Repeatedly measured material and behavioral factors changed the explanation of socioeconomic inequalities in all-cause mortality

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Journal of Clinical Epidemiology 2017;91:137-145

ABSTRACT

Objective

We examined whether using repeatedly measured material and behavioral factors contributed differently to socioeconomic inequalities in all-cause mortality compared to one baseline measurement.

Study design and setting

Data from the Dutch prospective GLOBE cohort were linked to mortality register data (1991 – 2013; N=4,851). Socioeconomic position was measured at baseline by educational level and occupation. Material factors (financial difficulties, housing tenure, health insurance) and behavioral factors (smoking, leisure time physical activity, sports participation and body mass index) were self-reported in 1991, 1997 and 2004. Cox proportional hazards regression and bootstrap methods were used to examine the contribution of baseline-only and time-varying risk factors to socioeconomic inequalities in mortality.

Results

Men and women in the lowest educational and occupational groups were at an increased risk of dying compared to the highest groups. The contribution of material factors to socioeconomic inequalities in mortality was smaller when multiple instead of baseline-only measurements were used (25%–65% versus 49%–93%). The contribution of behavioral factors was larger when multiple measurements were used (39%–51% versus 19%–40%).

Conclusion

Inclusion of time-dependent risk factors contributes to understanding socioeconomic inequalities in mortality, but careful examination of the underlying mechanisms and suitability of the model is required.

INTRODUCTION

There have been consistent reports of socioeconomic inequalities in mortality.[1, 2] Explanations for socioeconomic gradients in mortality have steadily increased since the landmark publication of the Black Report in 1980, in which the main explanations mentioned were greater exposure to unfavorable material and behavioral factors among those in lower socioeconomic groups.[3, 4]

Observational studies examining explanations for socioeconomic inequalities in mortality mainly used explanatory factors measured once at baseline. Recently, studies estimated the contribution of health behaviors modeled as time-varying risk factors.[5-7] The main rationale for this approach is that inequalities in health behaviors may widen or decrease over time, which is not taken into account when only baseline measures are used. Accounting for such changes over time may provide a more accurate estimation of the contribution of these factors to inequalities in mortality. Studies that have taken this approach suggest that the contribution of some health behaviors was greater when measured at multiple times during the life-course than when measured at only one point in time, although results differed between countries.[5-9]

Previous studies have shown that material factors contribute most to socioeconomic inequalities in mortality,[10, 11] but none of these studies have included both time-varying material and behavioral factors in order to assess their contributions to the explanation of socioeconomic inequalities in mortality. Clearly, both behavioral and material risk factors may change over time. Further, not controlling for material factors may have overestimated the explanatory role of time-varying health behaviors in recent studies, since living in suboptimal material conditions may induce unhealthy behavior.[3, 4, 10-12] Lastly, since the association between socioeconomic position and mortality and the socioeconomic distribution of risk factors can differ between men and women[13-16], it is important to asses potential differences between men and women. In order to fill these lacunae, we investigated how material and behavioral factors measured three times during adulthood contributed to the explanation of socioeconomic inequalities in mortality. To do so, we used a prospective cohort of Dutch adults with 23 years of follow-up. The main objective of the study was to investigate differences between models with only baseline measurements of the risk factors and models with time-varying risk factors. Given the potential gender differences, all analyses were carried out separately for men and women.

METHODS

Study population

The GLOBE study (Dutch acronym for 'Health and Living Conditions of the Population of Eindhoven and surroundings') is a prospective cohort study in the Southern part of the Netherlands. At baseline (1991), a postal questionnaire was sent out to a random sample, stratified by age, degree of urbanization, and socioeconomic status, of non-institutionalized Dutch persons aged 14-75 years living in Eindhoven and surrounding municipalities (response rate 70.1%, N=18,973). From this sample two subsamples were invited for subsequent stages of data collection. One subsample was chosen randomly from the baseline survey participants (response 79.3%, N=2,800), the other subsample included an over-representation of chronically ill persons (response 72.3%, N=2,867). Both subsamples were stratified on age with an over-representation of persons aged 45 and older. These two subsamples formed the longitudinal GLOBE cohort (N=5,667) and were used in the analyses for this paper. Specifically, data from the baseline postal survey and additional interviews in 1991, data from the second postal survey and additional interviews in 1997, and data from the third postal survey in 2004 were used. In-depth details about the study design and sampling methods of the GLOBE study are provided elsewhere.[17, 18] The use of personal data in the GLOBE study is in compliance with the Dutch Personal Data Protection Act and the Municipal Database Act, and has been registered with the Dutch Data Protection Authority (number 1248943).

Measures

All-cause mortality data up to December 31st 2013 were obtained from Statistics Netherlands. We were able to link 5,344 participants to the register data (94%). Participants were censored at their date of death or at the end of follow-up. We restricted all analyses to participants 25 years or older at baseline because younger persons may not have finalized their education, leaving 4,851 participants for the analyses.

Socioeconomic position was measured by both educational and occupational level. From information on the highest attained educational level of the participant at baseline four categories were defined according to the International Standard Classification of Education (ISCED): 1 – high (higher professional education and university; ISCED 5–7); 2 – middle (intermediate professional and higher general education; ISCED 3–4); 3 – low (lower professional and intermediate general education; ISCED 2); 4 – lowest (primary education; ISCED 0–1). Occupation was classified in 3 categories according to the Erikson, Goldthorpe, and Portocarero (EGP) scheme:[19] 1 – professionals (top-level management, advanced academic competencies, high level of independence); 2 – white-collar (middle management, routine non-manual work); 3 – blue-collar occupations (skilled and unskilled manual work). We used occupation for men and occupation

of the head of the household for women. Those not in workforce were excluded from the analyses, since these included non-comparable categories such as retirees, rentiers and unemployed participants (men: N=33; women: N=343).

