- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

# Association of socioeconomic position with health behaviors and mortality

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

Stringhini, Silvia; Sabia, Séverine; Shipley, Martin; Brunner, Eric; Nabi, Hermann; Kivimaki, Mika; Singh-Manoux, Archana

# Association of Socioeconomic Position With Health Behaviors and Mortality

Silvia Stringhini, MSc

Séverine Sabia, PhD

Martin Shipley, MSc

Eric Brunner, PhD

Hermann Nabi, PhD

Mika Kivimaki, PhD

Archana Singh-Manoux, PhD

L IFESTYLE AND HEALTH-RELATED behaviors are recognized as major determinants of morbidity and mortality worldwide.[1-3] Concurrently, there is evidence to suggest that the socioeconomic differences in morbidity and mortality have increased.[4-6] The higher prevalence of unhealthy behaviors in lower socioeconomic positions[7-9] is seen to be one of the mechanisms linking lower socioeconomic position to worse health.[10,11] Combinations of potentially modifiable behavioral factors such as smoking, alcohol consumption, dietary patterns, physical activity, and body mass index have been shown to explain 12% to 54% of the socioeconomic differences in mortality.[12-17] In those studies, health behaviors typically have been assessed at only 1 point in time, assuming implicitly that they remain constant over time.

However, major changes have occurred in population lifestyles. These include the decreasing prevalence of smoking[18] and a remarkable increase in obesity since the 1990s.[19] Given that changes in health behaviors may be socially patterned,[20,21] previous studies with a single assessment of behaviors may have provided an inaccurate esti-

**Context** Previous studies may have underestimated the contribution of health behaviors to social inequalities in mortality because health behaviors were assessed only at the baseline of the study.

**Objective** To examine the role of health behaviors in the association between socioeconomic position and mortality and compare whether their contribution differs when assessed at only 1 point in time with that assessed longitudinally through the follow-up period.

**Design, Setting, and Participants** Established in 1985, the British Whitehall II longitudinal cohort study includes 10 308 civil servants, aged 35 to 55 years, living in London, England. Analyses are based on 9590 men and women followed up for mortality until April 30, 2009. Socioeconomic position was derived from civil service employment grade (high, intermediate, and low) at baseline. Smoking, alcohol consumption, diet, and physical activity were assessed 4 times during the follow-up period.

**Main Outcome Measures** All-cause and cause-specific mortality.

**Results** A total of 654 participants died during the follow-up period. In the analyses adjusted for sex and year of birth, those with the lowest socioeconomic position had 1.60 times higher risk of death from all causes than those with the highest socioeconomic position (a rate difference of 1.94/1000 person-years). This association was attenuated by 42% (95% confidence interval [CI], 21%-94%) when health behaviors assessed at baseline were entered into the model and by 72% (95% CI, 42%-154%) when they were entered as time-dependent covariates. The corresponding attenuations were 29% (95% CI, 11%-54%) and 45% (95% CI, 24%-79%) for cardiovascular mortality and 61% (95% CI, 16%-425%) and 94% (95% CI, 35%-595%) for noncancer and noncardiovascular mortality. The difference between the baseline only and repeated assessments of health behaviors was mostly due to an increased explanatory power of diet (from 7% to 17% for all-cause mortality, respectively), physical activity (from 5% to 21% for all-cause mortality), and alcohol consumption (from 3% to 12% for all-cause mortality). The role of smoking, the strongest mediator in these analyses, did not change when using baseline or repeat assessments (from 32% to 35% for all-cause mortality).

**Conclusion** In a civil service population in London, England, there was an association between socioeconomic position and mortality that was substantially accounted for by adjustment for health behaviors, particularly when the behaviors were assessed repeatedly.

*JAMA. 2010;303(12):1159-1166*                                    www.jama.com

mation of their contribution to the association between socioeconomic factors and mortality. In this study, health behaviors over a 24-year period were used to assess their role when only baseline measures were used compared with when measures were repeated over the follow-up period. We further examined whether this difference is similar

**Author Affiliations:** INSERM U1018, Centre for Research in Epidemiology and Population Health, Villejuif, France (Ms Stringhini and Drs Sabia, Nabi, and Singh-Manoux); Department of Epidemiology and Public Health, University College London, London, England (Mr Shipley and Drs Brunner, Kivimaki, and Singh-Manoux); and Centre de Gérontologie, Hôpital Ste Périne, AP-HP, Paris, France (Dr Singh-Manoux).
**Corresponding Author:** Silvia Stringhini, MSc, INSERM U1018, Centre for Research in Epidemiology and Population Health, Hôpital Paul Brousse, Bât 15/16, 16 Avenue Paul Vaillant Couturier, 94807 Villejuif Cedex, France (silvia.stringhini@inserm.fr).

for the 4 health behaviors of smoking, alcohol consumption, diet, and physical activity.

## METHODS

### Study Population

The British Whitehall II cohort was established in 1985 to examine the socioeconomic gradient in health and disease among 10 308 civil servants.[22] All civil servants, aged 35 to 55 years and working in 20 departments in London, England, were invited to participate by letter and 73% agreed. Baseline examination (phase 1) took place during 1985-1988 and involved a clinical examination and a self-administered questionnaire containing sections on demographic characteristics, health, lifestyle factors, work characteristics, social support, and life events. Individuals provided informed written consent to participate and the University College London ethics committee approved the study.

### Socioeconomic Position

Socioeconomic position is approximated by the British civil service occupational grade at baseline; a 3-level variable representing high (administrative), intermediate (professional or executive), and low (clerical or support) grades. This measure is a comprehensive marker of socioeconomic circumstances and is related to salary, social status, level of responsibility at work, and future pension.[23] Administrative grades in the British civil service represent the highest grades; administrators run the different government departments.

