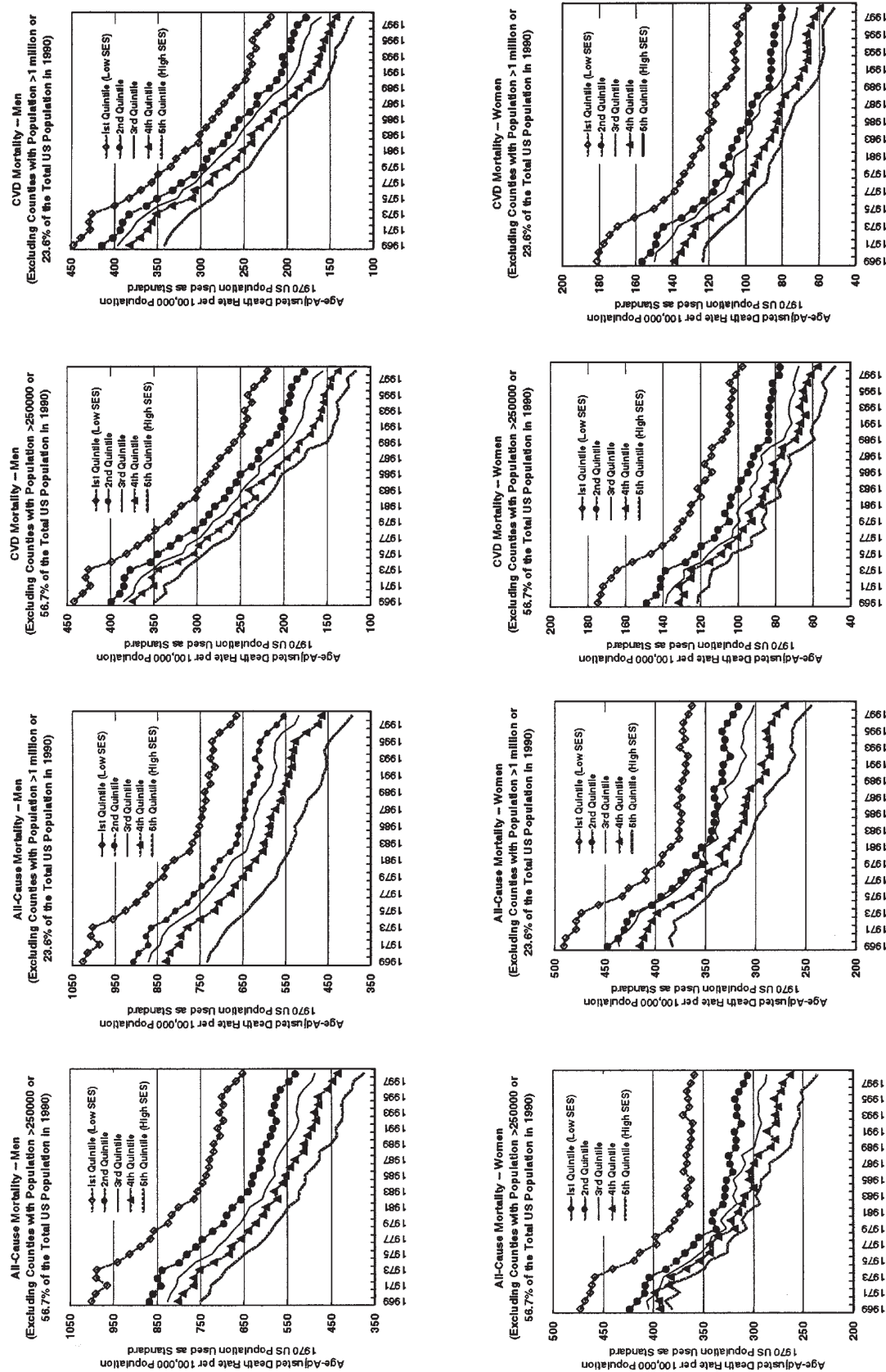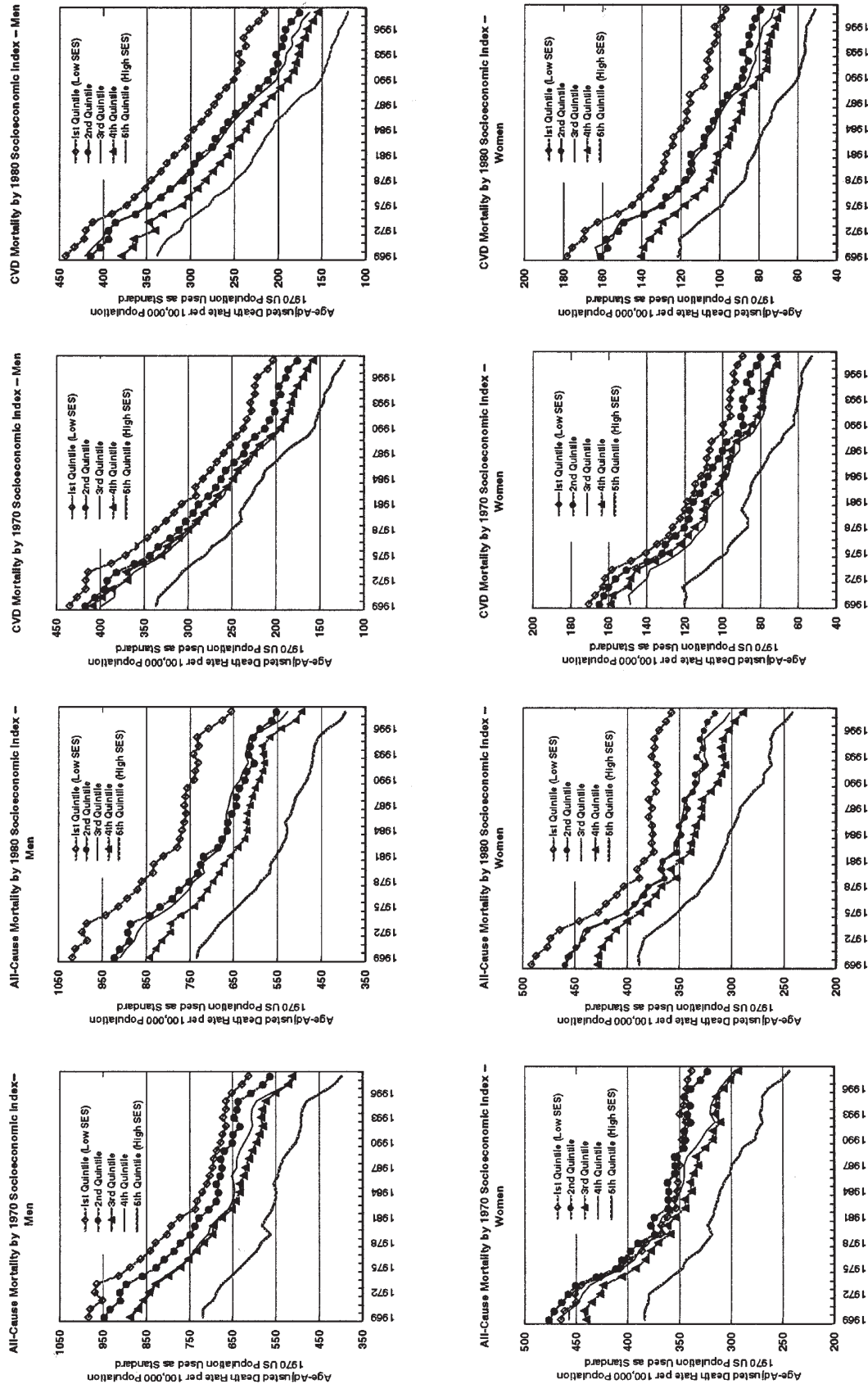
Figure 4 (Sensitivity analysis). All-cause and cardiovascular disease (CVD) mortality among US men and women aged 25–64 years by the 1990 area socio-economic status (SES) index and county population size