Material factors included financial difficulties, housing tenure and type of health insurance, three measures which have been applied in several studies among the GLOBE cohort.[10, 11, 20] Financial difficulties were measured by asking participants whether they had experienced any financial difficulties in paying bills for food, rent, electricity and so forth during the preceding year. Three categories were used: 1 – no financial difficulties; 2 – some financial difficulties; 3 – major financial difficulties. Housing tenure was divided into 1 – house owner or 2 – rented house. Health insurance was divided into 1 – private insurance or 2 – other insurance (civil servant, public or no insurance).

The behavioral factors included smoking status, leisure time physical activity, sports participation and body mass index (as an indicator for caloric imbalance). Smoking status was self-reported based on the question "Do you smoke?" and categorized as 1 – non-smoker; 2 – former smoker; 3 – current smoker. Physical activity (hours per week) was divided up into non-sports leisure time physical activity and sports participation. In 1991 and 1997, participants were asked to report both non-sports leisure time physical activity (time per week spent on walking, cycling, and gardening during leisure time) and sports participation (time per week spent on sport activities). Participants could choose between 4 categories (hardly ever, <1 hour, 1–2 hours, >2 hours). In 2004 the validated SQUASH questionnaire (Short QUestionnaire to ASsess Health-enhancing physical activity) was used.[21] Participants were asked to report frequency (times per week) and average duration (minutes per day) for both non-sports leisure time physical activity (separate questions for walking, cycling, and gardening in leisure time) and sport participation (maximum of four sports could be reported). The separate questions were summarized before being categorized into the four categories similar to 1991 and 1997. For both non-sports leisure time physical activity and sports participation, participants were classified as 1 – active (>2 hr/w); 2 –moderately active (1-2 hr/w); 3 – little active (<1 hr/w); 4 – inactive (no activity). Body mass index (BMI) was calculated from self-reported weight divided by self-reported height squared and classified as 1 – normal weight (BMI >20-25); 2 – underweight (BMI ≤20); 3 – overweight (BMI >25-30); 4 – obese (BMI >30).

Statistical analysis

First, prevalence rates were calculated for all risk factors by educational attainment at baseline and the two follow-up waves. The prevalence rates were age-standardized (5-year age groups) using the age distribution in the original random sample of the GLOBE baseline (N=18,973) as the standard population.

Second, we used a four-step mediation approach to assess the contribution of the material and behavioral risk factors to socioeconomic inequalities in mortality. In the

first step, Cox proportional hazards regression models using age as a time scale were used to estimate the hazard ratios (HR) and their 95% confidence intervals (CI) for the association between socioeconomic position and mortality. Sensitivity analysis showed that results were similar when using time-on-study as a time scale. In the second step, age-standardized prevalence rates of the material and behavioral risk factors at baseline were calculated for each socioeconomic group. In the third step, the material and behavioral factors were added to the models from step 1 to estimate the association between the material and behavioral risk factors and mortality, adjusted for socioeconomic position. In the fourth step, the estimated HRs for the association between socioeconomic position and mortality from step 1 (not adjusted for the mediators) were compared to the estimated HRs from step 3 (adjusted for the mediators). We compared models where only the baseline measurement of the risk factors was used with models where the risk factors were added as time-varying covariates. The mediating role of the risk factors was determined by the percentage reduction in excess risk after inclusion of the risk factors in the model, using the following formula: $(HR_{model1} - HR_{model1 + risk\ factors}) / (HR_{model1} - 1)$ x 100%. A 95% confidence interval for this percentage reduction was calculated using a bootstrap method with 1000 resamples per imputed dataset.

To control for possible time-varying confounding by health status in the time-varying models, marginal structural models that included severe illness at baseline were also fitted.[6, 22-24] In these marginal structural models, the direct effect of socioeconomic position on mortality was obtained by using inverse probability weighting. However, a violation of the positivity assumption (the condition that there are both exposed and unexposed individuals at every level of the confounders)[24] resulted in severely inflated and biased inverse probability weights and standard errors. This made the marginal structural models uninterpretable and as a result they were left out of the study.

All analyses were carried out separately for men and women and were weighted by respondent-level sample weights to account for the sampling strategy within the GLOBE study. All models were adjusted for marital status at baseline and country of birth.

Of the 4,851 participants who participated at baseline 2,498 participated in all three waves. From these participants 68% had complete data for all risk factors. Since all participants were linked to mortality data and a large amount of information was available from the baseline measurement, both attrition and missing data on risk factors were handled by multiple imputation using data from all three waves and the outcome. This yields more valid results, assuming both attrition and missing data are missing at random.[25] Five imputed datasets were created. Since we were interested in the contribution of risk factors to the association between socioeconomic position and mortality, we decided not to impute missing data on the socioeconomic position indicators (2% missing) based on those risk factors and the outcome. All analyses were performed using STATA,

version 12 (StataCorp LP, College Station, Texas) and bootstrapping calculations were performed in R, version 2.15 (R Foundation for Statistical Computing, Vienna, Austria).

RESULTS

Sample characteristics

A total of 934 men (38.8%) and 746 women (30.5%) died in the 23-years of follow-up. The mean age at baseline was 52.8 years, with 75% of participants aged 45 or older (table 1). One-quarter of the men were in the highest educational groups and 20% in the lowest, 40% had a professional occupation and 40% a blue collar occupation. One-tenth of the women were in the highest educational group and 28% were in the lowest; the occupation of the head of the household was for 37% of the women professional and for 42% blue collar.