### Health Behaviors

Data on health behaviors were drawn from phase 1 (1985-1988), phase 3 (1991-1993), phase 5 (1997-1999), and phase 7 (2002-2004) of the study. Smoking status was self-reported (never, former, or current). Alcohol consumption was assessed using questions on the number of alcoholic drinks (measures of spirits, glasses of wine, and pints of beer) consumed in the last week. This was converted to number of alcohol units (1 unit corre-

sponds to 8 g of alcohol) consumed per week.[24] Participants' alcohol consumption was categorized as never (0 unit/week), moderate (1-21 units/week for men, 1-14 for women), and heavy (>21 units/week for men, >14 for women). Dietary patterns were assessed via questions on the frequency of fruit and vegetable consumption (8-point scale, ranging from seldom or never to ≥2 times per day), the type of bread (white, brown, or both), and milk (no, whole, semi-skimmed, skimmed, other) consumed. A diet score was calculated and classified as (1) unhealthy if participants ate white bread most frequently, consumed whole milk, and ate fruit and vegetables less than 3 times per month; (2) healthy if they ate wholemeal, wheatmeal, or other brown bread most frequently, did not consume milk or only used skimmed or other types of milk, and ate fruit and vegetables daily or 2 or more times per day; or (3) moderately healthy if their dietary pattern was in between these 2 descriptions. Physical activity was assessed at phases 1 and 3 based on answers to questions about the frequency and duration of participation in mildly energetic (eg, weeding, general housework, bicycle repair), moderately energetic (eg, dancing, cycling, leisurely swimming), and vigorous physical activity (eg, running, hard swimming, playing squash). At phases 5 and 7, the questionnaire was modified to include 20 items on frequency and duration of participation in different physical activities (eg, walking, cycling, sports) that were used to compute hours per week of each intensity level. Participants were classified as active (>2.5 hours/week of moderate physical activity or >1 hour/week of vigorous physical activity), inactive (<1 hour/week of moderate physical activity and <1 hour/week of vigorous physical activity), or moderately active (if not active or inactive). For 20% of the participants, data on health behaviors were missing at 1 of the follow-up assessments (phases 3, 5, or 7); missing data were replaced with data from

1 phase immediately prior or subsequent to that phase.

### Mortality

A total of 10 297 participants (99.9%) were successfully traced and have been followed up for mortality through the national mortality register kept by the National Health Services Central Registry, using the National Health Service identification number assigned to each British citizen. Mortality follow-up, including the cause of death, was available until April 30, 2009: a mean of 19.4 years.

All-cause mortality, cancer mortality, cardiovascular disease mortality, and noncancer and noncardiovascular disease mortality were examined. The *International Classification of Diseases, Ninth Revision (ICD-9)*, and *10th Revision (ICD-10)* codes were used to define cancer (*ICD-9* 140.0-209.9 and *ICD-10* C00-C97) and cardiovascular disease (*ICD-9* 390.0-458.9, *ICD-10* I00-I99) mortality. Noncancer and noncardiovascular disease mortality includes all remaining deaths not classified as cancer or cardiovascular disease. This embraced various causes of death, the most common being diseases of the respiratory system (*ICD-9* 460.0-519.9 and *ICD-10* J00-J99); diseases of the digestive system (*ICD-9* 520.0-579.9 and *ICD-10* K00-K93); injuries, poisoning, and external causes of death (*ICD-9* 800.0-999.9 and *ICD-10* S00-T98); and diseases of the nervous system (*ICD-9* 320.0-389.9 and *ICD-10* G00-G99).

### Statistical Analysis

For each socioeconomic position and health behavior, mortality rates per 1000 person-years and 95% confidence intervals (CIs)[25] were calculated for all-cause, cancer, cardiovascular disease, and noncancer and noncardiovascular disease mortality. These rates were standardized for age at baseline (4-year age groups) and sex, using the whole analytical sample as the standard population. Subsequently, Cox proportional regression analysis with age as the time scale was used to estimate the hazard ratios (HRs) and their 95% CIs for the as-

sociation between socioeconomic position and mortality. Of the 9590 participants with information on the 4 health behaviors at baseline, 7344 had complete data on all health behaviors at all phases prior to being censored at their date of death or at the end of follow-up (April 30, 2009). The remaining 2246 participants were censored at the last date at which they had complete data (after imputation) for all health behaviors in the preceding phases.

In the Cox regression, the first model included adjustment for sex and year of birth (model 1). Subsequently, the 4 health behaviors of smoking status, alcohol consumption, dietary patterns, and physical activity that were assessed at baseline were entered one at a time and then simultaneously into model 1. In the second set of analyses, this procedure was repeated with the health behaviors assessed at phases 1, 3, 5, and 7 that were entered as time-dependent covariates. In both these analyses, the measure of socioeconomic position was used as a continuous 3-level variable. The HR for 1 unit change was squared to correspond to the increased risk of mortality in participants with the lowest socioeconomic position compared with those with the highest socioeconomic position under the assumption of linearity of association between socioeconomic position and mortality.

The mediating role of each health behavior was determined by the percentage reduction in the coefficient for socioeconomic position after inclusion of the health behaviors in question, using the formula: $100 \times (\beta_{Model\ 1} - \beta_{Model\ 1 + health\ behaviors})/(\beta_{Model\ 1})$. A 95% CI was then calculated around the percentage attenuation using a bias-corrected accelerated bootstrap method with 2000 resamplings.[26] The same procedure was used to test the difference between adjustment for health behaviors assessed at baseline and health behaviors assessed longitudinally. If the 95% CI did not include 0, the estimations from the 2 models were considered to be different.

