The contribution of health behaviors to socioeconomic inequalities in health: a systematic review

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ABSTRACT

Unhealthy behaviors and their social patterning have been frequently proposed as factors mediating socioeconomic differences in health. However, a clear quantification of the contribution of health behaviors to the socioeconomic gradient in health is lacking. This study systematically reviews the role of health behaviors in explaining socioeconomic inequalities in health.

Published studies were identified by a systematic review of PubMed, Embase and Web-of-Science. Four health behaviors were considered: smoking, alcohol consumption, physical activity and diet. We restricted health outcomes to cardiometabolic disorders and mortality. To allow comparison between studies, the contribution of health behaviors, or the part of the socioeconomic gradient in health that is explained by health behaviors, was recalculated in all studies according to the absolute scale difference method.

We identified 114 articles on socioeconomic position, health behaviors and cardiometabolic disorders or mortality from electronic databases and articles reference lists. Lower socioeconomic position was associated with an increased risk of all-cause mortality and cardiometabolic disorders, this gradient was explained by health behaviors to varying degrees (minimum contribution -43%; maximum contribution 261%).

Health behaviors explained a larger proportion of the SEP-health gradient in studies conducted in North America and Northern Europe, in studies examining all-cause mortality and cardiovascular disease, among men, in younger individuals, and in longitudinal studies, when compared to other settings. Of the four behaviors examined, smoking contributed the most to social inequalities in health, with a median contribution of 19%.

Health behaviors contribute to the socioeconomic gradient in cardiometabolic disease and mortality, but this contribution varies according to population and study characteristics. Nevertheless, our results should encourage the implementation of interventions targeting health behaviors, as they may reduce socioeconomic inequalities in health and increase population health.

INTRODUCTION

The existence of a stepwise association between socioeconomic position (SEP) and health related outcomes (1-4), also referred as the socioeconomic gradient in health, constitutes one of the most consistent findings of epidemiologic research. Individuals with a lower socioeconomic position, as measured by occupational position, educational attainment, income, or composite indexes, are more likely to die earlier and have a higher incidence of cardiovascular events, diabetes, obesity, and other diseases than their more advantaged counterparts (4, 5). As eliminating socioeconomic disadvantage from society is difficult, quantifying modifiable intermediate factors and targeting them could have important public health benefits. Epidemiologic research has long investigated potential mediating factors of the association between socioeconomic position and health outcomes, with health behaviors, environmental exposures or psychosocial factors having been identified as major mechanisms in the link between low SEP and increased disease risk (Supplementary Figure 1) (6-11).

Health behaviors such as smoking, alcohol consumption, diet and physical activity (PA) are major risk or protective factors for chronic diseases (12-14) and are also strongly socially patterned, with detrimental behaviors being more prevalent in lower SEP groups when compared to higher SEP groups (15-17). Yet, despite extensive investigations, a clear understanding of the role of health behaviors in social inequalities in health is still lacking, a major challenge being that their estimated contribution to the socioeconomic gradient in health varies greatly across studies, ranging from 12% to 72% (11, 18-23).

The reasons for the differential contribution of health behaviors to social inequalities in health are numerous and include cultural differences between countries (18), demographic characteristics of the participants included in the studies (24), between-studies differences in the SEP measures, health behaviors and health outcomes examined, and methodological differences in the calculation of the contribution of health behaviors (23, 25). Another potential explanation may be related to the stage of the epidemiologic transition, which designates the changes in the prevalence of diseases, disease risk factors, and the changes in the adherence to health behaviors over time and in different sociodemographic contexts (26). However, there is currently no attempt in the literature to synthesize the wealth of research on this topic and provide a more comprehensive assessment of health behaviors as mechanisms underlying the association between SEP and health. However, this is a crucial step for identifying targets for policies aimed at reducing socioeconomic differences in health as well as improving health at the population level.

In this study, we conducted a systematic review and synthesis of the literature on the contribution of smoking, alcohol intake, physical activity and dietary patterns to socioeconomic inequalities in all-cause mortality and risk of cardiometabolic disorders, two health outcomes showing a particularly consistent socioeconomic gradient across studies (27-30). The overarching purpose of this review was to examine all previously published studies investigating the contribution of health behaviors to socioeconomic inequalities in health, and to provide a complete and comprehensive analysis regarding the sources of heterogeneity of this contribution, with a particular focus on methodological, sociodemographic and cultural factors.

METHODS

Search strategy and inclusion criteria

In this systematic review, we aimed to retrieve and analyze all articles that examined the contribution of health behaviors to the socioeconomic gradient in all-cause mortality and cardiometabolic disorders. We used four main groups of search terms: terms related to SEP, terms related to health behaviors, terms related to health outcomes, and terms related to "contribution", "role", or "mediation" (Supplementary Material – search strategy**)**. Article search was performed from August 2015 to December 2016 by searching PubMed, Embase and Web-of-Science electronic databases following the PRISMA-Equity guidelines (31). No publication date restrictions were imposed. Articles in English and French were considered. Two reviewers (DP, CdM) independently examined the titles and abstracts of the papers identified in the databases search, removed papers that did not meet the inclusion criteria and selected eligible papers for full-text review. The reference lists of reviewed papers were also searched for additional articles of interest that were not identified by the electronic search.

In this review, we included four health behaviors that had been previously strongly related to SEP, but also to all-cause mortality and cardiometabolic disorders: smoking, alcohol consumption, physical activity, and dietary patterns (12-14, 32-36). We also considered papers that performed analyses adjusted for multiple health behaviors simultaneously (i.e. smoking *and* alcohol). We searched for papers that reported SEP as measured by education, occupation, income, wealth, area-based indicators, childhood SEP indicators, partner's SEP as well as composite SEP scores (i.e. education and occupation). We included both cross-sectional and longitudinal observational studies investigating the contribution of the four health behaviors to socioeconomic inequalities in all-cause mortality and cardiometabolic outcomes (defined as cardiovascular disease, hypertension, coronary heart disease, stroke, diabetes, impaired glucose tolerance, metabolic syndrome, allostatic load, obesity). Despite the fact that some studies used BMI as a proxy for diet or a risk factor for other diseases, in the present review we considered it as a health outcome.

The main inclusion criterion in selected articles was the presence of a quantification of the contribution of health behaviors to the SEP gradient in health, or the possibility to estimate this from the data according to the difference method, which compares the coefficients from the SEP-health association model that is unadjusted for health behaviors, with the coefficients from a model additionally adjusted for health behaviors (23). Experimental studies (i.e. health education programs, randomized control trials), articles published in non-peer-reviewed journals, non-original research papers (i.e. reviews, commentaries), duplicate publications and articles limited to an abstract (i.e. congress proceedings) were excluded. After removing non-eligible papers, CdM and DP examined the papers to be included in the systematic review. For the title and abstract screening process, the level of agreement between the two reviewers was >90%, while for full-text screening, the level of agreement between the two reviewers was >95%. Whenever a conflict was encountered, the two reviewers discussed the article in question to decide whether to include it or not.

Data extraction

For each study, the following data were extracted: title, last name of first author, study region or country, cohort name, study period, study design, sample size, characteristics of participants, SEP indicator(s) (exposure), health outcome(s) (outcome) and health behavior(s) (mediating factor) along with their measurement methods (i.e. self-administered questionnaires, medical records, death registries), and two regression coefficients for SEP (β, hazard ratio (HR), odds ratio (OR), risk ratio (RR)) with 95% confidence intervals (CI); the first coefficient from the unadjusted regression model: SEP → health outcome (Model 1), and the second coefficient from the regression model additionally adjusted for health behavior(s) or mediator(s): SEP → health behavior(s) → health outcome (Model 2).

While the majority of the included papers did not provide any direct assessment of the contribution of health behaviors to socioeconomic differences in all-cause mortality and risk of cardiometabolic disorders, in 31 studies this contribution was calculated according to the absolute (n=13) (7, 23, 28, 37-46) or relative scale difference methods (n=18) (11, 19, 21, 22, 47-60) which compare the beta coefficient for SEP from the unadjusted regression model (Model 1) with the beta coefficient from the regression model additionally adjusted for health behaviors (Model 2). Nine studies provided a quantification of the contribution of health behaviors by using alternative methods, namely path analysis model (61, 62), likelihood-ratio test statistic (63), Sobel's mediation test (64-66) and the mediation method based on direct and indirect effects (67-69).