Figure 5 (Sensitivity analysis). All-cause and cardiovascular disease (CVD) mortality among US men and women aged 25–64 years by 1970 and 1980 area socio-economic status (SES) indices

Note. The 1970 and 1980 area socio-economic indices, although highly correlated with the 1990 area socio-economic index, are based on a truncated set of county-level variables.

Although the indicators used to construct the 1990 area index do not exhaust the domain of all indicators underlying area socio-economic status, they may be an adequate representation, especially of material aspects.[6] A more comprehensive index might include other aspects of social life, such as indicators that measure quality of working life (average working hours, travel time to work, work benefits), quality of housing, access to recreation, outdoor parks and other social amenities, public transportation, public safety, health care provision, civic and political participation, social and communities ties.[6,14,47,65] Although the indicators measuring these additional aspects were not available, it should be pointed out that some of the individual indicators comprising our index, such as education and income, might very well be correlated with health care provision, availability of social services, degree of political participation, community attachment, and the distribution of other valued resources in the community.[6,43]

An important property of the 1990 area index was its temporal stability. We have presented a variety of statistics to confirm the relative stability of socio-economic classification of counties based on the 1990 index during the 1969–1998 period. The use of the truncated 1970 and 1980 SES indices produced essentially similar trends in areal socio-economic inequalities in mortality.