**Table 1.** Baseline Characteristics by Socioeconomic Position[a]

| Characteristics | Socioeconomic Position (N = 9590) | | |
| --- | --- | --- | --- |
| | High (n = 2867) | Intermediate (n = 4663) | Low (n = 2060) |
| Age, mean (SD), y | 45.0 (5.8) | 43.3 (6.0) | 46.0 (6.0) |
| No. (%) of Participants [SE] | | | |
| Male sex | 2513 (87.7) [0.6] | 3429 (73.5) [0.6] | 569 (27.6) [1.0] |
| University degree[b] | 1473 (56.6) [0.9] | 793 (18.8) [0.6] | 104 (5.9) [0.5] |
| Smokers | 290 (10.1) [0.6] | 845 (18.1) [0.5] | 612 (29.7) [1.0] |
| Alcohol consumption | | | |
| Never | 227 (7.9) [0.5] | 745 (16.0) [0.5] | 747 (36.3) [1.1] |
| Heavy | 558 (19.5) [0.7] | 821 (17.6) [0.6] | 142 (6.9) [0.6] |
| Unhealthy diet[c] | 167 (5.8) [0.4] | 507 (10.9) [0.5] | 306 (14.9) [0.8] |
| Physically inactive[d] | 189 (6.6) [0.5] | 512 (11.0) [0.5] | 730 (35.4) [1.1] |

[a] Socioeconomic position is related to salary. Salary range on August 1, 1992, was drawn from employers' records. The conversion rate on August 1, 1992, was £1 to US $1.92. High indicates administrative grade (salary range: £25 330-£87 620); intermediate, professional or executive grade (salary range: £8517-£25 554); and low, clerical or support grade (salary range: £7387-£11 917). Administrative grades in the British civil service represent the highest grades; administrators run the different government departments. For all baseline characteristics, the tests for heterogeneity across socioeconomic position groups were significant ($P < .001$).
[b] The measure of education was available for 89% of the study population and is presented for descriptive purposes only.
[c] Defined as eating white bread most frequently, drinking whole milk, and eating fruit and vegetables less than 3 times per month.
[d] Defined as performing less than 1 hour per week of moderate physical activity and less than 1 hour per week of vigorous physical activity.

The proportional hazard assumptions for Cox regression models (tested using Schoenfeld residuals) were not violated. Statistical tests were 2-sided and a *P* value of less than .05 was considered statistically significant. The main analysis was performed using Stata statistical software version 10 (StataCorp, College Station, Texas). Bootstrap 95% CIs were calculated using SAS statistical software version 9 (SAS Institute Inc, Cary, North Carolina) using the %BOOT and %BOOTCI macros.

## RESULTS

A total of 707 participants were excluded from the analysis because they had missing data on health behaviors at baseline (smoking: n=89; alcohol consumption: n=94; diet: n=162; physical activity: n=416; these categories were not mutually exclusive) and 11 participants were excluded because they had not been followed-up for mortality (corresponding to 7% of the total baseline population). The analysis was based on the remaining 9590 participants (68% male and 32% female). More of those excluded at baseline were from the lowest socioeconomic position (39% vs 21%; *P*<.001). There were no age differences be-

tween the included and excluded men (44.3 vs 44.0 years; *P*=.34), but the women with missing data were older (46.7 vs 45.0 years; *P*<.001). For 5 individuals, the cause of death was not known and they were excluded from the cause-specific analysis.

TABLE 1 shows characteristics of the study population. There was a marked social gradient in health behaviors at baseline. Participants in the lower socioeconomic positions were more likely to smoke, abstain from alcohol consumption, follow an unhealthy diet, and be physically inactive and less likely to consume heavy amounts of alcohol (all *P*<.001). Over the total follow-up (data not shown), the prevalence of smoking decreased from 10.1% to 4.8% among participants in the highest socioeconomic position and from 29.7% to 16.5% in the lowest socioeconomic position. Alcohol abstention changed little among participants in the highest socioeconomic position (from 7.9% to 7.7%), but increased among participants in the lowest socioeconomic position (from 36.3% to 42.2%). The prevalence of unhealthy diet decreased from 5.8% to 1.0% in the highest socioeconomic position and from 14.9% to 5.2% in the lowest socioeco-

nomic position. However, the prevalence of sedentary behavior increased from 6.6% to 21.4% in the highest socioeconomic position and from 35.4% to 41.6% in the lowest socioeconomic position. In terms of relative differences between the lowest and highest socioeconomic positions, the changes in prevalence indicate increased differences for smoking (from a ratio of 2.9 to 3.4), alcohol abstention (from a ratio of 4.6 to 5.5), and unhealthy diet (from a ratio of 2.6 to 5.2); there was a decreased difference for sedentary behavior (from a ratio of 5.4 to 1.9).

A total of 654 participants died during the 24-year follow-up. The most common causes of death were cancer (n=311) and cardiovascular disease (n=188). TABLE 2 shows age- and sex-standardized mortality rates per 1000 person-years for all causes, cancer, cardiovascular disease, and other (noncancer and noncardiovascular disease). There was a graded association between socioeconomic position and all-cause, cardiovascular disease, and other mortality. However, the HR for cancer mortality for lowest vs highest socioeconomic position was 1.07 (95% CI, 0.76-1.52) in a model adjusted for sex and birth year (a rate difference of −0.01 per 1000 person-years). Health behaviors were associated with mortality with the exception of diet for cardiovascular disease mortality and physical activity for cancer mortality in which there was no clear pattern (Table 2). There was a U-shaped relationship between alcohol consumption and all-cause mortality. Participants who abstain from alcohol consumption were at higher risk for cardiovascular disease mortality. Those who consumed heavy amounts of alcohol were at higher risk for cancer mortality. No further analyses were performed on cancer mortality.

Results on the mediating role of health behaviors are presented in TABLE 3 for all-cause mortality, TABLE 4 for cardiovascular disease mortality, and TABLE 5 for noncancer and noncardiovascular disease mortality. For all-cause mortality, the HR for lowest vs highest socioeconomic position was 1.60 (95% CI, 1.26-2.04) in the model adjusted for sex and year of birth (a rate difference of 1.94/1000 person-years). When health behaviors at baseline were added to this model, only smoking substantially attenuated the HR by 32% (95% CI, 21%-70%). When health behaviors were entered as time-dependent covariates, the attenuation for smoking was similar to that using only the baseline measure but the explanatory power of the other behaviors improved substantially. For alcohol consumption, it improved by 9% (95% CI, 0%-25%), for diet by 10% (95% CI, 0%-28%), and for physical activity by 16% (95% CI, 4%-39%). Overall, health behaviors assessed at baseline explained 42% (95% CI, 21%-94%) of the association between socioeconomic position and all-cause mortality; this increased to 72% (95%