Out of the 114 papers included in this review, 111 papers provided the estimators for the unadjusted and the health behavior adjusted models allowing the implementation of the difference method, while three studies assessed the contribution of health behaviors with an alternative method, and did not provide adequate information regarding the unadjusted and the adjusted models (Supplementary Figure 2) (69-71). Despite limitations of the difference method for assessing the contribution of mediating factors in an association, including unmeasured confounding variables and interactions (72) as well as the possibility of yielding counter-intuitive negative contributions by health behaviors, this is to date the only statistical procedure that allows computing contribution of mediators based on statistical coefficients (β, OR, HR or RR) without individual-level data. Consequently, to allow comparison between studies, we recalculated the contribution of health behaviors with the absolute scale difference method for 111 out of 114 studies:

$$\text{Contribution of health behaviors (\%)} =$$

$$100 \times (\beta_{\text{Model 1}} - \beta_{\text{Model 2: Model 1 + health behavior(s)}})/\beta_{\text{Model 1}}$$

where β = β regression coefficient or log (HR, OR, RR) of the least advantaged SEP group for studies that used highest SEP group as a reference (n=105). For studies that used the lowest SEP group as a reference, β coefficients from the highest SEP group were used for computing the contribution of health behaviors (38, 60, 73-79). To illustrate the computation of the contribution of health behaviors, we can consider an example taken from a study by Stringhini et al. (Table 4 – Whitehall II data) (7). The HR coefficient from the unadjusted model for the association between occupation and all-cause mortality is: 1.62 95%CI[1.28-2.05]. In the model additionally adjusted for smoking, the HR for the association between occupational position and all-cause mortality is 1.39 95%CI[1.09-1.75]. The contribution of smoking to the association between occupational position and all-cause mortality, is then calculated as:

$$100 \times (\log(1.62)-\log(1.39))/\log(1.62) = 32\%$$

This percentage means that smoking contributes to approximately one third of the association between occupational position and all-cause mortality.

To analyze whether the contribution of health behaviors to the socioeconomic gradient differed by study settings, the contribution estimates computed for each article were grouped according to three main SEP indicators; namely education and occupation, which are the two most commonly used indicators, thought to capture multiple dimensions of SEP, and “Other SEP indicators” which included the remaining SEP markers (23, 80). The contribution figures were further aggregated according to health outcome, sex, geographic location, age group of study participants, type of study (longitudinal vs. cross-sectional) and assessment method of health behaviors (questionnaire vs. objective assessment methods). For each group of studies that presented the same SEP indicator and aggregating factor, a median, minimum and maximum contribution were computed.

Mediators, confounders, and moderators/modifiers of the SEP-health association

In addition to mediating factors, the studies included in this review also reported specific sets of confounding and/or modifying factors that may affect the SEP-health association. In order to avoid confusion between the terms mediator, confounders and modifier, we provide the following explanations regarding their respective effects. Health behaviors are usually considered as mediating factors of the SEP-health association as they are strongly socially patterned and are simultaneously major risk or protective factors for health-related outcomes (23, 33, 81). Consequently, they contribute to this association by being located on the assumed causal pathway between SEP (exposure) and health (outcome)(81). In contrast to mediators, factors such as age, sex, or ethnicity are usually considered as confounders, as they influence the SEP-health association but are not located on the causal pathway. Confounders are generally conceptualized as pre-existing or tangential to the exposure and often distort the effect of exposure on the outcome (81, 82). Finally, there may also be risk or protective factors referred to as moderators or modifiers, which modify the association between the exposure and the outcome, when the effect of the exposure differs across levels of the moderator/modifier (83, 84).

RESULTS

Our search strategy identified 855 potentially relevant articles, of which 740 were found in three electronic databases and 115 were retrieved from reference lists. The article selection process and flow-chart are presented in **Supplementary Figure 2**. A total of 537 articles were rejected based on Title/Abstract screening. These studies were mostly health intervention programs, randomized controlled trials or other experimental studies, did not assess the association between SEP and a health outcome, did not include one of the health outcomes of interest or performed reversed analyses (health outcome as predictor of SEP). A total of 318 articles were selected for full text reading, of which 204 were excluded, the main reason for exclusion being that they did not provide an estimate of the contribution of health behaviors separate from major confounders such as sex, age and/or pre-existing diseases. Other articles excluded based on full text reading were either narrative reviews or commentaries and not original articles, or used SEP as an adjustment factor only. The selection process eventually yielded 114 articles that were included in the systematic review.

General characteristics

General characteristics of the papers included in this systematic review are summarized in **Table 1**. The included studies (39 cross-sectional; 75 longitudinal) took place between 1948 and 2016, and were mainly conducted in high-income countries (United States (n=27), United Kingdom (n=23) and other countries from the Organization for Economic Co-operation and Development (n=57) (85)). Four studies took place in low or middle income countries, namely Kenya, Seychelles and China, and three were international consortia. In 113 articles, analyses were carried out in adults, of which 13 also included adolescents. One article reported analyses performed in individuals aged 8-19 (86). In 27 articles, analyses were stratified by sex while ten studies included men only and ten women only. To assess the association between SEP and health outcomes, most studies relied on logistic or Cox proportional hazards regression models, whereas others used linear or non-linear (Poisson) regression models.

SEP indicators

In two thirds of the included studies (n=72), only one SEP indicator was used, while 42 studies used more than one indicator. 89 articles used self-administered questionnaires to measure SEP, while 25 relied on more objective methods including work registries or adjusted questionnaires according to validated methods (i.e. Registrar general's classification based on occupation (41, 44, 87)). The main SEP indicator was participant's education (n=63), followed by income (n=31) and occupation (n=30). Alternative indicators were also used, such as wealth or poverty levels (n=18), partner's education or occupation (n=2), area based indicators (n=8) as well as composite SEP scores (n=14) which were computed based on several SEP indicators (i.e. education and occupation). Other studies assessed childhood SEP indicators, such as parental education, occupation or living conditions in childhood.

Health outcomes

The majority of studies included only one health outcome (n=96), 17 studies examined two health outcomes and, one study assessed three outcomes. Generally, health outcomes were assessed through objective measures including death registries or medical records (n=98). Most studies assessed cardiovascular diseases such as stroke, coronary heart disease or hypertension (n=57) and all-cause mortality (n=31). A total of 29 studies assessed diabetes or impaired glucose tolerance, whereas obesity was used as an outcome in 6 studies, and composite health outcomes such as metabolic syndrome and allostatic load were assessed in 10 studies.

Health behaviors

Generally, included studies assessed the contribution of several health behaviors (n=96), whose information was almost exclusively collected through self-administered questionnaire (n=113), except for one study that also assessed smoking according to cotinine levels in blood (88). Smoking was the most common behavior assessed (n=103), followed by physical activity (n=83), alcohol consumption (n=73) and dietary patterns (n= 31).

Table 2 shows the median contribution of multiple health behaviors to socioeconomic differences in all-cause mortality and cardiometabolic disorders, stratified by the type of SEP indicator, health outcomes, sex, study region, age groups, type of study and assessment method of health behaviors. Health behaviors generally contributed similarly to the SEP gradient in the health outcomes examined; the median contributions being between 20% and 26% for all-cause mortality, between 16% and 33% for cardiovascular disorders, and between 17% and 29% for metabolic disorders.

However, a generally higher contribution of health behaviors was observed in studies that used occupational position instead of other SEP indicators. Health behaviors generally contributed to a greater extent to the associations between SEP and health outcomes in Northern Europe, with **median contributions** varying between 29% and 36%, followed by the remaining regions (other OECD countries and other low and middle-income countries) (16% to 25%), North America (12% to 25%) and Central/Southern Europe with median contributions ranging between 10% to 18% (one outlier study with 64% contribution (61)). Finally, median contributions tended to be higher in longitudinal studies (23% to 31%) when compared to cross-sectional studies (12% to 21%).

Table 3 presents the median contribution of smoking (Panel A) and alcohol consumption (Panel B) to socioeconomic differences in all-cause mortality and cardiometabolic disorders. The median contribution of smoking to the socioeconomic gradient was the highest for all-cause mortality (19% to 32%), followed by metabolic disorders (14% to 22%) and cardiovascular disease (15% to 17%). However, the median contribution varied according to SEP indicator, and was generally higher for occupation. Smoking contributed to the socioeconomic gradient slightly more in men (12% to 22%) than in women (6% to 19%), and more in Northern Europe (17% to 19%) and North America (2% to 35%), than in Central/Southern Europe (4%) or other regions (11% to 15%). The median contribution of smoking was also higher in studies with greater proportion of younger individuals, as well as in longitudinal studies than in cross-sectional ones. Alcohol's median contribution (Panel B) was higher for cardiovascular disorders (6% to 64%) than for all-cause mortality (-2% to 17%) or metabolic disorders (2%). While no particular difference was observed between men and women, the median contribution of alcohol tended to be higher and broader in North America (2% to 139%) than in other regions.