Table 1. Baseline descriptives of GLOBE participants (absolute numbers).

	Men	Women
Age groups		
25–34 years	288	297
35–44 years	324	308
45–54 years	651	710
55–64 years	672	658
65–75 years	471	472
Educational level		
High	576	244
Middle	560	374
Low	763	1102
Lowest	465	656
Occupation [a]		
Professional	951	755
White collar	423	439
Blue collar	933	866
Not in workforce	33	343
Marital status		
Married	1935	1804
Unmarried	247	212
Divorced	140	184
Widowed	63	214
Birth country		
Netherlands	2265	2314
Other	114	108

Table 1. Baseline descriptives of GLOBE participants (absolute numbers). (continued)

	Men	Women
Financial difficulties		
No difficulties	1841	1797
Some difficulties	433	481
Major difficulties	106	123
Housing tenure		
House owner	1281	1233
Rented house	1113	1179
Health Insurance		
Private insurance	951	734
Other insurance	1453	1697
Smoking status		
Non-smoker	349	993
Former smoker	1067	685
Current smoker	978	743
Leisure time activity		
Active	1160	943
Moderately active	628	660
Little active	300	424
Inactive	295	362
Sports participation		
Active	447	299
Moderately active	375	499
Little active	159	201
Inactive	1406	1376
Body mass index		
Normal weight	1186	1230
Underweight	76	224
Overweight	977	672
Obese	112	227

[a] For women occupation of the head of the household was used.

Association between socioeconomic position and mortality

Table 2 shows socioeconomic position was strongly associated with mortality for both indicators of socioeconomic position. For men, the HRs of the models for the lowest socioeconomic position as compared to the highest were 1.84 (95% CI 1.40, 2.41) for education and 1.40 (95% CI 1.14, 1.71) for occupation. For women the HRs were 1.69 (95% CI 1.03, 2.76) for education and 1.51 (95% CI 1.17, 1.95) for occupation of the head of the household.

Table 2. Bivariate associations[ab] between socioeconomic position and mortality.

	Men			Women		
	HR	95% CI	Sample size (No. deaths)	HR	95% CI	Sample size (No. deaths)
Education						
High	1.00	Referent	576 (160)	1.00	Referent	244 (36)
Middle	1.41	1.04, 1.90	560 (205)	1.53	0.87, 2.70	374 (76)
Lower	1.22	0.92, 1.62	763 (283)	1.55	0.96, 2.50	1102 (294)
Lowest	1.84	1.40, 2.41	465 (270)	1.69	1.03, 2.76	656 (307)
Occupation[c]						
Professional	1.00	Referent	951 (321)	1.00	Referent	943 (319)
White collar	1.23	0.96, 1.57	423 (174)	1.16	0.85, 1.59	455 (181)
Blue collar	1.40	1.14, 1.71	933 (395)	1.51	1.17, 1.95	921 (393)

[a] All analysis included respondent-level sample weights.
[b] All models were adjusted for country of birth and marital status at baseline; age was used as the time scale.
[c] For women occupation of the head of the household was used.

Association between socioeconomic position and material and behavioral risk factors

There were marked socioeconomic gradients for all risk factors, with those in the lower socioeconomic groups having a greater exposure to unfavorable factors (Appendix Table 1). Between baseline (1991) and the last wave of data collection (2004), the socioeconomic gradient in prevalence rates increased for all risk factors, except for type of health insurance, BMI for men and leisure time physical activity for women (Appendix Table 2 and 3).

Association between material and behavioral risk factors and mortality

All risk factors were significantly associated with mortality in either the baseline, the time-varying or both models after adjusting for education (Table 3). The association between material factors and mortality mostly decreased when the material factors were entered as time-varying covariates as compared to a fixed baseline level of the material factors, whereas the association between behavioral factors and mortality mostly increased in time-varying models (except for BMI).

Mediating role of material and behavioral factors in the association between socioeconomic position and mortality

Including material factors measured at baseline only attenuated the association between education and mortality by 75% (95% CI 44%, 129%) for men (Table 4) and 49% (95% CI 9%, 186%) for women (Table 5). In time-varying models the explanatory role of material factors was smaller, i.e. 56% (95% CI 28%, 101%) for men and 36% (95% CI -4%,

139%) for women. Additional analyses on the separate risk factors (Appendix table 4 and 5) showed a decline in the contribution of all material factors, except for housing tenure among women.

Table 3. Bivariate associations[ab] between risk factors and mortality.