**Table 2.** Mortality as a Function of Socioeconomic Position and Health Behaviors at Baseline

| | All-Cause Mortality | | Cancer Mortality | | Cardiovascular Disease Mortality | | Other Mortality[a] | |
|---|---|---|---|---|---|---|---|---|
| | No. | Rate (95% CI)[b] | No. | Rate (95% CI)[b] | No. | Rate (95% CI)[b] | No. | Rate (95% CI)[b] |
| Overall (N = 9590) | 654 | 3.56 (3.29 to 3.84) | 311 | 1.70 (1.52 to 1.90) | 188 | 1.02 (0.89 to 1.18) | 155 | 0.84 (0.72 to 0.98) |
| **Socioeconomic position** | | | | | | | | |
| High (n = 2867) | 191 | 2.99 (2.48 to 3.60) | 94 | 1.57 (1.20 to 2.06) | 52 | 0.63 (0.48 to 0.83) | 45 | 0.78 (0.52 to 1.17) |
| Intermediate (n = 4663) | 306 | 3.68 (3.29 to 4.13) | 151 | 1.86 (1.58 to 2.19) | 78 | 0.95 (0.76 to 1.19) | 77 | 0.88 (0.70 to 1.10) |
| Low (n = 2060) | 157 | 4.93 (4.00 to 6.06) | 66 | 1.56 (1.12 to 2.18) | 58 | 2.21 (1.60 to 3.06) | 33 | 1.16 (0.75 to 1.79) |
| Difference (low minus high) | | 1.94 (0.78 to 3.10) | | −0.01 (−0.68 to 0.66) | | 1.58 (0.84 to 2.32) | | 0.38 (−0.22 to 0.98) |
| **Health behaviors** | | | | | | | | |
| Smoking | | | | | | | | |
| Never (n = 4746) | 258 | 2.83 (2.50 to 3.20) | 131 | 1.24 (1.19 to 1.68) | 73 | 0.82 (0.65 to 1.03) | 54 | 0.59 (0.45 to 0.78) |
| Former (n = 3097) | 204 | 3.16 (2.75 to 3.64) | 91 | 1.41 (1.14 to 1.75) | 65 | 1.01 (0.78 to 1.29) | 48 | 0.74 (0.56 to 1.00) |
| Current (n = 1747) | 192 | 6.47 (5.60 to 7.47) | 89 | 2.94 (2.37 to 3.63) | 50 | 1.79 (1.35 to 2.37) | 53 | 1.75 (1.33 to 2.30) |
| Alcohol consumption | | | | | | | | |
| Never (n = 1719) | 136 | 4.29 (3.59 to 5.12) | 49 | 1.43 (1.06 to 1.93) | 58 | 1.92 (1.46 to 2.51) | 29 | 0.94 (0.64 to 1.38) |
| Moderate (n = 6350) | 391 | 3.14 (2.84 to 3.47) | 191 | 1.55 (1.35 to 1.79) | 110 | 0.87 (0.72 to 1.05) | 90 | 0.72 (0.58 to 0.88) |
| Heavy (n = 1521) | 127 | 4.63 (3.82 to 5.60) | 71 | 2.70 (2.09 to 3.48) | 20 | 0.66 (0.41 to 1.06) | 36 | 1.27 (0.89 to 1.81) |
| Diet | | | | | | | | |
| Healthy (n = 1140) | 62 | 2.85 (2.20 to 3.70) | 28 | 1.25 (0.85 to 1.85) | 20 | 0.98 (0.62 to 1.54) | 14 | 0.62 (0.36 to 1.06) |
| Moderately healthy (n = 7470) | 515 | 3.56 (3.26 to 3.88) | 248 | 1.72 (1.52 to 1.95) | 152 | 1.05 (0.89 to 1.23) | 115 | 0.79 (0.66 to 0.95) |
| Unhealthy (n = 980) | 77 | 4.28 (3.41 to 5.38) | 35 | 1.94 (1.39 to 2.72) | 16 | 0.93 (0.56 to 1.53) | 26 | 1.41 (0.96 to 2.09) |
| Physical activity | | | | | | | | |
| Active (n = 1431) | 368 | 3.26 (2.93 to 3.62) | 183 | 1.66 (1.43 to 1.93) | 97 | 0.84 (0.69 to 1.03) | 26 | 0.75 (0.61 to 0.93) |
| Moderately active (n = 2240) | 173 | 4.03 (3.47 to 4.68) | 79 | 1.83 (1.46 to 2.28) | 53 | 1.25 (0.95 to 1.63) | 41 | 0.96 (0.70 to 1.30) |
| Sedentary (n = 5919) | 113 | 3.90 (3.17 to 4.80) | 49 | 1.55 (1.13 to 2.13) | 38 | 1.43 (1.01 to 2.04) | 88 | 0.91 (0.59 to 1.41) |

Abbreviation: CI, confidence interval.
[a] Indicates noncancer and noncardiovascular disease.
[b] The mortality rates were standardized for age and sex. The rates are per 1000 person-years.

CI, 42%-154%) when they were entered as time-dependent covariates, which is a difference of 30% (95% CI, 10%-70%).

The HR for cardiovascular disease mortality for the lowest socioeconomic position compared with the highest socioeconomic position was 3.05 (95% CI, 1.94-4.78) in the model adjusted for sex and year of birth (a rate difference of 1.58/1000 person-years; Table 4). Adding smoking to the model (using the baseline smoking data only or repeated measures of smoking) reduced the HR by 12% (95% CI, 5%-25%). Of the 4 health behaviors, only the effect of diet was significantly greater, which reduced the HR by 10% (95% CI, 3%-22%), when assessed repeatedly through the follow-up period. However, all health behaviors taken together at baseline explained 29% (95% CI, 11%-54%) of the gradient for cardiovascular mortality and 45% (95% CI, 24%-79%) when they were entered as time-dependent covariates. Compared with participants in the highest socioeconomic position, those in the lowest socioeconomic position had a greater risk of noncancer and noncardiovascular disease mortality (HR, 1.67; 95% CI, 1.01-2.75, which is a rate difference of 0.38/1000 person-years; Table 5). Longitudinal assessment of all 4 health behaviors explained 94% (95% CI, 35%-595%) of this association. The contribution of health behaviors was significantly greater only for physical activity (a difference of 33%; 95% CI, 3%-221%).