The contributions of physical activity (Panel A) and dietary patterns (Panel B) to socioeconomic differences in health are shown in **Table 4**. The median contribution of PA to the SEP-health gradient was higher for all-cause mortality (12% to 20%) and cardiovascular disorders (4% to 19%) than for metabolic disorders (6% to 9%), but varied in men and women according to the SEP indicator. Similarly to smoking and alcohol, the contribution of PA was higher for studies conducted in Northern Europe (6% to 13%) and North America (-2% to 26%) than in Central/Southern Europe (8%). Dietary patterns contributed more to the SEP gradient in all-cause mortality (17% to 21%) and cardiovascular disorders (7% to 24%) than in metabolic disorders (10% to 11%). Furthermore, the median contribution was higher in men (36%) than in women (11%). The contribution of dietary patterns was generally higher in Northern Europe (13% to 26%) and North America (11% to 29%) and for middle-aged individuals (13% to 27%) than for other regions or age groups.

DISCUSSION

In this study, we reviewed the evidence on the contribution of smoking, alcohol consumption, physical activity and dietary patterns on social inequalities in all-cause mortality and cardiometabolic disorders. We confirmed the existence of a strong association between SEP and health outcomes, and showed that health behaviors contribute to the SEP gradient in health to varying degrees. In general, the contribution of health behaviors to socioeconomic differences in health was higher in studies conducted in North America and Northern Europe than in Central/Southern Europe, in men than in women, in younger and middle-aged individuals than in older individuals, for smoking when compared to other health behaviors, for all-cause mortality and cardiovascular disease than for metabolic disorders and in longitudinal studies compared to cross-sectional studies. Furthermore, we also observed that the contribution tended to be higher for the socioeconomic gradient in health when occupational position was used as the indicator of socioeconomic position. These findings are of particular interest when considering implementation of prevention policies, as future measures and interventions aiming to reduce the socioeconomic gradient in health could focus on health behaviors with the highest impact in given geographic and sociodemographic contexts (30).

Health behaviors are plausible mediators of social inequalities in health as they are strongly socially patterned and simultaneously related to health outcomes (12, 13, 16, 89). Previous research has shown that socially disadvantaged individuals tend to adhere more to health detrimental behaviors either due to material and financial constraints, perception of fewer benefits of health behaviors for longevity, a lack of knowledge of their detrimental effect, difficulties to take up health promoting messages as well as more pessimistic attitudes about life (17, 18, 90). Previous studies have also shown that low SEP individuals lack the resources to buy adequate food or sports equipment (91), or have no access to sports facilities, as safe areas or adequate transport may not be always available (16, 92). Furthermore, deprived neighborhoods frequently offer little opportunity for a healthy life (93). These areas are often characterized by an absence of supermarkets offering a variety of affordable and healthy foods but on the other hand are full of small convenience stores which sell highly-advertised tobacco, alcohol, processed foods (i.e. snacks, sodas) and no or few fruits and vegetables (93). An additional aspect concerns the motivations, beliefs and attitudes that socially disadvantaged individuals have towards health behaviors. For example, it has been shown that less advantaged SEP individuals tend to be less conscious about healthy behaviors, have stronger beliefs in the influence of chance over health and were generally more pessimistic or fatalistic about their life expectancy, altogether acting as an additional barrier to a healthy lifestyle (17).

Social patterning of health behaviors

Our review confirms that health behaviors contribute to the socioeconomic gradient in health, yet the extent of this contribution varied greatly across included articles, the main reason being the differential social patterning of health behaviors, which designates an unequal distribution of health behaviors across socioeconomic groups in given socio-demographic, regional and cultural contexts (18). The differential social patterning of health behaviors according to age, gender and region may be explained by the epidemiologic transition from the "diseases of affluence" towards the "diseases of the poor". According to this model, coronary heart disease and related health behaviors such as smoking and an energy-dense diet were originally more prevalent in the higher socioeconomic groups, but their burden started to gradually shift to the lower SEP groups along with the progression of the epidemiologic transition (94, 95). The epidemiologic transition progressed at a different pace in different geographical regions and for men and women, due to economic, social or cultural factors (96). In the same way, it is hypothesized that the socioeconomic gradient in chronic diseases and related health behaviors also reversed (from higher prevalence in the higher SEP groups to higher prevalence in the lower) at different times in different countries and for men than for women (18). We have tested this hypothesis by stratifying the articles by periods during which the studies were conducted, and observed that the overall contribution of smoking to the socioeconomic gradient in health has increased over time (results available from the authors). These results are in line with the smoking epidemic model, which shows that smoking prevalence rates differ by gender and SEP in different stages of the epidemic (97). These differences are likely due to socio-cultural factors such as the level of gender equality in the country, as smoking could be/has been perceived as a symbol of emancipation by women, especially in the higher socioeconomic groups at the early stages of the epidemics (98, 99). As regions such as Southern Europe are at later stages of the smoking epidemics, smoking may still be more common in women with higher education, likely due to the delayed acquisition of full social and political rights (98-101). The succession of different stages of the smoking epidemic may also explain the differences in the patterning of health behaviors according to age groups, as we observed higher contributions of smoking to the socioeconomic gradient in health in younger and middle-aged individuals compared to older individuals. A possible explanation may be that the behavioral characteristics of a given stage of the smoking epidemic have been imprinted within individuals during specific periods, resulting in a different social patterning of health behaviors across generations (7, 97, 102). Hence, in older generations smoking patterns may be the ones observed during the earlier stages of the smoking epidemic, with a relatively high prevalence of smoking and a weak socioeconomic gradient, while younger generations may be characterized by a smaller smoking prevalence and a strong social patterning of smoking (97, 102). Alternatively, age related differences in the contribution of health behaviors may also be explained by a decrease in these inequalities with ageing, as older people are more likely to have stopped smoking or decreased alcohol intake (103, 104). Nevertheless, as a consequence of the ongoing globalization process, the socioeconomic gradient in health behaviors is likely to become increasingly homogenous and omnipresent on a worldwide scale in the next years or decades. Even though we found a stronger contribution of health behaviors to social inequalities in health in Northern Europe or North

America compared to other countries, increasing social differences in health behaviors are being reported in a growing number of regions, including emerging economies, as low SEP individuals are being increasingly exposed to unhealthy behaviors, including sedentary behavior and the adherence to the so-called “neo-liberal diet”, characterized by cheap, highly-processed and energy dense food (105-107).

In addition to the epidemiologic transition hypothesis, the differential social patterning of health behaviors may also be related to cultural aspects and norms (101). Previous studies have suggested that the observed SEP-health behavior gradient in Northern countries may result from the expression of social distinction, while in Southern European regions, dietary patterns, alcohol intake or smoking still tend to be related to cultural norms rather than SEP (4, 18). Moreover, in countries such as Italy, Spain or Greece, dietary patterns characterized by a high consumption of fruits, vegetables, olive oil and moderate wine intake were very common in every socioeconomic group as a result of the overall availability of these products (4). Additional cultural aspects that could explain the differential social patterning of health behaviors by gender may be related to the perception of body size, standards of beauty or signs of dominance and rank (107, 108). Previous studies have found that in low and middle income countries, men with high SEP tend to be frequently obese and adhere to health behaviors that would reflect their affluent position and lifestyle, including smoking, an energy-dense diet and sedentary behavior resulting from the use of motorized transport or leisure activities such as television watching. Alternatively, women with high SEP would tend to adopt Western standards of beauty or attractiveness, centered towards thinness and thus pay attention to their lifestyle (33, 107, 108).

The stronger contribution of smoking when compared to the contribution of other health behaviors is also related to the degree of social patterning of health behaviors (32, 97). Smoking may be so prevalent among disadvantaged SEP groups as it may help managing stress, regulating mood and dealing with every day hassles occurring as a consequence of poverty and other adverse social circumstances (109). Moreover, while smoking may have become stigmatized in socially advantaged individuals, in lower SEP groups smoking generally remains more tolerated (32). Smoking uptake occurs earlier in poor children whose parents, family and peers usually smoke or may consider smoking as being the norm or socially acceptable (32, 110).

We have also observed that the contribution of health behaviors tended to be higher when occupation was used as an exposure when compared to education and the other SEP indicators. This may be related to the fact that occupation is strongly associated to work-related stress, job strain and feelings of control (80, 111). Former studies have shown that these job-related psychosocial factors, particularly stress, may lead to an increased adherence to high-rewarding unhealthy behaviors, such as smoking, alcohol drinking, overeating, or drug use, which eventually lead to adverse health outcomes (17, 112).