	Men				Women			
	Baseline models		Time-varying models		Baseline models		Time-varying models	
	HR	95% CI	HR	95% CI	HR	95% CI	HR	95% CI
Financial difficulties								
No financial difficulties	1	Referent	1	Referent	1	Referent	1	Referent
Some financial difficulties	1.09	0.84, 1.40	1.05	0.79, 1.41	1.33	1.06, 1.66	0.92	0.63, 1.33
Major financial difficulties	1.97	1.28, 3.03	1.39	0.68, 2.83	1.57	1.00, 2.47	1.27	0.69, 2.31
Housing tenure								
House owner	1	Referent	1	Referent	1	Referent	1	Referent
Rented house	1.50	1.21, 1.86	1.41	1.13, 1.75	1.28	1.03, 1.59	1.38	1.08, 1.76
Health insurance								
Private insurance	1	Referent	1	Referent	1	Referent	1	Referent
Other insurance	1.44	1.16, 1.79	1.28	1.02, 1.60	1.27	1.02, 1.58	1.10	0.84, 1.43
Smoking status								
Non-smoker	1	Referent	1	Referent	1	Referent	1	Referent
Former smoker	1.78	1.25, 2.52	1.91	1.30, 2.80	0.86	0.69, 1.08	1.08	0.84, 1.39
Current smoker	3.15	2.21, 4.48	3.12	2.18, 4.48	1.81	1.41, 2.32	1.97	1.48, 2.60
Leisure time physical activity								
Active	1	Referent	1	Referent	1	Referent	1	Referent
Moderately active	1.06	0.84, 1.32	1.48	1.13, 1.95	1.06	0.84, 1.35	1.15	0.68, 1.95
Little active	1.03	0.74, 1.44	1.79	1.13, 2.83	1.37	1.05, 1.79	1.50	0.98, 2.30
Inactive	1.28	0.96, 1.69	2.27	1.77, 2.91	1.64	1.22, 2.19	2.11	1.63, 2.72
Sports participation								
Active	1	Referent	1	Referent	1	Referent	1	Referent
Moderately active	1.16	0.81, 1.66	1.48	0.89, 2.44	0.81	0.54, 1.22	1.02	0.64, 1.65
Little active	0.87	0.58, 1.31	1.09	0.59, 2.00	0.99	0.63, 1.55	1.71	0.95, 3.07
Inactive	1.28	1.02, 1.62	1.99	1.48, 2.67	1.22	0.88, 1.69	1.53	0.97, 2.41
Body mass index								
Normal weight	1	Referent	1	Referent	1	Referent	1	Referent
Underweight	1.57	1.00, 2.46	1.55	0.91, 2.62	1.29	0.85, 1.96	1.42	0.89, 2.26
Overweight	0.92	0.76, 1.11	0.75	0.60, 0.95	1.08	0.87, 1.34	0.83	0.66, 1.04
Obese	1.66	1.06, 2.60	1.03	0.71, 1.50	1.54	1.12, 2.11	1.34	0.97, 1.86

[a] All analysis included respondent-level sample weights.

[b] All models were adjusted for country of birth, marital status at baseline and education; age was used as the time scale.

Table 4. The role of material and behavioral factors in the association[ab] between socioeconomic position and mortality (men).

	No risk factors included		Baseline risk factors		Time-varying risk factors		Percent explained[e] Baseline risk factors		Percent explained[e] Time-varying risk factors	
	HR	95% CI	HR	95% CI	HR	95% CI	Estimate	95% CI	Estimate	95% CI
Material factors[c]										
Education										
Lowest vs high	1.84	1.40, 2.41	1.21	0.87, 1.69	1.37	1.01, 1.87	75%	44%, 129%	56%	28%, 101%
Occupation										
Blue collar vs professional	1.40	1.14, 1.71	1.03	0.81, 1.30	1.14	0.90, 1.46	93%	50%, 226%	65%	24%, 167%
Behavioral factors[d]										
Education										
Lowest vs high	1.84	1.40, 2.41	1.68	1.26, 2.24	1.44	1.09, 1.91	19%	-4%, 46%	48%	39%, 92%
Occupation										
Blue collar vs professional	1.40	1.14, 1.71	1.24	1.01, 1.53	1.21	0.98, 1.49	40%	13%, 93%	48%	22%, 113%
Both material and behavioral factors[cd]										
Education										
Lowest vs high	1.84	1.40, 2.41	1.21	0.86, 1.69	1.21	0.88, 1.66	75%	42%, 134%	75%	55%, 134%
Occupation										
Blue collar vs professional	1.40	1.14, 1.71	0.95	0.75, 1.21	1.07	0.84, 1.38	100%[f]	64%, 263%	83%	35%, 188%

[a] All analysis included respondent-level sample weights.

[b] All models were adjusted for country of birth and marital status at baseline; age was used as the time scale.

[c] Material factors included financial difficulties, housing tenure and health insurance.

[d] Behavioral factors included smoking status, leisure time physical activity, sports participation and body mass index.

[e] Percent explained: $(HR_{model1} - HR_{model1 + risk\ factors}) / (HR_{model1} - 1) \times 100\%$.

[f] Truncated at 100%.

Table 5. The role of material and behavioral factors in the association[ab] between socioeconomic position and mortality (women).

	No risk factors included		Baseline risk factors		Time-varying risk factors		Percent explained[e] Baseline risk factors		Percent explained[e] Time-varying risk factors	
	HR	95% CI	HR	95% CI	HR	95% CI	Estimate	95% CI	Estimate	95% CI
Material factors[c]										
Education										
Lowest vs high	1.69	1.03, 2.76	1.35	0.82, 2.22	1.44	0.85, 2.43	49%	9%, 186%	36%	-4%, 139%
Occupation										
Blue collar vs professional	1.51	1.17, 1.95	1.24	0.94, 1.64	1.38	1.04, 1.82	53%	14%, 121%	25%	-12%, 77%
Behavioral factors[d]										
Education										
Lowest vs high	1.69	1.03, 2.76	1.43	0.85, 2.40	1.34	0.80, 2.22	38%	-1%, 167%	51%	34%, 211%
Occupation										
Blue collar vs professional	1.51	1.17, 1.95	1.42	1.08, 1.86	1.31	1.01, 1.69	18%	-8%, 61%	39%	13%, 88%
Both material and behavioral factors[cd]										
Education										
Lowest vs high	1.69	1.03, 2.76	1.19	0.71, 2.01	1.17	0.69, 1.95	72%	21%, 267%	75%	37%, 307%
Occupation										
Blue collar vs professional	1.51	1.17, 1.95	1.23	0.92, 1.63	1.27	0.97, 1.67	55%	14%, 134%	47%	-1%, 110%

[a] All analysis included respondent-level sample weights.