It is possible that participants who died early in the follow-up period did not benefit from the effect of recent policies aimed at improving lifestyles. Because this could be a source of bias in the analyses, all analyses were repeated with follow-up time as the time scale and age as a covariate. These results were not different compared with those using age as the time scale. All analyses on all-cause mortality also were repeated including only participants with complete data on health behaviors at all phases (the results did not differ).

The measure of socioeconomic position at baseline was used in all analyses because different estimates of the socioeconomic gradient for the baseline and the longitudinal model would not allow comparisons to be made for the effect of health behaviors. However, in supplementary analyses, the socioeconomic gradient remained the same throughout the follow-up period. This was verified by entering the measure of socioeconomic position as a time-dependent covariate. In analyses adjusted for sex and year of birth, the HRs

**Table 3.** Role of Health Behaviors in Explaining the Association Between Socioeconomic Position and All-Cause Mortality [a]

| | Assessment of Health Behaviors | | | | Difference Between Baseline and Longitudinal Assessments, % Attenuation (95% CI) [c] |
| | Baseline (Phase 1) | | Phases 1, 3, 5 and 7 | | |
| | HR (95% CI) | % Attenuation (95% CI) [b] | HR (95% CI) | % Attenuation (95% CI) [b] | |
|---|---|---|---|---|---|
| Model 1 | 1.60 (1.26 to 2.04) [d] | NA | 1.60 (1.26 to 2.04) [d] | NA | NA |
| Plus smoking | 1.36 (1.06 to 1.74) | 32 (21 to 70) | 1.38 (1.08 to 1.76) | 35 (19 to 65) | −3 (−12 to 3) |
| Plus alcohol consumption | 1.58 (1.24 to 2.03) | 3 (−10 to 17) | 1.51 (1.18 to 1.94) | 12 (0 to 36) | 9 (0 to 25) |
| Plus diet | 1.55 (1.21 to 1.98) | 7 (−9 to 21) | 1.48 (1.16 to 1.89) | 17 (7 to 40) | 10 (0 to 28) |
| Plus physical activity | 1.57 (1.23 to 2.00) | 5 (−6 to 19) | 1.45 (1.14 to 1.85) | 21 (11 to 44) | 16 (4 to 39) |
| Fully adjusted | 1.31 (1.02 to 1.69) [e] | 42 (21 to 94) | 1.14 (0.89 to 1.47) [e] | 72 (42 to 154) | 30 (10 to 70) |

Abbreviations: CI, confidence interval; HR, hazard ratio; NA, data not applicable.
[a] Of a total of 9590 participants in the Whitehall II study, there were 654 deaths.
[b] Percent attenuation = 100 × ($\beta_{Model\ 1+health\ behavior(s)} - \beta_{Model\ 1}$)/($\beta_{Model\ 1}$).
[c] Difference between the model with repeated assessment compared with the baseline assessment of health behaviors.
[d] Lowest vs highest socioeconomic position, adjusted for sex and year of birth.
[e] Includes everything in footnote "d" plus all health behaviors.

**Table 4.** Role of Health Behaviors in Explaining the Association Between Socioeconomic Position and Cardiovascular Mortality [a]

| | Assessment of Health Behaviors | | | | Difference Between Baseline and Longitudinal Assessments, % Attenuation (95% CI) [c] |
| | Baseline (Phase 1) | | Phases 1, 3, 5, and 7 | | |
| | HR (95% CI) | % Attenuation (95% CI) [b] | HR (95% CI) | % Attenuation (95% CI) [b] | |
|---|---|---|---|---|---|
| Model 1 | 3.05 (1.94 to 4.78) [d] | NA | 3.05 (1.94 to 4.78) [d] | NA | NA |
| Plus smoking | 2.67 (1.69 to 4.21) | 12 (5 to 24) | 2.66 (1.69 to 4.19) | 12 (5 to 25) | 0 (−3 to 3) |
| Plus alcohol consumption | 2.57 (1.62 to 4.07) | 15 (6 to 31) | 2.50 (1.57 to 3.97) | 18 (7 to 36) | 3 (−6 to 13) |
| Plus diet | 3.16 (2.01 to 4.99) | −3 (−10 to 3) | 2.82 (1.79 to 4.46) | 7 (−1 to 17) | 10 (3 to 22) |
| Plus physical activity | 2.84 (1.80 to 4.50) | 6 (3 to 18) | 2.66 (1.69 to 4.19) | 12 (4 to 23) | 6 (−6 to 19) |
| Fully adjusted | 2.22 (1.37 to 3.58) [e] | 29 (11 to 54) | 1.85 (1.15 to 2.98) [e] | 45 (24 to 79) | 16 (2 to 38) |

Abbreviations: CI, confidence interval; HR, hazard ratio; NA, data not applicable.
[a] Of 9590 participants in the Whitehall II study, there were 188 deaths attributable to cardiovascular mortality.
[b] Percent attenuation = 100 × ($\beta_{Model\ 1+health\ behavior(s)} - \beta_{Model\ 1}$)/($\beta_{Model\ 1}$).
[c] Difference between the model with repeated assessment compared with the baseline assessment of health behaviors.
[d] Lowest vs highest socioeconomic position, adjusted for sex and year of birth.
[e] Includes everything in footnote "d" plus all health behaviors.