Physiological aspects

The contribution of health behaviors to the socioeconomic gradient in health also varied depending on the health outcome. This may be related to the fact that some physiological systems are more affected by certain types of behaviors than others. For example, smoking would have greater consequences on occurrence of respiratory diseases, malignancies and atherosclerosis than on obesity, which tends to be more related to dietary patterns and physical activity (113, 114). Furthermore, the contribution of genetic factors varies from one health outcome to another, thus moderating or interfering with the impact of health behaviors (115-118).

Methodological aspects

Methodological aspects can also explain heterogeneity across studies. Health behaviors may explain a larger proportion of the SEP-health gradient when their assessment is repeated and thus more accurate over time, as in longitudinal studies (23). The contribution of health behaviors may also vary depending on the specific confounders or modifying factors that are controlled for in the various studies (18).

Finally, we have seen that health behaviors contribute to varying degrees to SEP differences in health, the main reason being the differential social patterning of health behaviors which is due to cultural, political or demographic factors. However, it is important to note that health behaviors do not entirely explain the socioeconomic gradient in health. Other mediators including psychosocial factors, working conditions, environmental exposures as well as access to healthcare likely constitute additional mechanisms through which SEP affects health, and the study of their contribution, along with health behaviors, may help understand the SEP gradient globally.

Strengths and limitations

To our knowledge, this is the first study to have systematically reviewed the evidence on the contribution of health behaviors to socioeconomic inequalities in health. Our study has limitations to acknowledge. All the studies included in this review assume a causal association between socioeconomic factors and health. Although the majority of studies were longitudinal studies conducted on healthy individuals where the exposure preceded the outcome, reverse causation cannot be completely ruled out, especially for cross-sectional studies which are less well suited for determining causal associations (112, 119, 120). While the causal association from health towards SEP was generally found to be negligible when compared to the causal association going from SEP towards health (112, 121, 122), some former studies have reported that children showing evidence of illness were more likely to be downwardly mobile in the socioeconomic structure in later life (112, 123, 124). Another limitation is the frequent uneven distribution of studies across categories of different aggregating factors (study region, age-range, type of study, assessment method of health behaviors), which challenges interpretation and identification of factors that affect the contribution of health behaviors. Further, differences in the set of confounders included in the analysis across studies may represent an additional source of heterogeneity. Another limitation of this work concerns the use of the absolute difference method to compute the contribution of health behaviors, as this method does not take into account all the possible confounding and interactions between the exposure, the mediators and the outcomes, and is therefore subject to bias (125). Only nine papers used alternative mediation methods, of which two applied the counterfactual mediation methods based on direct and indirect effects (67, 68), which restrict bias by including all possible confounding between the exposure, the mediators and the outcome. Moreover, an additional limitation may be related to the fact that some of the included studies used BMI as a risk factor or a proxy for diet, while other studies used it as an outcome. This differential use of BMI may further challenge the interpretation of the contribution of health behaviors, as BMI was not used consistently across the included studies. Furthermore, differences in sociodemographic aspects, study-periods, and assessment methods of SEP indicators, health behaviors, and health outcomes, greatly challenge between-study comparisons of the contribution of health behaviors to the SEP gradient in health, and preclude conducting formal meta-analyses and assessing associated parameters (i.e. publication bias, quality score). Consequently, this heterogeneity may hinder an adequate interpretation of the contribution of health behaviors and prevent drawing right conclusions (126, 127). The use of objective and validated measurement and classification methods such as the European socio-economic classification scheme (ESEC) for classifying socioeconomic position, accelerometer or cotinine levels for assessing health behaviors, and clinical parameters and medical records for determining health outcomes, should be preferred over less valid and inaccurate methods (i.e. self-report), in order to limit bias and further improve the quality of studies (4, 128-131). However, we did not assess additional aspects related to study quality in this systematic review, such as comprehensive reporting of results, or the validity and reliability of questionnaire, which may potentially represent a limitation in terms of study comparison. Additionally, longitudinal designs should be preferred over the cross-sectional ones, as they allow to determine causality and mediation, and account for the fact that the assessment of health outcomes, the adherence to health behaviors, and the socioeconomic position evolve over the life-course and follow secular trends, as suggested by the epidemiologic transition and the smoking epidemic model (23, 80, 97, 132-134). Finally, another potential issue may be related to the contribution of multiple health behaviors when compared to the contribution of individual health behaviors, as we cannot exclude potential non-additive effects (i.e. interaction between health behaviors) in models adjusting for multiple health behaviors, which may affect or bias the extent of the contribution of health behaviors.

Conclusion

This is the first study to provide a complete and comprehensive synthesis on the factors influencing the contribution of health behaviors to the socioeconomic gradient in health. We observed that health behaviors overall contribute to the association between SEP and health outcomes, but that this contribution varies substantially according to geographic location, sex, age, health outcomes and methodological differences between included studies, the main reason for this heterogeneity being the differential socioeconomic patterning of health behaviors in given regional and demographic contexts. While our results provide a global understanding of the role of health behaviors to the socioeconomic gradient in health, they also encourage implementation of policies aimed at reducing socioeconomic inequalities in health, for example addressing the unequal distribution of unhealthy behaviors.

An overall challenge regarding the socioeconomic gradient in health would be to identify all the mediators involved in this association, such as psychosocial factors, material conditions, environmental exposures or work conditions in order to provide a global and complete understanding of mechanisms underlying socioeconomic inequalities in health. Finally, an experimental approach and monitoring regarding the effectiveness of these policies should also be considered to ensure that socioeconomic inequalities are indeed reduced.

COMPLIANCE WITH ETHICAL STANDARDS

For this type of study ethics approval is not required

CONFLICTS OF INTEREST

None

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Table 1: General characteristics of the studies included in the systematic review

Study	Country	Survey period	Study/cohort name	Type of study	Age at baseline	Number included	SEP indicator(s)	Outcome(s)	Lifestyle behavior(s)
Notkola et al., 1985 (135)	Finland	1959-1974	East-West study	Longitudinal	40-60+	1711	Childhood SES (OA)	CVD (OA)	Smoking (Q)
Jacobsen et al., 1988 (136)	Norway	1980	The Tromso Heart Study	Cross-sectional	25-55	11562	Education (Q)	CVD (OA)	Alcohol, Smoking, PA, Diet (Q)
Jeffery et al., 1991 (70)	US	<1991	Healthy Worker Project	Cross-sectional	38.7 (mean age)	4647	SES score (Q)	Obesity (OA)	Smoking, PA, Diet (Q)
Stamler R. et al., 1992 (137)	International	1982-1985	Intersalt Study	Cross-sectional	20-59	8477	Education (Q)	CVD (OA)	Alcohol, Smoking, Diet (Q)
Helmert et al., 1994 (138)	Germany	1984-1991	German Cardiovascular Prevention Study	Cross-sectional	25-69	44363	SES score (Q)	Diabetes, CVD (OA)	Smoking (Q)
Gliksman M.D. et al., 1995 (139)	US	1976-1990	Nurses' Health Study Cohort	Longitudinal	30-55	117006	Childhood SES (Q)	CVD (OA)	Alcohol, PA, Diet (Q)
Pekkanen et al., 1995(140)	Finland	1972-1987	North Karelia Project	Longitudinal	25-59	18661	Occupation (Q)	ACM, CVD (OA)	Smoking (Q)
Brancati et al., 1996 (141)	US	1972-1974	Three Area Stroke Study	Cross-sectional	35-54	1393	SES score (Q)	Diabetes (OA)	Smoking (Q)
Lynch et al., 1996 (47)	Finland	1984-1993	Kuopio Ischemic Heart Disease Risk Factor Study	Longitudinal	42-90	2682	Income (Q)	ACM, CVD (OA)	Alcohol, Smoking, PA (Q)
Suadicani et al., 1997 (142)	Denmark	1985-1991	Copenhagen Male Study	Longitudinal	53-75	2974	Occupation (Q)	CVD (Q+OA)	Alcohol, PA, Diet (Q)
Wannamethee SG et al., 1997 (143)	UK	1983-1995	British Regional Heart Study	Longitudinal	40-59	7262	Occupation (RGC)	ACM, CVD (OA)	Smoking (Q)
Chandola et al., 1998 (144)	UK	1984-1995	The Health Lifestyles Survey	Longitudinal	≥18	9003	Occupation (Q)	CVD (OA)	Alcohol, Smoking, PA, Diet (Q)
Lantz et al., 1998 (20)	US	1986-1994	Americans' Changing Live's Survey	Longitudinal	≥25	3617	Education, Income (Q)	ACM (OA)	Alcohol, Smoking, PA (Q)
Schrijvers et al., 1999 (21)	Netherlands	1991-1996	Longitudinal Study on Socioeconomic Health Differences	Longitudinal	15-74	15451	Education (Q)	ACM (OA)	Alcohol, Smoking, PA (Q)
Hart C.L. et al., 2000 (145)	UK	1972-1976	Renfrew/Praisley General Population Study	Longitudinal	45-64	14947	Occupation, Wealth (RGC)	CVD (OA)	Smoking (Q)
Kilander L et al., 2001 (146)	Sweden	1970-1995	Uppsala Male Health Survey	Longitudinal	50	2301	Education (Q)	CVD (OA)	Smoking (Q)
Suadicani P. et al., 2001 (28)	Denmark	1971-1993	Copenhagen Male Study	Longitudinal	40-59	5028	SES score (Q)	CVD (OA)	Alcohol, Smoking, PA