The results of our study are consistent with previous studies in the US that have shown a widening of the area SES gradient and a greater reduction in heart disease mortality for the more affluent areas.[24–27] However, these studies vary greatly in terms of the choice of geographical areas as units of analysis and areal SES measures. Some studies have used census tracts and counties as the unit of analysis, while others have used state economic areas or aggregates of contiguous counties.[1,24–29] Although the Kitagawa and Hauser study showed consistent areal SES gradients in all-cause mortality for men and women aged ⩾65 years in Chicago (those in the lowest SES tracts having approximately twice the mortality rate of those in the highest SES tracts) in 1929–1931, 1940, 1950, and 1960, the areal SES mortality gradient was virtually stable over time, a result different from our finding of increasing inequalities in mortality.[1] Kitagawa and Hauser used median rent at the census tract level in 1930 and 1940 and tract median family income in 1950 and 1960 to define area socio-economic groupings. Although mortality declined for all SES groups over the 30-year period, the nearly two-fold mortality differential between the lowest and highest area SES groups remained.[1]

The size of the area SES gradient in our study was much greater than that reported by Armstrong *et al.* and Wing *et al.*[24,26] Wing *et al.* used per cent white collar occupation in a county as the areal measure to show an increasing inverse relationship between SES and ischaemic heart disease mortality during 1968–1982.[26] However, the size of the SES gradients were smaller in the Wing *et al.* study and the area SES differentials were somewhat larger for men than for women, a result different from results reported here which show larger SES gradients in CVD mortality for women than for men. A cross-sectional study of census tract socio-economic and mortality data in Ohio showed a steeper gradient in heart disease mortality in 1980 than the corresponding gradient in US cardiovascular mortality shown here.[10]

Mortality trends could be affected if the registration of deaths and the reporting of CVD as an underlying cause of death varied systematically between the area SES groups and over time. The registration of deaths in the US is believed to be almost 100% complete although the quality of medical certification on the death certificate may vary between geographical areas.[37] However, the use of the broader CVD category rather than specific major component causes such as coronary heart disease, stroke, or atherosclerosis reduces the likelihood of misclassifying cardiovascular deaths between areas and over time.

For confidentiality protection of individual information on death certificates, US mortality data are not available for geographical areas smaller than counties, such as zip codes, census tracts, or block groups. Because of substantial socio-economic and demographic heterogeneity, especially within large urban counties, the magnitude of the association between area SES and mortality may have been underestimated.[39] Despite this limitation, temporal county data do have certain advantages. Almost all US counties maintain fairly stable social, political, administrative and geographical boundaries over time. They are considerably less likely than census tracts (socio-economically homogeneous units with an average population of 4000) to experience substantial fluctuations in their sociodemographic composition during a specific decade or over time. Counties vary greatly in population size, from the smallest county of 107 people to the largest county of Los Angeles with a population of almost 9 million in 1990. The median and mean population size for all US counties in 1990 were 22 085 and 79 182, respectively.[50,51]

Although US counties are genuine political and administrative units, whether a large urban county of several millions (e.g. Los Angeles) can be usefully described as a community is often subject to debate. According to Warren, community may be defined as a social entity involving a common territorial space, people, shared institutions and interests, social interaction, distribution of power, and a social system.[66,67] US counties meet most if not all of these criteria. Counties are the smallest geographical entity in the US for which health, socio-economic, and population statistics are most consistently available. They are also the smallest geographical entity within a state with the social, political and legal responsibility for providing a broad range of social services, public safety, law enforcement, transportation, schools, workforce policies, and tax collection. Counties may also qualify as communities to the extent that they participate in community action and development by identifying county-wide problems or goals, collecting health, social and environmental data, and by formulating and implementing specific public policy measures.[66] Counties vary greatly with respect to the level of social interaction, with smaller rural counties being generally more cohesive, socially integrated and having a greater sense of community than larger urban counties which may be characterized by diverse social networks and social support systems, anonymity, heterogeneity, and formalized and impersonal relationships.[66,68] Caution should therefore be exercised when comparing large, socially heterogeneous counties with smaller, more homogeneous counties which tend to exhibit characteristics often associated with compact, cohesive neighbourhoods or localized communities.