**Table 5.** Role of Health Behaviors in Explaining the Association Between Socioeconomic Position and Noncancer and Noncardiovascular Disease Mortality[a]

| | Assessment of Health Behaviors | | | | Difference Between Baseline and Longitudinal Assessments, % Attenuation (95% CI)[c] |
| | Baseline (Phase 1) | | Phases 1, 3, 5, and 7 | | |
| | HR (95% CI) | % Attenuation (95% CI)[b] | HR (95% CI) | % Attenuation (95% CI)[b] | |
|---|---|---|---|---|---|
| Model 1 | 1.67 (1.01 to 2.75)[d] | NA | 1.67 (1.01 to 2.75)[d] | NA | NA |
| Plus smoking | 1.32 (0.80 to 2.17) | 46 (18 to 277) | 1.38 (0.84 to 2.28) | 37 (13 to 265) | −9 (−57 to 5) |
| Plus alcohol consumption | 1.69 (1.01 to 2.80) | −2 (−47 to 42) | 1.58 (0.95 to 2.64) | 10 (−19 to 126) | 12 (−11 to 127) |
| Plus diet | 1.50 (0.91 to 2.49) | 20 (2 to 192) | 1.47 (0.89 to 2.44) | 24 (2 to 198) | 4 (−42 to 52) |
| Plus physical activity | 1.61 (0.97 to 2.68) | 7 (−19 to 80) | 1.36 (0.83 to 2.23) | 40 (13 to 255) | 33 (3 to 221) |
| Fully adjusted | 1.22 (0.72 to 2.06)[e] | 61 (16 to 425) | 1.03 (0.61 to 1.74)[e] | 94 (35 to 595) | 33 (−16 to 262) |

Abbreviations: CI, confidence interval; HR, hazard ratio; NA, data not applicable.
[a] Of 9590 participants in the Whitehall II study, there were 150 deaths attributable to noncancer and noncardiovascular mortality.
[b] Percent attenuation = $100 \times (\beta_{\text{Model 1+health behavior(s)}} - \beta_{\text{Model 1}})/(\beta_{\text{Model 1}})$.
[c] Difference between the model with repeated assessment compared with the baseline assessment of health behaviors.
[d] Lowest vs highest socioeconomic position, adjusted for sex and year of birth.
[e] Includes everything in footnote "d" plus all health behaviors.

were similar to those reported in the main analyses (all-cause mortality: HR, 1.54 [95% CI, 1.17-2.02]; cancer mortality: HR, 0.96 [95% CI, 0.64-1.43]; cardiovascular disease: HR, 2.95 [95% CI, 1.81-4.83]; and noncancer and noncardiovascular disease mortality: HR, 1.89 [95% CI, 1.07-3.36]). Furthermore, the role of health behaviors changed little when both health behaviors and the socioeconomic measure were entered as time-dependent covariates (for all-cause mortality, the attenuation in the association was 67%, which is comparable with the 72% reported in Table 3).

## COMMENT

This study sought to quantify the contribution of health behaviors to the association between socioeconomic position and all-cause, cardiovascular disease, and noncancer and noncardiovascular disease mortality. It also compared the effect of a single baseline assessment of behaviors with that of 4 separate assessments over 24 years of follow-up. The results show a clear social gradient in mortality with lower socioeconomic position being associated with higher mortality. Unhealthy behaviors such as smoking, unhealthy diet, and low levels of physical activity were strongly related to mortality, as well as nonconsumption of alcohol; these behaviors were more prevalent among participants in the lower socioeconomic positions. Heavy consumption of alcohol was more prevalent among participants in the highest socioeconomic position. Overall, health behaviors assessed at baseline explained 42%, 29%, and 61% of the socioeconomic gradient in all-cause, cardiovascular disease, and noncancer and noncardiovascular disease mortality, respectively. Analyses based on repeated assessments of these behaviors through follow-up showed them to make a greater contribution to explaining social inequalities in mortality; the corresponding percentage attenuations were 72%, 45%, and 94%, respectively.

Multiple interrelated pathways have been proposed to explain social inequalities in health,[27-31] with the prominent mechanisms being health behaviors, psychosocial factors, and material factors. The overriding conclusion from our study is that the effect of health behaviors in explaining social inequalities in health is greater when they are assessed longitudinally. However, our analysis does not allow conclusions to be drawn on the relative importance of health behaviors in relation to psychosocial and material factors because these were not analyzed. Furthermore, it is possible that the effect of material and psychosocial factors on health is mediated through health behaviors.[14,16] Differences in exposure to environmental hazards across social strata and access to medical care also are important contributors in many settings.[32-35] However, these are unlikely to play a major role in our data because the participants are white collar workers with universal access to health care. For example, previous findings in this cohort show little socioeconomic difference in access to cardiac diagnosis and treatment.[36]

Studies that aim to assess the role of behavioral factors for mortality have typically explained between 12% and 54% of the socioeconomic gradient.[12-14,16,37] Our study is not easily comparable with these studies because of important differences in the set of behaviors included, in the socioeconomic measure used, and the population studied. Furthermore, our calculation of percentage attenuation is conservative because it uses the log of the HRs in the calculation of the attenuation to reflect the assumed linearity in the association between socioeconomic position and mortality. An alternative formula ($100 \times (\text{HR}_{\text{Model 1}} - \text{HR}_{\text{Model 1+ health behaviors}})/(\text{HR}_{\text{Model 1}} - 1)$) used in many previous studies is based on the excess hazards and when applied to our longitudinal models explained 77%, 59%, and 96% of the social gradient in all-cause, cardiovascular disease, and noncancer and noncardiovascular disease mortality, respectively.

The use of a bootstrap method allowed us to formally test the difference between the baseline and the longitudinal adjustment for health behaviors. Our results show that there is a significant increase in the predic-

tive ability of health behaviors when assessed longitudinally for all-cause mortality and cardiovascular disease mortality. This increase in explanatory power may relate to better estimation of the association between socioeconomic position and health behaviors over time and also of that between changes in health behaviors over time and mortality. For example, it has been shown that individuals from lower socioeconomic positions are more resistant to changing their unhealthy behaviors compared with their more advantaged counterparts.[38,39] A number of studies[40-43] have shown that changes in health behaviors over the follow-up period are responsible for changes in the resulting association with poor health outcomes. Repeated assessment of health behaviors allowed us to take such changes into account.

The explanatory power of diet, physical activity, and alcohol consumption increased between the baseline and longitudinal assessments. In contrast, the impact of smoking did not change even though it was the main explanatory factor of the social gradient in mortality. The prevalence of smoking decreased over time in the study sample but it is possible that the time lapse necessary to see the effect on mortality is longer. For some causes of mortality, such as chronic obstructive pulmonary disease or lung cancer,[44,45] the lapse of time in our study would not be sufficient to modify the associated risks of death. However, for other causes, such as coronary death,[44] the increased risk of death associated with smoking has been found to decrease from 5 years after smoking cessation. Despite decreasing prevalence, the social gradient in smoking in our study decreased little over the follow-up period.