									(Q)
Egeland GM et al., 2002 (73)	Norway	1977-1992	Second Cardiovascular Disease and Risk Factor Screening Survey	Longitudinal	35-52	20038	Education, Partner's SES (Q)	CVD (OA)	Smoking (Q)
Van Lenthe et al., 2002 (48)	Netherlands	1991-1996	Globe study	Longitudinal	15-74	9872	Education (Q)	CVD (OA)	Alcohol, Smoking, PA (Q)
Aslanyan et al., 2003 (147)	UK	1991-1998	Stroke Patients admitted to the Western Infirmary Acute Stroke Unit in Glasgow	Cross-sectional	≥18	2026	Area SES (OA)	CVD (OA)	Smoking (Q)
Osler et al., 2003 (74)	Denmark	1980-1997	Copenhagen City Heart Study	Longitudinal	≥20	21721	Income, Area SES (OA)	CVD (OA)	Alcohol, Smoking, PA (Q)
Stamler et al., 2003 (37)	US	1992	Intermap Study	Cross-sectional	40-59	2195	Education (Q)	CVD (OA)	Alcohol, Diet (Q)
Woodward et al., 2003 (88)	UK	1984-1993	Scottish Heart Health Study	Longitudinal	40-59	11629	Wealth (Q)	CVD (OA)	Alcohol, Smoking, PA (Q+OA)
Agardh et al., 2004 (49)	Sweden	1992-1998	Stockholm Diabetes Prevention Program	Cross-sectional	35-56	7949	Occupation (Q)	Diabetes (OA)	Smoking, PA (Q)
Lawlor D.A. et al., 2004 (148)	UK	1999-2001	British Women's Heart and Health Study	Cross-sectional	60-79	3444	Childhood SES (RGC)	CVD (OA)	Smoking, PA (Q)
Strand et al., 2004 (50)	Norway	1974-2000	Cardiovascular Disease Study in Finnmark, Sogn og Fjordan, Oppland	Longitudinal	35-74	44144	Education (Q)	CVD (OA)	Smoking, PA (Q)
van Oort et al., 2004 (51)	Netherlands	1991-1998	Globe Study	Longitudinal	15-74	16980	Education (Q)	ACM (OA)	Alcohol, Smoking, PA (Q)
Blakely et al., 2005 (149)	New Zealand	1981-1984 1996-1999	New Zealand Census Mortality Study	Longitudinal	45-74	1175000	Education (Q)	ACM, CVD (OA)	Smoking (Q)
Khang et al., 2005 (52)	South Korea	1998	KNHANES Study	Cross-sectional	≥30	5437	Income (Q)	ACM (OA)	Alcohol, Smoking, PA (Q)
Maty S.C. et al., 2005 (150)	US	1965-1999	Alameda County Study	Longitudinal	17-94	6147	Education, Occupation, Income (Q)	Diabetes (Q)	Alcohol, Smoking, PA (Q)
Power C. et al., 2005 (151)	UK	1958-1991	British Birth Cohort	Longitudinal	14-49	11855	Partner's SES, Childhood SES (RGC)	ACM (OA)	Smoking (Q)

Silventoinen et al., 2005 (75)	Finland	1992-2001		Longitudinal	25-64	1909	Education (Q)	CVD, MS (OA)	Alcohol, Smoking, PA, Diet (Q)
van Oort et al., 2005 (11)	Netherlands	1991-1998	Globe study	Longitudinal	15-74	3979	Education (Q)	ACM (OA)	Alcohol, Smoking, PA (Q)
Avendano et al., 2006 (152)	US	1982-1994	Epese Study	Longitudinal	65-74	2812	Education, Income (Q)	CVD (Q+OA)	Alcohol, Smoking, PA (Q)
Kittleson et al., 2006 (153)	US Doctors (all age groups)	1948-1988	Johns Hopkins Precursors Study	Longitudinal	26-70	1131	Childhood SES (Q)	CVD (OA)	Smoking, PA (Q)
Kittleson et al., 2006 (153)	US (<50y of age)	1948-1988	Johns Hopkins Precursors Study	Longitudinal	26-50	<1131	Childhood SES (Q)	CVD (OA)	Smoking, PA (Q)
Rathmann et al., 2006 (154)	Germany	1999	KORA survey 2000	Cross-sectional	55-74	1476	SES score (Q)	Diabetes (OA)	Smoking, PA (Q)
Yan et al., 2006 (155)	US	1985-2001	Coronary Artery Risk Development in Young Adults Study	Longitudinal	18-30	2913	Education (Q)	CVD (OA)	Smoking, PA (Q)
Agardh et al., 2007 (156)	Sweden	1992-1998	Stockholm Diabetes Prevention Program	Cross-sectional	35-56	7949	Education, Occupation, Childhood SES (Q)	Diabetes (OA)	Smoking, PA (Q)
Feinglass et al., 2007 (157)	US	1992-2002	Health and Retirement Study	Longitudinal	51-61	9759	Education, Income, Wealth (Q)	ACM (OA)	Smoking, PA (Q)
Gorman et al., 2007 (76)	US	2001	National Health Interview Survey	Cross-sectional	≥25	29767	Education, Wealth (Q)	CVD (Q)	Alcohol, Smoking, PA (Q)
Kivimäki M. et al., 2007 (158)	Finland	2000-2002	The Finnish Public Sector Study	Cross-sectional	17-65	48592	Income (OA)	CVD (Q)	Alcohol, Smoking, PA (Q)
Kuper et al., 2007 (159)	Sweden	1991-2002	Women's Lifestyle and Health Cohort Study	Longitudinal	30-50	47942	Education (Q)	CVD (OA)	Alcohol, Smoking, PA (Q)
Loucks et al., 2007 (160)	US	1988-1994	NHANES III	Cross-sectional	≥25	11107	Education, Wealth (Q)	MS (OA)	Alcohol, Smoking, PA, Diet (Q)
Prescott et al., 2007 (77)	Denmark	1976-2003	Copenhagen City Heart Study	Cross-sectional	≥20	6069	Education (Q)	MS (OA)	Alcohol, Smoking, PA (Q)
Ito S et al., 2008 (161)	Japan	1990-2003	Japan Public Health Center-based Prospective Study	Longitudinal	40-59	39228	Education (Q)	ACM, CVD (OA)	Alcohol, Smoking, PA, Diet (Q)
Laaksonen et al.,	Finland	1979-2001	Finnish Health	Longitudinal	25-64	60000	Education (Q)	ACM, CVD	Alcohol,

2008 (19)			Behaviors Survey and Finnish National Causes of Death Register					(OA)	Smoking, PA, Diet (Q)
Laszlo et al., 2008 (38)	Sweden	1996-2000		Longitudinal	<75	188	Income (Q)	CVD (OA)	Alcohol, Smoking (Q)
Marmot et al., 2008 (39)	UK	1985-2004	Whitehall II	Longitudinal	35-55	5312	Occupation (Q)	CVD (OA)	Alcohol, Smoking, PA, Diet (Q)
Maty S.C. et al., 2008 (162)	US	1965-1999	Alameda County Study	Longitudinal	17-94	5913	Education, Occupation, Income, Childhood SES (Q)	Diabetes (Q)	Alcohol, Smoking, PA (Q)
McFadden et al., 2008 (87)	UK	1993-2006	EPIC-Norfolk Cohort	Longitudinal	39-79	22486	Occupation (RGC)	ACM, CVD (OA)	Smoking (Q)
Panagiotakos et al., 2008 (163)	Greece	2001-2005	Attica Study	Longitudinal	≥18	3042	Education (Q)	CVD (OA)	Alcohol, Diet (Q)
Ramsay S.E. et al., 2008 (164)	UK	1978-2000	British Regional Heart Study	Cross-sectional	60-79	2968	Occupation, Childhood SES (RGC)	MS (OA)	Alcohol, Smoking, PA (Q)
Schulz A.J. et al., 2008 (71)	US	2002	Healthy Environments Partnership Community Survey	Cross-sectional	≥25	919	Education, Income (Q)	Obesity (OA)	Alcohol, PA (Q)
Silva et al., 2008 (53)	Netherlands	2002-2006	Generation R Study	Cross-sectional	30-35	9778	Education (Q)	CVD (OA)	Alcohol, Smoking (Q)
Singh-Manoux et al., 2008 (54)	UK	1985-2004	Whitehall II	Longitudinal	35-55	5363	Occupation (OA)	CVD (OA)	Smoking (Q)
Khang/Selmer et al., 2009 (55)	South Korea	1998-2001	Korea National Health and Nutrition Examination Survey (KNHANES)	Longitudinal	≥30	8366	Education, Occupation (Q)	ACM (OA)	Alcohol, Smoking, PA (Q)
McFadden et al., 2009 (165)	UK	1993-1997	Norfolk Cohort	Longitudinal	39-79	22488	Occupation (RGC)	CVD (OA)	Alcohol, Smoking, PA, Diet (Q)
Münster E et al., 2009 (166)	Germany	2006-2007	German National Telephone Health Interview Survey and OI-Survey	Cross-sectional	≥40	9267	Wealth (Q)	Obesity (Q)	Smoking (Q)
Rosengren et al., 2009 (167)	International	1999-2003	Interheart study	Longitudinal	≥18	27098	Education, Occupation, Income, Wealth (Q)	CVD (OA)	Alcohol, Smoking, PA, Diet (Q)
Rostad et al., 2009 (168)	Norway	1995-2007	The HUNT Study	Longitudinal	≥70	5607	Education (Q)	ACM, CVD (OA)	Smoking, PA (Q)