[b] All models were adjusted for country of birth and marital status at baseline; age was used as the time scale.

[c] Material factors included financial difficulties, housing tenure and health insurance.

[d] Behavioral factors included smoking status, leisure time physical activity, sports participation and body mass index.

[e] Percent explained: $(HR_{model1} - HR_{model1 + risk\ factors}) / (HR_{model1} - 1) \times 100\%$.

[f] Truncated at 100%.

Including behavioral factors measured at baseline in the model attenuated the association between education and mortality by 19% (95% CI -4%, 46%) for men and 38% (95% CI -1%, 167%) for women. Including behavioral factors as time-varying covariates increased their explanatory role to 48% (95% CI 39%, 92%) for men and 51% (95% CI 34%, 211%) for women. This result was largely driven by a greater association of leisure time physical activity and sports participation with mortality (Appendix Table 4 and 5).

Including both behavioral and material factors explained about three-quarters of the educational gradient in mortality for both men and women. The role of the risk factors in the explanation of occupational inequalities in mortality showed similar patterns as the results for educational inequalities, although among men the risk factors attenuated more of the occupational gradient than of the educational gradient, while the reverse was true for women.

DISCUSSION

Summary of main findings

This study showed that both behavioral and material factors impact upon the explanation of socioeconomic inequalities in mortality. The contribution of behavioral factors was greater when three measurements were used than when measured at baseline only. The contribution of material factors was smaller when measured three times.

Limitations of the study

This study is not without limitations. First, the four-step mediation approach used in this study has several important assumptions related to potential confounding: there should be no confounding between exposure and outcome, between exposure and mediator, and between mediator and outcome.[23, 26] These assumptions require additional scrutiny in the time-varying models, since time-varying models also introduce the possibility of time-varying confounding. In our study, the assumptions of no confounding were arguably most at risk by the possibility of time-varying confounding by health status. Moreover, time-varying confounding by health status may have influenced the comparison of models with the mediators measured at baseline and measured at multiple time points.[6, 22] Since adjusting for health status in our models would underestimate the path linking socioeconomic position to mortality, we fitted a marginal structural model which controls for time-varying confounding by using inverse probability weighting. However, in our study a violation of the positivity assumption prohibited the use of marginal structural models. Sensitivity analyses, where using the conventional regression approach we adjusted for severe illness at baseline, showed no substantial change in the role of behavioral and material factors. Moreover, in our data, having a severe

disease in a previous time period was associated only with physical activity, not with any of the other risk factors. Second, our mediation method also assumes there is no interaction between socioeconomic position and the risk factors.[23, 26] The assumption of no interaction was tested by adding interaction terms between socioeconomic position and risk factors to the models and assessing whether these were statistically significant at the 5% level. None were found to be statistically significant in the time-varying models. However, in the models with only baseline measurements there was a significant interaction between education and underweight for men, and between occupation and leisure time physical inactivity, sports participation and major financial difficulties for women. Third, we used brief self-reported measures of socioeconomic position and risk factors, which may have given rise to measurement error. Perhaps of more concern, measures of physical activity differed between data waves. Although we were able to re-categorize the data into similar categories, some non-differential misclassification may have occurred. Fourth, although the study population was chosen because of its representativeness for the Dutch population, generalizability to other countries may be limited. This may be most apparent with regard to the material factors, since Dutch legislation has impacted on the distribution of these risk factors. Fifth, the dynamics between socioeconomic position, material factors and health behaviors may involve more complexity and dynamic structures than our models were able to capture.

Comparison with other studies

Previous studies measuring material and behavioral factors only at baseline have suggested that material factors contribute most to socioeconomic inequalities in mortality.[10, 11] Our results suggest these studies may have overestimated the role of material factors, since the contribution of these factors was smaller when they were measured multiple times. In addition, our results show that the role of health behaviors was likely underestimated in research where behaviors were only measured at baseline. This increased contribution of time-varying health behaviors for socioeconomic inequalities in mortality has also been found in other studies [5-7] and emphasizes the importance of sustaining a healthy lifestyle throughout life. Notwithstanding, previous GLOBE study results also showed overlap between the contribution of material and behavioral factors to socioeconomic inequalities in mortality. Most likely, part of the effect of behavioral factors can be attributed to material factors, since unhealthy behavior may be induced by adverse material conditions.[3, 4, 10-12] This shows that even though the contribution of material factors in the explanation of socioeconomic inequalities in mortality is smaller in time-varying models, adverse material conditions still impact strongly on health disparities.

Interpretation of the results

Differences in results between baseline and time-varying models may be due to changes in the socioeconomic gradients of the risk factors or changes in the association between risk factors and mortality.[27] Our results are most likely attributable to the latter, since the contribution of material factors to inequalities in mortality was smaller when all measurements were used, even though the socioeconomic gradient in the prevalence of most material factors increased over time. The reasons for the changing contributions to socioeconomic inequalities in mortality probably vary with the risk factors.