As shown here and in many European studies, census-based indices could serve as a powerful tool for documenting and monitoring social inequalities in health over time. They provide

a summary description of diverse social and economic conditions in an area.[6] Some of these indices, like our areal index, could be temporally stable in their classification of areas and can therefore be used to assess the effects of specific societal interventions or policy programmes designed to reduce health disparities.[6] Areal indices can provide useful information in the context of health planning and resource allocation.[6,20,69] They can also be used in multilevel studies that examine the contextual effect of social environment on individuals' risks of poor health and mortality. Additionally, they can be used as a summary control variable in ecological studies that examine the net impact of environmental conditions, behavioural and health care factors.[39,69]

Areal socio-economic gradients in mortality should not be considered as proxies for socio-economic differentials at the individual level.[3,14,24,70–72] Such consideration may lead to the ecological fallacy. In this study, we have analysed county variations in mortality rates as a function of an ecological variable, area socio-economic status. Generally, the individual-level SES effects are larger than those at the societal level, and temporal trends in socio-economic inequalities in mortality based on individual level data may be more pronounced.[3,14,30,31,34,72]

The increasing areal inequalities in mortality shown here may be related to increasing temporal differences in the material and social living conditions between areas. Although the relative ranking of the area groups may have been stable during the study period, absolute differences in socio-economic conditions between them appear to have increased markedly (Table 2). The absolute income disparity between the lowest and highest area SES groups increased from $5000 in 1970 to $22 000 in 1990. Similarly, the gap in the median home value between the lowest and highest area SES groups widened from $12 600 in 1970 to over $86 000 in 1990. The change in the relative income disparity measure was also quite remarkable. The relative income disparity was four times greater in the lowest than in the highest area SES group in 1970, but the gap in relative income disparity widened to almost 10-fold in 1990. Unemployment differed very little in 1970, but in 1990 the rate was 4.3 percentage points higher in the lowest than in the highest area SES group. Also, the difference between lowest and highest area SES groups in female labour force participation and female-headed household rates was significantly larger in 1990 than in 1970. Data on health care personnel, such as the number of doctors and nurses per capita, also show a widening gap between the area SES groups during 1970–1990. Social disintegration or instability indicators such as rates of suicide, homicide, violent crime and migration tended to be generally higher in lower area SES groups, although in the absence of temporal data it is not clear the extent to which varying levels of social integration may account for areal socio-economic gradients in mortality.

It is important to note that although all of the variables used to define areal SES are derived from census microdata, these variables are characteristics of the aggregate population entities (e.g. census tracts or counties) and are not quite reducible to the level of the individual. Medians, means, percentages, rates, and numbers describing the distribution, composition, and size of the population are characteristics of aggregates.[43,47] Similarly, mortality rates are characteristics of a community or a population, not individuals. An explanation of the variation in such rates therefore requires a focus on the effects of social structural and population-level determinants.[43,47,73–75] Such a viewpoint is consistent with the Durkheimian notion that it is 'in the nature of the society itself that we must seek the explanation of social life'.[76] The structure of social stratification is external to individuals, systematically influencing options, choices or opportunities that are available to members of a population.[43] As Schwartz and Diez-Roux contend, variations in laws, customs, physical environments, and social network characteristics may very well be the most important explanations of population variations in disease rates.[75] While identifying major determinants of the widening socio-economic gradients in US all-cause and CVD mortality remains an important challenge for future research, in policy terms narrowing the socio-economic gap between affluent and disadvantaged areas has the potential to substantially reduce mortality.

KEY MESSAGES

- A composite, census-based index of area socio-economic status is developed for the US, which shows temporal stability in its relative socio-economic classification of counties.

- Higher levels of area socio-economic deprivation are associated with substantially higher all-cause and cardiovascular mortality rates among US men and women aged 25–64 years.

- Areal socio-economic inequalities in US all-cause and cardiovascular mortality increased substantially between 1969 and 1998.

- Increasing areal inequalities in US mortality may be related to increasing temporal differences in the material and social living conditions between areas.

- While identifying major determinants of the widening socio-economic gradients in US mortality remains an important challenge for future research, in policy terms narrowing the socio-economic gap between affluent and disadvantaged areas has the potential to substantially reduce mortality.

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