Skalicka et al., 2009 (22)	Norway	1995-1997	Hunt Study	Longitudinal	24-80	36525	Education, Income (OA)	ACM (OA)	Alcohol, Smoking, PA (Q)
Beauchamp et al., 2010 (56)	Australia	1991-1994	Melbourne Collaborative Cohort Study	Longitudinal	40-69	38355	Education (Q)	CVD (OA)	Alcohol, Smoking, PA, Diet (Q)
Chaix et al., 2010 (61)	France	2007-2008		Cross-sectional	30-79	5941	Education, Area SES (OA)	CVD (OA)	Alcohol, Smoking (Q)
Chapman et al., 2010 (57)	US	1995-2005	Midlife Development in the United States Study	Longitudinal	25-74	2998	SES score (Q)	ACM (OA)	Alcohol, Smoking, PA (Q)
Kavanagh et al., 2010 (40)	Australia	1999-2000	AusDiab Study	Cross-sectional	25-64	8866	Education, Income (Q)	Diabetes, CVD (OA)	Alcohol, Smoking, PA, Diet (Q)
Krishnan S. et al., 2010 (169)	US	1995-2007	Black Women's Health Study	Longitudinal	30-69	46382	Education, Income, Area SES (OA)	Diabetes (OA)	Alcohol, Smoking, PA (Q)
Lantz et al., 2010 (170)	US	1986-2005	Americans' Changing Live's Survey	Longitudinal	≥25	3617	Education, Income (Q)	ACM (OA)	Alcohol, Smoking, PA (Q)
Manuck S.B. et al., 2010 (171)	US	2001-2005	Adult Health and Behavior Registry	Cross-sectional	30-54	981	SES score (Q)	MS (OA)	Smoking, PA (Q)
Maty et al., 2010 (172)	US White	1965-1995	Alameda County Study	Longitudinal	20-94	4774	Education, Occupation, Income, Childhood SES (Q)	Diabetes (Q)	Alcohol, Smoking, PA (Q)
Maty et al., 2010 (172)	US Black	1965-1995	Alameda County Study	Longitudinal	20-94	4774	Education, Occupation, Income, Childhood SES (Q)	Diabetes (Q)	Alcohol, Smoking, PA (Q)
Schreier et al., 2010 (86)	Canada	2008		Cross-sectional	8-19	88	Childhood SES (Q)	CVD (OA)	Smoking, PA (Q)
Steptoe A. et al., 2010 (173)	UK	2006-2008	Whitehall II Study	Cross-sectional	53-76	528	Occupation (OA)	CVD (OA)	Alcohol, Smoking, PA (Q)
Stringhini et al., 2010 (23)	UK	1985-2009	Whitehall II Study	Longitudinal	35-55	10308	Occupation (OA)	ACM, CVD (OA)	Alcohol, Smoking, PA, Diet (Q)
Williams et al., 2010 (174)	Australia	1999-2005	AusDiab Study	Longitudinal	≥25	4405	Education (Q)	Diabetes (OA)	Smoking, PA (Q)
Brummett B.H. et al., 2011 (175)	US	1995-2008	National Longitudinal Study of Adolescent Health	Longitudinal	28-30	14299	Education, Income, Childhood SES (Q)	CVD (OA)	Alcohol, Smoking, PA (Q)
Demakakos et al., 2011 (176)	UK	1998-2003	ELSA	Longitudinal	≥50	7432	Education, Occupation,	Diabetes (OA)	Alcohol, Smoking, PA

						Income, Wealth, Childhood SES (Q)		(Q)
Dinca et al., 2011 (177)	Canada	2005	Canadian Community Health Survey	Cross-sectional	≥12	98298	Education, Income (Q)	Diabetes (Q)	PA (Q)
Franks et al., 2011 (178)	US	1987-1997	Atherosclerosis Risk in Communities Study	Longitudinal	45-64	15495	SES score (Q)	CVD (OA)	Smoking (Q)
Fu C et al., 2011 (78)	China	2006-2007	Rural Deqing Cohort Study	Cross-sectional	18-64	5898	Education, Occupation, Income (Q)	Diabetes (OA)	Alcohol, Smoking, PA (Q)
Gustafsson et al., 2011 (179)	Sweden	1983-2008	Northern Swedish Cohort	Longitudinal	16	832	SES score (Q)	MS (OA)	Alcohol, Smoking, PA (Q)
Niedhammer et al., 2011 (180)	France	1996-2008	Lorhandicap Study	Longitudinal	≥15	4118	Occupation (Q)	ACM (OA)	Alcohol, Smoking (Q)
Silhol et al., 2011 (181)	France	1990-2000	Gazel Cohort	Longitudinal	35-55	19808	Education, Occupation, Income, Area SES (Q)	CVD (OA)	Smoking, Diet (Q)
Stringhini et al., 2011 (7)	UK-Whitehall	1985-2005	Whitehall II Study	Longitudinal	35-55	9771	Education, Occupation, Income (OA)	ACM (OA)	Alcohol, Smoking, PA, Diet (Q)
Stringhini et al., 2011 (7)	France-Gazel	1985-2005	Gazel Cohort	Longitudinal	35-50	17760	Education, Occupation, Income (OA)	ACM (OA)	Alcohol, Smoking, PA, Diet (Q)
Dinca et al., 2012 (182)	Canada	1994-2007	Canada's National Population Health Survey	Longitudinal	≥12	17276	Income (Q)	Diabetes (Q)	PA (Q)
Hagger-Johnson et al., 2012 (41)	UK	1984-2009		Longitudinal	35-75	5450	SES score (RGC)	ACM (OA)	Alcohol, Smoking, PA, Diet (Q)
Ploubidis et al., 2012 (183)	Kenya - urban population	2007-2008	Nakuru Population-Based Survey	Cross-sectional	≥50	4314	Education, Wealth (Q)	Diabetes, CVD (Q+OA)	Alcohol, Smoking (Q)
Ploubidis et al., 2012 (183)	Kenya - rural population	2007-2008	Nakuru Population-Based Survey	Cross-sectional	≥50	4314	Education, Wealth (Q)	Diabetes, CVD (Q+OA)	Alcohol, Smoking (Q)
Seligman H.K. et al., 2012 (64)	US	2008-2009	Immigration, Culture and Healthcare Study	Cross-sectional	≥18	711	Wealth (OA)	Diabetes (OA)	Diet (Q)
Stringhini et al., 2012 (8)	UK	1991-2009	Whitehall II	Longitudinal	35-55	7237	Occupation (OA)	Diabetes (OA)	Alcohol, Smoking, PA, Diet (Q)
Tanaka et al., 2012 (184)	UK	2004-2008	English Longitudinal Study of Ageing	Longitudinal	≥50	9432	Income, Wealth (Q)	Diabetes, Obesity (Q+OA)	Alcohol, Smoking, PA (Q)