The contribution of smoking to socioeconomic inequalities was larger in the time-varying models for women, while no clear pattern could be observed for men. The association between sports participation and leisure time physical activity and mortality greatly increased in the time-varying models, which has also been found in previous research.[5, 7] The contribution of BMI to socioeconomic inequalities in mortality was found to be limited, which again corresponds to previous findings.[7] Interestingly, overweight was negatively associated with mortality in the time-varying models. Similar results have contributed to debates about an 'obesity paradox'.[28, 29] In our relatively older study population, overweight and obesity may be less of a risk factor for mortality. A period effect can also not be excluded. For example, better medical treatment of overweight and obese patients has been linked to a lower risk of mortality.[30, 31]

Whereas health behaviors contributed more to the explanation of socioeconomic inequalities in mortality, the contribution of material factors decreased in time-varying models. For type of health insurance, the decrease may be caused by non-differential shifts in the classification of health insurance. Some subjects likely switched from private insurance at baseline to public insurance at one of the follow-up waves due to changes in the eligibility criteria for public health insurance, among which a raise of the income threshold.[32, 33]. Further, a drop in income after retirement may also have shifted some subjects from private health insurance to public health insurance. For financial difficulties, the decreasing association with mortality suggests that experiencing financial difficulties at a younger age is associated with worse health outcomes than experiencing them at a higher age. Although we did not find a clear pattern in the relationship between age and the strength of the association between financial difficulties and mortality, we did observe a stronger association for the younger half of the sample compared to the older half. Further, it may be that experiencing financial difficulties in the early 1990s is associated with worse health outcomes than experiencing financial difficulties in later years, since the negative effect of financial difficulties may have lessened due to an overall rise in economic prosperity during follow-up. Finally, housing tenure was an important explanatory factor for socioeconomic inequalities in mortality in both baseline and time-varying models.

Implications

Our findings emphasize that promoting healthy lifestyles among lower socioeconomic groups is even more important than previously thought. Health behaviors are especially receptive to change, and retaining a healthy lifestyle throughout life is essential for reducing the risk of mortality. Moreover, tackling unhealthy behaviors is especially critical for lower socioeconomic groups, since our results clearly showed increasing socioeconomic gradients in almost all behaviors over time.

In addition, the results showed that material factors remain important contributors to socioeconomic inequalities in mortality. This contribution is likely not only due to a direct effect of material factors on mortality, but also indirect via healthy behaviors. These findings highlight the need for policies and interventions to address material adversities in order to reduce inequalities in health.

Lastly, our findings have some important methodological implications. The observed differences between the baseline-only and time-varying models could be caused by different mechanisms. In addition to the intuitive explanation of changing socioeconomic inequalities in material and behavioral factors over time, time-varying associations of these factors with mortality are important. Whereas our results showed that the latter were more important, previous studies have mostly neglected to investigate these different mechanisms.[5-9]

Whether baseline-only models or time-varying models should be preferred will depend on the research question and context of the study. Time-varying models seem preferable because they take changes in mediators into account, but they lose validity if they are not correctly specified to the time lapse needed before changes in mediators cause an actual change in mortality risk.[27] If different time lapses are not accurately modelled in the time-varying models, the time-varying models lose validity and baseline-only models may be preferred.

CONCLUSIONS

This study suggests that repeatedly measured material and behavioral factors change the explanation of socioeconomic inequalities in all-cause mortality compared to baseline-only measurements, whereby measuring risk factors multiple times resulted in a smaller contribution of material factors and a larger contribution of health behaviors. Inclusion of time-dependent mediators contributes to understanding socioeconomic inequalities in mortality in a life course perspective, but careful examination of the underlying mechanisms and suitability of the model is required.

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APPENDIX

Table A1. Educational gradients[a] in age-standardized[b] risk factors at baseline (25-75 years).

	Men (N=2364)				Women (N=2376)			
	Educational attainment				Educational attainment			
	High	Middle	Low	Lowest	High	Middle	Low	Lowest
Financial difficulties								
No difficulties	91.9%	81.9%	78.6%	63.3%	89.8%	85.4%	78.5%	64.3%
Some difficulties	6.7%	14.4%	19.1%	29.0%	9.8%	12.4%	17.4%	25.8%
Major difficulties	1.4%	3.7%	2.4%	7.7%	0.5%	2.1%	4.1%	9.9%
Housing tenure								
House owner	74.9%	62.8%	52.3%	31.1%	77.6%	68.6%	54.9%	33.5%
Rented house	25.1%	37.2%	48.7%	68.9%	22.4%	31.4%	45.1%	66.5%
Health Insurance								
Private insurance	76.7%	48.8%	28.4%	7.6%	66.1%	46.4%	31.4%	15.6%
Other insurance	23.3%	51.2%	71.6%	92.4%	33.9%	53.6%	68.6%	84.4%
Smoking status								
Non-smoker	21.6%	14.6%	16.6%	6.6%	49.2%	46.1%	39.2%	43.2%
Former smoker	43.6%	46.2%	41.1%	34.7%	36.6%	26.5%	28.2%	22.1%
Current smoker	34.8%	39.2%	42.2%	58.6%	14.2%	27.4%	32.6%	34.7%
Leisure time activity								
Active	47.0%	47.5%	52.2%	52.6%	43.4%	44.8%	46.1%	36.4%
Moderately active	27.2%	26.2%	25.8%	20.4%	34.7%	24.6%	25.6%	29.0%
Little active	16.7%	11.7%	10.6%	10.6%	15.8%	16.7%	15.6%	14.7%
Inactive	9.1%	14.6%	11.4%	16.4%	6.0%	13.9%	12.7%	20.0%
Sports participation								
Active	22.3%	24.2%	19.1%	13.8%	14.7%	13.7%	16.2%	6.7%
Moderately active	25.3%	18.1%	14.3%	6.9%	22.1%	31.4%	21.9%	15.8%
Little active	7.8%	8.9%	6.9%	5.4%	11.6%	7.2%	6.6%	11.2%
Inactive	44.6%	48.8%	59.7%	73.9%	51.6%	47.8%	55.3%	66.2%
Body mass index								
Normal weight	60.8%	52.7%	48.5%	46.2%	66.8%	63.3%	53.4%	50.4%
Underweight	3.7%	4.2%	3.3%	4.5%	12.5%	10.6%	10.2%	5.4%
Overweight	33.0%	39.5%	43.1%	42.9%	10.9%	20.5%	28.7%	31.8%
Obese	2.5%	3.6%	5.0%	6.4%	9.8%	5.7%	7.8%	12.5%

[a] All prevalence rates included respondent-level sample weights.