Participants in all socioeconomic positions improved their dietary behaviors during the follow-up period, but this was more evident among participants in the highest socioeconomic position. Unhealthy diet was about twice as prevalent at baseline in the lowest socioeconomic position but the differ-

ence was 5-fold at the end of follow-up. Use of the repeated measurements allows these widening differences to be taken into account when explaining the social gradient in mortality. Participants became less physically active in all socioeconomic positions during the follow-up period, although the social patterning of physical inactivity decreased. In summary, the increased contribution of diet, physical activity, and alcohol consumption to inequalities in mortality when assessed through the follow-up period seems to be due to a combined effect of behavioral changes that occurred during the study period and to changes in social patterning of these behaviors. However, it is possible that changes in health behaviors over time are due to changes in health status. The analyses reported herein do not allow us to tease apart the precise sequence of events that lead to the association between socioeconomic position, health behaviors, and mortality.

This study has 2 major strengths. First, unlike previous studies, health behaviors were assessed 4 times over the 24-year follow-up, at an interval of 4 to 5 years. Second, the unique feature of this study is that it is one of the first studies to provide a 95% CI for the effect of health behaviors on the socioeconomic gradient in mortality (calculated using the bootstrap method). The use of the bootstrap method has allowed us to add a degree of precision around the estimate of the attenuation that is often expressed simply as a percentage.

There are a number of limitations to the results reported herein. The Whitehall II study is based on a white collar cohort and is not representative of the general population in terms of the socioeconomic spectrum or the range of unhealthy behaviors. However, this may mean that socioeconomic differences observed and explained in this cohort are smaller than those in the general population. A further concern is that about 20% of the participants had at least 1 of the 4 behaviors imputed (with the preceding or subsequent phase) at

1 of the phases. This decision was made because a complete case approach in proportional hazards regression models has been shown to be inappropriate when data are not missing at random.[46] However, there were no important differences in the estimates from complete case analysis compared with imputed values in our data. A further limitation is our use of subjective measures of health behaviors. Objective, precise, and more detailed measures of behaviors, such as a nicotine/cotinine urine test for smoking, actigraphs for physical activity or more detailed questions, and food frequency questionnaires for dietary patterns might have yielded a more accurate estimation of their contribution to social inequalities in mortality.

Despite there being more than 650 deaths, we were only able to analyze broad groupings of causes of death. Even then, the noncancer and noncardiovascular disease mortality outcome, which contained a range of disparate causes of death, still generated bootstrap 95% CIs that were particularly wide. Similarly, pooling all types of cancer is not ideal because social inequalities differ by cancer site, with some of them showing a reverse gradient. This may lead to results in which the social patterns for different cancer types cancel each other out and could explain the lack of association between socioeconomic position and cancer mortality.

## CONCLUSIONS

This study suggests that health behaviors explain a substantial part of social inequalities in mortality and demonstrates the importance of taking into account changes over time in health behaviors when examining their role in social inequalities. In our study, they explained 72% of social inequalities in all-cause mortality when the 4 health behaviors were assessed 4 times over 24 years of follow-up against 42% when only assessed at baseline. Our findings may not necessarily have straightforward policy implications. On the one hand, the findings imply that health

policies and interventions focusing on individual health behaviors have the potential not only to increase the population's health but also to substantially reduce inequalities in health. On the other hand, if health behaviors are socially patterned and determined, for example, by financial factors,[14,16] the capacity to respond to health education messages,[21,47] or the environment in which they live,[48] the same policies aimed at improving the population's health may contribute to an increase in social inequalities in health.

## REFERENCES

1. Berkman L, Breslow L. *Health and Ways of Living: The Alameda County Study.* New York, NY: Oxford University Press; 1983.
2. Mokdad AH, Marks JS, Stroup DF, Gerberding JL. Actual causes of death in the United States, 2000. *JAMA*. 2004;291(10):1238-1245.
3. Khaw KT, Wareham N, Bingham S, et al. Combined impact of health behaviours and mortality in men and women. *PLoS Med*. 2008;5(1):e12.