Williams E.D. et al., 2012 (185)	Australia	1999-2004	AusDiab study	Longitudinal	≥25	4572	Area SES (OA)	Diabetes (OA)	Alcohol, Smoking, PA, Diet (Q)
Woodside et al., 2012 (43)	France and UK	1991-2004	Prime Study	Longitudinal	50-59	10600	Education, Wealth (Q)	ACM, CVD (OA)	Alcohol, PA, Diet (Q)
Ni et al., 2013 (65)	Taiwan	2002	Taiwanese Survey on Prevalence of Hypertension, Hyperglycemia and Hyperlipidemia	Cross-sectional	18-94	6188	SES score (Q)	MS (OA)	Alcohol, Smoking (Q)
Shamshirgaran et al., 2013 (113)	Australia	2006-2009	45 and Up Study	Cross-sectional	≥45	266848	Education, Income, Wealth (Q)	Diabetes (Q)	Smoking, PA (Q)
Dinwiddie et al., 2014 (114)	US - Foreign born US Mexicans	2001-2008	National Health and Nutrition Examination Survey	Cross-sectional	≥20	6032	Education (Q)	Diabetes, CVD, Obesity (OA)	Alcohol, Smoking, PA (Q)
Dinwiddie et al., 2014 (114)	US - US born US Mexicans	2001-2008	National Health and Nutrition Examination Survey	Cross-sectional	≥20	6032	Education (Q)	Diabetes, CVD, Obesity (OA)	Alcohol, Smoking, PA (Q)
Giesinger et al., 2014 (44)	UK	1971-2002	1946 Birth Cohort	Longitudinal	26	2132	Childhood SES (RGC)	ACM (OA)	Smoking (Q)
Hwang J et al., 2014 (186)	South Korea	2010-2012	Korea National Health and Nutrition Examination Survey (KNHANES)	Cross-sectional	30-65+	14330	Education, Income, Wealth (Q)	Diabetes (Q+OA)	Alcohol, Smoking, PA (Q)
Lear S.A. et al., 2014 (187)	International	2002-2009	Prospective Urban Rural Epidemiology Study	Cross-sectional	35-70	139000	Wealth (Q)	Diabetes, Obesity (Q+OA)	PA (Q)
Lipowicz et al., 2014 (188)	Poland	1983-1993	Lower Silesian Centre for Preventive Medicine Health Survey	Cross-sectional	25-60	3887	Education (Q)	MS (OA)	Alcohol, Smoking, PA (Q)
Nandi et al., 2014 (58)	US	1992; 1998-2008	Health and Retirement Study	Longitudinal	57-67	8037	Education, Occupation, Income, Wealth, SES score, Childhood SES (Q)	ACM (OA)	Alcohol, Smoking, PA (Q)
Nordahl et al., 2014 (67)	Denmark	1981-2009		Longitudinal	≥18	69513	Education (Q)	CVD (OA)	Smoking, PA (Q)
Nordahl et al., 2014 (68)	Denmark	Differs-2009	Social Inequality in Cancer Cohort	Longitudinal	30-70	76294	Education (Q)	ACM, CVD (OA)	Smoking (Q)

			Study						
Stringhini et al., 2014 (45)	Seychelles	1989-1994-2004-(2012)	Seychelles Study	Longitudinal	25-64	3246	Occupation (Q)	ACM (OA)	Alcohol, Smoking (Q)
Tamayo T. et al., 2014 (189)	Germany	2006-2008	Heinz Nixdorf Recall Study	Cross-sectional	67.2±7.3	662	Education, Income, Wealth (Q)	Diabetes (Q)	Alcohol, Smoking, PA (Q)
Dupre et al., 2015 (190)	US elderly (low Hba1c)	2006-2008	Health and Retirement Study	Longitudinal	65-75	3312	Education (Q)	ACM (OA)	Alcohol, Smoking, PA (Q)
Dupre et al., 2015 (190)	US elderly (high Hba1c)	2006-2008	Health and Retirement Study	Longitudinal	65-75	3312	Education (Q)	ACM (OA)	Alcohol, Smoking, PA (Q)
Panagiotakos et al., 2015 (191)	Greece	2001-2002	Attica Study	Longitudinal	18-89	2020	Education (Q)	CVD (OA)	Alcohol, Smoking, PA, Diet (Q)
Robertson et al., 2015 (62)	UK	1987-2008	West of Scotland Twenty-07 Study	Longitudinal	35	1444	Occupation (RGC)	MS (OA)	Alcohol, Smoking, PA, Diet (Q)
Zhu et al., 2015 (66)	China	2013		Cross-sectional	35-76	3243	Occupation, Income (Q)	Diabetes (OA)	Alcohol, Smoking, PA, Diet (Q)
Bihan et al., 2016 (59)	Australia	1999-2012	AusDiab Cohort	Longitudinal	≥25	9338	Education, Area SES (Q+OA)	ACM (OA)	Smoking, PA, Diet (Q)
Bonaccio et al., 2016 (60)	Italy	2005-2010	MOLI-SANI	Longitudinal	≥35	16247	SES score (Q)	ACM (OA)	Smoking, PA, Diet (Q)
Deere et al., 2016 (79)	US	2000-2008	Jackson Heart Study	Cross-sectional	21-95	3114	Education, Income, Childhood SES (Q)	CVD (OA)	Alcohol, Smoking, PA, Diet (Q)
Floud et al., 2016 (63)	UK	1996-2011	Million Women Study	Longitudinal	44-68	1202983	Education, Area SES (Q)	CVD (OA)	Alcohol, Smoking, PA (Q)
Houle et al., 2016 (69)	Canada	2016		Cross-sectional	31-83	284	Education, Childhood SES (Q)	Diabetes (OA)	Diet (Q)
Montez et al., 2016 (192)	US	1996-2013	Study of Women's Health Across the Nation	Longitudinal	42-52	826	Education, Childhood SES (Q)	MS (OA)	Alcohol, Smoking, PA (Q)
Montez et al., 2016 (192)	US	1996-2013	Study of Women's Health Across the Nation	Cross-sectional	42-52	826	Education, Childhood SES (Q)	MS (OA)	Alcohol, Smoking, PA (Q)
Poulsen et al., 2016 (193)	Denmark	1995-2005	Danish Work Environment Cohort Study	Longitudinal	30-59	6823	Occupation (Q)	Diabetes (OA)	Smoking (Q)
Stringhini et al., 2016 (46)	UK	2004-2013	ELSA	Longitudinal	≥50	6218	Education, Wealth, SES score, Childhood SES (Q)	Diabetes (OA)	Alcohol, Smoking, PA (Q)

ACM: All-cause mortality, CVD: Cardiovascular disease (including mortality, incidence, morbidity, prevalence, stroke, coronary heart disease), MS: Metabolic syndrome (including allostatic load), PA: Physical activity.

Assessment methods: Q: Self-administered questionnaire, Qa: Questionnaire adjusted according to validated methods (FFQ); OA: Objective assessment (death registries, medical records, accelerometer for measure of physical activity,…), RGC: Registrar's general classification based on occupation

Table 2: Median, minimum and maximum contribution of multiple health behaviors for associations between SEP and health outcomes. Contributions are displayed according to education, occupation, other SEP indicators (predictors - columns), and according to six major groups of study settings

	Education	**Occupation**	**Other SEP indicators**
[a] **Outcome**			
All-cause mortality	24% [b] (-16%;43%) [c]; n=11 [d]	26% (0%;75%); n=10	20% (-3%;55%); n=12
Cardiovascular disorders	18% (-59%;56%); n=21	26% (-7%;73%); n=11	30% (-16%;69%); n=15
Metabolic disorders	15% (-43%;67%); n=24	29% (-6%;68%); n=7	19% (-11%;61%); n=23
[a] **Sex (20 studies)**			
Men	9% (-12%;61%); n=13	43% (30%;69%); n=7	26% (-3%;69%); n=9
Women	18% (-43%;64%); n=18	30% (9%;53%); n=5	27% (-6%;68%); n=14
[a] **Region**			
Central/Southern Europe	18% (-12%;42%); n=4	10% (0%;19%); n=2	64% (64%;64%); n=1
Northern Europe	24% (-12%;93%); n=23	36% (-7%;75%); n=21	29% (-6%;69%); n=24
North America	14% (-59%;64%); n=24		14% (-16%;60%); n=15
Other	26% (11%;47%); n=12	22% (-6%;73%); n=5	16% (-11%;47%); n=10
[a] **Age-range**			
Young (≤35 years)	32% (32%;32%); n=1	24% (24%;24%); n=1	35% (23%;47%); n=2
Middle-aged (30-65 years)	25% (-16%;50%); n=20	36% (9%;75%); n=18	32% (4%;69%); n=10
Old (≥65 years)	27% (11%;67%); n=5	36% (-7%;69%); n=3	36% (13%;61%); n=9
All age groups	15% (-43%;64%); n=28	25% (-6%;73%); n=6	16% (-16%;64%); n=29
[a] **Type of study**			
Cross-sectional	11% (-59%;64%); n=26	17% (-7%;53%); n=4	14% (-16%;64%); n=19
Longitudinal	23% (-16%;67%); n=30	31% (0%;75%); n=24	27% (-6%;69%); n=31
[a] **Assessment method of health behaviors**			
Questionnaire	18% (-43%;67%); n=54	27% (-7%;75%); n=28	21% (-16%;64%); n=48
Objective assessment			