[b] Direct standardization using the age distribution (5-year age groups) in the original random sample of the GLOBE baseline as the standard population.

Table A2. Absolute and relative differences in age-standardized[a] educational gradients[b] (lowest versus high) in risk factors (men).

	Absolute differences (lowest-high)			Relative differences (lowest/high)		
	1991	**1997**	**2004**	**1991**	**1997**	**2004**
Financial difficulties						
No difficulties	-28.6%	-17.0%	-35.8%	0.7	0.8	0.6
Some difficulties	22.3%	13.8%	26.6%	4.3	7.0	4.4
Major difficulties	6.3%	3.3%	9.2%	5.4	10.6	16.6
Housing tenure						
Home owner	-43.8%	-53.0%	-56.9%	0.4	0.4	0.3
Rented house	43.8%	53.0%	56.9%	2.7	4.0	4.5
Health insurance						
Private insurance	-69.1%	-72.1%	-64.8%	0.1	0.1	0.1
Non-private insurance	69.1%	72.1%	64.8%	4.0	4.4	3.3
Smoking status						
Non-smoker	-14.9%	-13.3%	-16.8%	0.3	0.3	0.3
Former smoker	-8.9%	-12.0%	-2.0%	0.8	0.8	1.0
Current smoker	23.8%	25.3%	18.8%	1.7	1.9	2.0
Leisure time physical activity						
Active	5.6%	-10.3%	-15.5%	1.1	0.8	0.8
Moderately active	-6.8%	-1.8%	0.3%	0.8	0.9	1.0
Little active	-6.1%	4.6%	2.2%	0.6	1.3	1.7
Inactive	7.3%	7.5%	13.0%	1.8	1.9	1.9
Sports participation						
Active	-8.4%	-17.9%	-27.7%	0.6	0.3	0.3
Moderately active	-18.5%	-14.1%	-7.9%	0.3	0.4	0.4
Little active	-2.4%	-2.9%	-1.1%	0.7	0.5	0.5
Inactive	29.3%	34.9%	36.8%	1.7	1.8	1.8
Body mass index						
Normal weight	-14.6%	-9.7%	-6.6%	0.8	0.8	0.9
Underweight	0.8%	-0.7%	-0.8%	1.2	0.8	0.6
Overweight	9.9%	6.1%	-0.5%	1.3	1.2	1.0
Obese	3.9%	4.3%	7.9%	2.6	1.9	1.9

[a] Direct standardization using the age distribution (5-year age groups) in the original random sample of the GLOBE baseline as the standard population.
[b] All prevalence rates included respondent-level sample weights.

Table A3. Absolute and relative differences in age-standardized[a] educational gradients[b] (lowest versus high) in risk factors (women).

	Absolute differences (lowest-high)			Relative differences (lowest/high)		
	1991	1997	2004	1991	1997	2004
Financial difficulties						
No difficulties	-25.5%	-15.0%	-20.8%	0.7	0.8	0.7
Some difficulties	16.0%	10.4%	11.8%	2.6	3.9	1.7
Major difficulties	9.4%	4.5%	8.9%	20.7	10.3	23.9
Housing tenure						
Home owner	-44.2%	-47.2%	-48.9%	0.4	0.4	0.4
Rented house	44.2%	47.2%	48.9%	3.0	3.4	3.3
Health insurance						
Private insurance	-50.5%	-54.3%	-47.7%	0.2	0.2	0.1
Non-private insurance	50.5%	54.3%	47.7%	2.5	2.7	2.1
Smoking status						
Non-smoker	-6.0%	-11.9%	-24.2%	0.9	0.8	0.7
Former smoker	-14.5%	-9.5%	5.2%	0.6	0.7	1.2
Current smoker	20.5%	21.4%	19.0%	2.4	3.1	3.9
Leisure time physical activity						
Active	-7.1%	-7.7%	-11.8%	0.8	0.8	0.8
Moderately active	-5.7%	-5.9%	4.3%	0.8	0.8	1.9
Little active	-1.2%	4.5%	-2.2%	0.9	1.3	0.6
Inactive	13.9%	9.1%	9.7%	3.3	1.8	1.5
Sports participation						
Active	-7.9%	-7.0%	-19.4%	0.5	0.5	0.4
Moderately active	-6.3%	-15.3%	-6.6%	0.7	0.4	0.6
Little active	-0.4%	-2.1%	-1.0%	1.0	0.8	0.8
Inactive	14.6%	24.5%	27.1%	1.3	1.5	1.6
Body mass index						
Normal weight	-16.5%	-26.0%	-15.3%	0.8	0.6	0.7
Underweight	-7.1%	-6.1%	-2.0%	0.4	0.5	0.6
Overweight	20.8%	23.8%	2.8%	2.9	2.5	1.1
Obese	2.7%	8.4%	14.5%	1.3	2.4	3.1

[a] Direct standardization using the age distribution (5-year age groups) in the original random sample of the GLOBE baseline as the standard population.

[b] All prevalence rates included respondent-level sample weights.

Table A4. The role of individual risk factors in the association[ab] between socioeconomic position and mortality (men).