4. Singh GK, Siahpush M. Increasing inequalities in all-cause and cardiovascular mortality among US adults aged 25-64 years by area socioeconomic status, 1969-1998. *Int J Epidemiol*. 2002;31(3):600-613.
5. Meara ER, Richards S, Cutler DM. The gap gets bigger. *Health Aff (Millwood)*. 2008;27(2):350-360.
6. Mackenbach JP, Bos V, Andersen O, et al. Widening socioeconomic inequalities in mortality in six Western European countries. *Int J Epidemiol*. 2003; 32(5):830-837.
7. Lynch JW, Kaplan GA, Salonen JT. Why do poor people behave poorly? *Soc Sci Med*. 1997;44(6): 809-819.
8. Lakka TA, Kauhanen J, Salonen JT. Conditioning leisure time physical activity and cardiorespiratory fitness in sociodemographic groups of middle-aged men in eastern Finland. *Int J Epidemiol*. 1996;25(1): 86-93.
9. Martikainen P, Brunner E, Marmot M. Socioeconomic differences in dietary patterns among middle-aged men and women. *Soc Sci Med*. 2003;56(7): 1397-1410.
10. Macintyre S. The Black Report and beyond. *Soc Sci Med*. 1997;44(6):723-745.
11. Townsend P, Davidson N. *Inequalities in Health: The Black Report.* Harmondsworth, England: Penguin Books; 1982.
12. Laaksonen M, Talala K, Martelin T, et al. Health behaviours as explanations for educational level differences in cardiovascular and all-cause mortality. *Eur J Public Health*. 2008;18(1):38-43.
13. Lantz PM, House JS, Lepkowski JM, et al. Socioeconomic factors, health behaviors, and mortality: results from a nationally representative prospective study of US adults. *JAMA*. 1998;279(21):1703-1708.
14. Schrijvers CT, Stronks K, van de Mheen HD, Mackenbach JP. Explaining educational differences in mortality: the role of behavioral and material factors. *Am J Public Health*. 1999;89(4):535-540.
15. Strand BH, Tverdal A. Can cardiovascular risk factors and lifestyle explain the educational inequalities in mortality from ischaemic heart disease and from other heart diseases? *J Epidemiol Community Health*. 2004;58(8):705-709.
16. van Oort FV, van Lenthe FJ, Mackenbach JP. Material, psychosocial, and behavioural factors in the explanation of educational inequalities in mortality in the Netherlands. *J Epidemiol Community Health*. 2005; 59(3):214-220.
17. Woodward M, Oliphant J, Lowe G, Tunstall-Pedoe H. Contribution of contemporaneous risk factors to social inequality in coronary heart disease and all causes mortality. *Prev Med*. 2003;36(5):561-568.
18. National Health and Social Care Information Centre. *Statistics on Smoking.* London, England: National Health and Social Care Information Centre; 2008.
19. National Health and Social Care Information Centre. *Statistics on Obesity, Physical Activity and Diet.* London, England: Health and Social Care Information Centre; 2008.
20. Chan RH, Gordon NF, Chong A, Alter DA; Socio-Economic and Acute Myocardial Infarction Investigators. Influence of socioeconomic status on lifestyle behavior modifications among survivors of acute myocardial infarction. *Am J Cardiol*. 2008;102 (12):1583-1588.
21. Purslow LR, Young EH, Wareham NJ, et al. Socioeconomic position and risk of short-term weight gain. *BMC Public Health*. 2008;8:112.
22. Marmot M, Brunner E. Cohort profile: the Whitehall II study. *Int J Epidemiol*. 2005;34(2):251-256.
23. Marmot MG, Smith GD, Stansfeld S, et al. Health inequalities among British civil servants: the Whitehall II study. *Lancet*. 1991;337(8754):1387-1393.
24. Britton A, Singh-Manoux A, Marmot M. Alcohol

consumption and cognitive function in the Whitehall II study. *Am J Epidemiol*. 2004;160(3):240-247.
25. Breslow NE, Day NE. Statistical methods in cancer research, volume II. *IARC Sci Publ*. 1987;(82): 1-406.
26. SAS Institute Inc. SAS OnlineDoc®: jackknife and bootstrap analyses. http://support.sas.com /kb/24/982.html.
27. Bartley M. *Health Inequality—An Introduction to Theories, Concepts and Methods.* Oxford, England: Blackwell Publishing; 2004.
28. Kaplan GA, Pamuk ER, Lynch JW, et al. Inequality in income and mortality in the United States: analysis of mortality and potential pathways. *BMJ*. 1996; 312(7037):999-1003.
29. Marmot M, Wilkinson R. *Social Determinants of Health.* New York, NY: Oxford University Press; 1999.
30. Townsend P, Davidson N, Whitehead M. *Inequalities in Health: The Black Report and the Health Divide.* London, England: Penguin Books; 1992.
31. Kivimäki M, Shipley MJ, Ferrie JE, et al. Best-practice interventions to reduce socioeconomic inequalities of coronary heart disease mortality in UK. *Lancet*. 2008;372(9650):1648-1654.
32. Hart JT. The inverse care law. *Lancet*. 1971; 1(7696):405-412.
33. Hemström O. Health inequalities by wage income in Sweden. *Soc Sci Med*. 2005;61(3):637-647.
34. Krieger N, Chen JT, Waterman PD, et al. The inverse hazard law. *Soc Sci Med*. 2008;67(12):1970-1981.
35. Krieger N, Rowley DL, Herman AA, et al. Racism, sexism, and social class. *Am J Prev Med*. 1993; 9(6)(suppl):82-122.
36. Britton A, Shipley M, Marmot M, Hemingway H. Does access to cardiac investigation and treatment contribute to social and ethnic differences in coronary heart disease? *BMJ*. 2004;329(7461):318.
37. Pekkanen J, Tuomilehto J, Uutela A, et al. Social class, health behaviour, and mortality among men and women in eastern Finland. *BMJ*. 1995;311(7005): 589-593.
38. Winkleby MA, Flora JA, Kraemer HC. A community-based heart disease intervention. *Am J Public Health*. 1994;84(5):767-772.
39. Sorensen G, Stoddard AM, Dubowitz T, et al. The influence of social context on changes in fruit and vegetable consumption. *Am J Public Health*. 2007; 97(7):1216-1227.
40. Paffenbarger RS Jr, Hyde RT, Wing AL, et al. The association of changes in physical-activity level and other lifestyle characteristics with mortality among men. *N Engl J Med*. 1993;328(8):538-545.
41. Byberg L, Melhus H, Gedeborg R, et al. Total mortality after changes in leisure time physical activity in 50 year old men. *BMJ*. 2009;338:b688.
42. Andersen LB. Relative risk of mortality in the physically inactive is underestimated because of real changes in exposure level during follow-up. *Am J Epidemiol*. 2004;160(2):189-195.
43. Grønbaek M, Johansen D, Becker U, et al. Changes in alcohol intake and mortality. *Epidemiology*. 2004; 15(2):222-228.
44. Kenfield SA, Stampfer MJ, Rosner BA, Colditz GA. Smoking and smoking cessation in relation to mortality in women. *JAMA*. 2008;299(17):2037-2047.
45. Godtfredsen NS, Lam TH, Hansel TT, et al. COPD-related morbidity and mortality after smoking cessation. *Eur Respir J*. 2008;32(4):844-853.
46. Demissie S, LaValley MP, Horton NJ, et al. Bias due to missing exposure data using complete-case analysis in the proportional hazards regression model. *Stat Med*. 2003;22(4):545-557.
47. Macintyre S. The social patterning of exercise behaviours. *Br J Sports Med*. 2000;34(1):6.
48. Macintyre S, Maciver S, Sooman A. Area, class and health. *J Soc Policy*. 1993;22:213-234.