	HR (95% CI)		**HR (95% CI)**		**Percent explained[c] (95% CI)**		**Percent explained[c] (95% CI)**	
	Education Lowest vs high		**Occupation breadwinner** Blue collar vs professional		**Education** Lowest vs high		**Occupation breadwinner** Blue collar vs professional	
	Baseline models	**Time-varying models**	**Baseline models**	**Time-varying models**	**Baseline models**	**Time-varying models**	**Baseline models**	**Time-varying models**
$Model_1$	1.84 (1.40, 2.41)	1.84 (1.40, 2.41)	1.40 (1.14, 1.71)	1.40 (1.14, 1.71)	NA	NA	NA	NA
Financial difficulties	1.73 (1.31, 2.28)	1.80 (1.37, 2.37)	1.33 (1.08, 1.64)	1.36 (1.11, 1.68)	13% (1%, 29%)	5% (-5%, 23%)	18% (4%, 46%)	10% (-1%, 40%)
Housing tenure	1.50 (1.11, 2.04)	1.53 (1.13, 2.07)	1.22 (0.98, 1.52)	1.24 (1.00, 1.54)	40% (19%, 79%)	37% (13%, 69%)	45% (19%, 115%)	40% (14%, 91%)
Health insurance	1.42 (1.03, 1.95)	1.56 (1.17, 2.09)	1.11 (0.88, 1.41)	1.22 (0.97, 1.55)	50% (22%, 95%)	33% (8%, 65%)	73% (32%, 168%)	45% (6%, 117%)
Smoking status	1.71 (1.30, 2.25)	1.66 (1.26, 2.17)	1.27 (1.04, 1.55)	1.29 (1.05, 1.57)	15% (1%, 36%)	21% (12%, 40%)	33% (12%, 74%)	28% (16%, 70%)
Leisure time physical activity	1.84 (1.40, 2.42)	1.69 (1.29, 2.23)	1.39 (1.13, 1.70)	1.30 (1.06, 1.60)	0% (-9%, 7%)	18% (12%, 41%)	3% (-8%, 13%)	25% (6%, 50%)
Sports participation	1.77 (1.33, 2.34)	1.58 (1.20, 2.07)	1.37 (1.12, 1.69)	1.30 (1.06, 1.59)	8% (-6%, 28%)	31% (24%, 62%)	7% (-7%, 25%)	25% (16%, 69%)
Body mass index	1.84 (1.39, 2.42)	1.87 (1.42, 2.47)	1.38 (1.12, 1.70)	1.45 (1.17, 1.79)	0% (-14%, 9%)	-4% (-11%, 3%)	5% (-14%, 24%)	-13% (-38%, 1%)

[a] All analysis included respondent-level sample weights.

[b] All models were adjusted for country of birth and marital status at baseline; age was used as the time scale.

[c] Percent explained: $(HR_{model1} - HR_{model1 + risk\ factors}) / (HR_{model1} - 1) \times 100\%$.

Table A5. The role of individual risk factors in the association[ab] between socioeconomic position and mortality (women).

	HR (95% CI)		**HR (95% CI)**		**Percent explained[c] (95% CI)**		**Percent explained[c] (95% CI)**	
	Education Lowest vs high		**Occupation breadwinner** Blue collar vs professional		**Education** Lowest vs high		**Occupation breadwinner** Blue collar vs professional	
	Baseline models	**Time-varying models**	**Baseline models**	**Time-varying models**	**Baseline models**	**Time-varying models**	**Baseline models**	**Time-varying models**
$Model_1$	1.69 (1.03, 2.76)	1.69 (1.03, 2.76)	1.51 (1.17, 1.95)	1.51 (1.17, 1.95)	NA	NA	NA	NA
Financial difficulties	1.56 (0.95, 2.56)	1.69 (1.03, 2.78)	1.41 (1.08, 1.83)	1.51 (1.16, 1.96)	19% (2%, 69%)	0% (-14%, 17%)	20% (5%, 57%)	0% (-20%, 14%)
Housing tenure	1.49 (0.91, 2.45)	1.45 (0.87, 2.41)	1.36 (1.05, 1.76)	1.34 (1.04, 1.74)	29% (-4%, 101%)	35% (6%, 103%)	29% (5%, 66%)	33% (9%, 67%)
Health insurance	1.47 (0.90, 2.42)	1.61 (0.97, 2.66)	1.36 (1.04, 1.79)	1.50 (1.13, 1.98)	32% (-2%, 118%)	12% (-28%, 61%)	29% (-6%, 76%)	2% (-34%, 45%)
Smoking status	1.57 (0.95, 2.61)	1.53 (0.93, 2.52)	1.50 (1.15, 1.96)	1.44 (1.11, 1.86)	17% (-6%, 98%)	23% (9%, 87%)	2% (-19%, 28%)	14% (1%, 33%)
Leisure time physical activity	1.59 (0.98, 2.59)	1.55 (0.94, 2.55)	1.49 (1.15, 1.92)	1.41 (1.09, 1.81)	14% (-6%, 55%)	20% (15%, 110%)	4% (-9%, 19%)	20% (6%, 49%)
Sports participation	1.69 (1.02, 2.80)	1.60 (0.97, 2.64)	1.48 (1.15, 1.92)	1.45 (1.12, 1.89)	0% (-22%, 23%)	13% (-1%, 62%)	6% (-6%, 18%)	12% (0%, 39%)
Body mass index	1.63 (0.99, 2.67)	1.60 (0.98, 2.62)	1.47 (1.13, 1.90)	1.47 (1.14, 1.90)	9% (-11%, 45%)	13% (-5%, 41%)	8% (-3%, 31%)	8% (-10%, 18%)

[a] All analysis included respondent-level sample weights.

[b] All models were adjusted for country of birth and marital status at baseline; age was used as the time scale.

[c] Percent explained: $(HR_{model1} - HR_{model1 + risk\ factors}) / (HR_{model1} - 1) \times 100\%$.