[a]: Study settings according to which the contribution of health behaviors was computed

[b]: Median contribution

[c]: Minimum and maximum computed contributions for each association. Contribution percentages for each association were computed according to the absolute scale difference method (23)

[d]: Number of found associations (one study may contain several associations)

Table 3: Median, minimum and maximum contribution of smoking (Panel A) and alcohol (Panel B) for associations between SEP and health outcomes. Contributions are displayed according to education, occupation, other SEP indicators (predictors - columns), and according to six major groups of study settings

A. Contribution by smoking			
	Education	**Occupation**	**Other SEP indicators**
[a] **Outcome**			
All-cause mortality	19% [b] (10%;24%) [c]; n=7 [d]	19% (-5%;32%); n=9	32% (13%;50%); n=2
Cardiovascular disorders	17% (-15%;48%); n=17	15% (-13%;36%); n=7	14% (-11%;136%); n=14
Metabolic disorders	14% (14%;14%); n=1	22% (5%;35%); n=4	15% (10%;24%); n=3
[a] **Sex (20 studies)**			
Men	22% (7%;48%); n=9	23% (14%;36%); n=8	12% (-11%;27%); n=5
Women	14% (-15%;23%); n=12	6% (-13%;35%); n=4	19% (4%;31%); n=5
[a] **Region**			
Central/Southern Europe		4% (4%;4%); n=1	
Northern Europe	19% (-15%;48%); n=19	19% (-13%;36%); n=17	17% (-11%;50%); n=14
North America	2% (2%;2%); n=1		35% (7%;136%); n=4
Other	15% (10%;20%); n=5	11% (6%;16%); n=2	
[a] **Age-range**			
Young (≤35 years)	-7% (-15%;2%); n=2	33% (33%;33%); n=1	93% (50%;136%); n=2
Middle-aged (30-65 years)	20% (4%;27%); n=11	18% (-13%;36%); n=17	18% (11%;31%); n=6
Old (≥65 years)			13% (13%;13%); n=1
All age groups	15% (4%;48%); n=12	11% (6%;16%); n=2	9% (-11%;24%); n=8
[a] **Type of study**			
Cross-sectional	0% (-15%;14%); n=3	25% (14%;35%); n=2	7% (-11%;24%); n=6
Longitudinal	19% (4%;48%); n=22	17% (-13%;36%); n=18	21% (11%;136%); n=11
[a] **Assessment method of smoking**			
Questionnaire	17% (-15%;48%); n=25	18% (-13%;36%); n=20	18% (-11%;136%); n=17
Objective assessment			29% (27%;31%); n=2
B. Contribution by alcohol			
	Education	**Occupation**	**Other SEP indicators**
Outcome			
All-cause mortality	-2% (-11%;10%); n=3	12% (7%;13%); n=4	17% (17%;17%); n=1
Cardiovascular disorders	6% (-2%;21%); n=8	10% (3%;18%); n=2	56% (-2%;261%); n=6
Metabolic disorders		2% (2%;2%); n=2	
Sex (20 studies)			
Men	-4% (-6%;-2%); n=2		21% (-2%;43%); n=2
Women	5% (-11%;21%); n=5		11% (6%;24%); n=3
Region			
Central/Southern Europe		7% (7%;7%); n=1	
Northern Europe	5% (-11%;21%); n=9	9% (2%;18%); n=5	15% (-2%;43%); n=4
North America	2% (2%;2%); n=1		139% (17%;261%); n=2
Other	5% (5%;5%); n=1	7% (3%;12%); n=2	
Age-range			
Young (≤35 years)	3% (3%;3%); n=1	2% (2%;2%); n=1	261% (261%;261%); n=1
Middle-aged (30-65 years)	0% (-11%;21%); n=6	10% (2%;18%); n=7	16% (-2%;43%); n=3
Old (≥65 years)			17% (17%;17%); n=1
All age groups	12% (5%;19%); n=4		18% (11%;24%); n=2
Type of study			
Cross-sectional	3% (2%;3%); n=2		
Longitudinal	6% (-11%;21%); n=9	9% (2%;18%); n=8	50% (-2%;261%); n=7
Assessment method of alcohol			
Questionnaire	4% (-11%;21%); n=11	9% (2%;18%); n=8	71% (11%;261%); n=5
Objective assessment			

[a]: Study settings according to which the contribution of smoking/alcohol was computed

[b]: Median contribution

[c]: Minimum and maximum computed contributions for each association. Contribution percentages for each association were computed according to the absolute scale difference method (23)

[d]: Number of found associations (one study may contain several associations)

Table 4: Median, minimum and maximum contribution of physical activity (Panel A) and dietary patterns (Panel B) for associations between SEP and health outcomes. Contributions are displayed according to education, occupation, other SEP indicators (predictors - columns), and according to six major groups of study settings

A. Contribution by physical activity	**Education**	**Occupation**	**Other SEP indicators**
[a] **Outcome**			
All-cause mortality	12% [b] (8%;17%) [c]; n=3 [d]	20% (8%;21%); n=3	17% (17%;17%); n=1
Cardiovascular disorders	4% (-5%;13%); n=12	12% (12%;12%); n=1	8% (-33%;34%); n=5
Metabolic disorders	9% (9%;9%); n=1	6% (4%;10%); n=4	
[a] **Sex (20 studies)**			
Men	4% (0%;13%); n=4	10% (10%;10%); n=1	15% (3%;27%); n=2
Women	6% (0%;11%); n=7	4% (4%;4%); n=1	9% (9%;9%); n=1
[a] **Region**			
Central/Southern Europe		8% (8%;8%); n=1	
Northern Europe	6% (0%;17%); n=13	11% (4%;21%); n=7	13% (3%;27%); n=3
North America	-2% (-5%;1%); n=2		6% (-33%;34%); n=3
Other	9% (9%;9%); n=1		
[a] **Age-range**			
Young (≤35 years)	1% (1%;1%); n=1	4% (4%;4%); n=1	34% (34%;34%); n=1
Middle-aged (30-65 years)	7% (-5%;13%); n=7	13% (4%;21%); n=7	15% (3%;27%); n=2
Old (≥65 years)			17% (17%;17%); n=1
All age groups	5% (0%;17%); n=8		-12% (-33%;9%); n=2
[a] **Type of study**			
Cross-sectional	2% (-5%;9%); n=3	7% (4%;10%); n=2	
Longitudinal	6% (0%;17%); n=13	14% (4%;21%); n=6	18% (3%;34%); n=5
[a] **Assessment method of health behaviors**			
Questionnaire	6% (-5%;17%); n=16	12% (4%;21%); n=8	18% (3%;34%); n=5
Objective assessment			

B. Contribution by diet	**Education**	**Occupation**	**Other SEP indicators**
Outcome			
All-cause mortality	21% [a] (17%;25%) [b]; n=2 [c]	17% (4%;24%); n=3	
Cardiovascular disorders	24% (2%;50%); n=5	7% (7%;7%); n=1	
Metabolic disorders		10% (8%;11%); n=2	11% (11%;11%); n=1
Sex (20 studies)			
Men	36% (25%;50%); n=3		
Women	11% (6%;17%); n=2		
Region			
Central/Southern Europe		4% (4%;4%); n=1	
Northern Europe	26% (6%;50%); n=5	13% (7%;24%); n=5	
North America	29% (29%;29%); n=1		11% (11%;11%); n=1
Other	2% (2%;2%); n=1		
Age-range			
Young (≤35 years)		11% (11%;11%); n=1	
Middle-aged (30-65 years)	27% (6%;50%); n=6	13% (4%;24%); n=5	
Old (≥65 years)			
All age groups	2% (2%;2%); n=1		11% (11%;11%); n=1
Type of study			
Cross-sectional	29% (29%;29%); n=1		11% (11%;11%); n=1
Longitudinal	22% (2%;50%); n=6	13% (4%;24%); n=6	
Assessment method of diet			
Questionnaire	23% (2%;50%); n=7	13% (4%;24%); n=6	11% (11%;11%); n=1
Objective assessment			

[a]: Study settings according to which the contribution of physical activity/diet was computed

[b]: Median contribution

[c]: Minimum and maximum computed contributions for each association. Contribution percentages for each association were computed according to the absolute scale difference method (23)

[d]: Number of found associations (one study may contain several associations)

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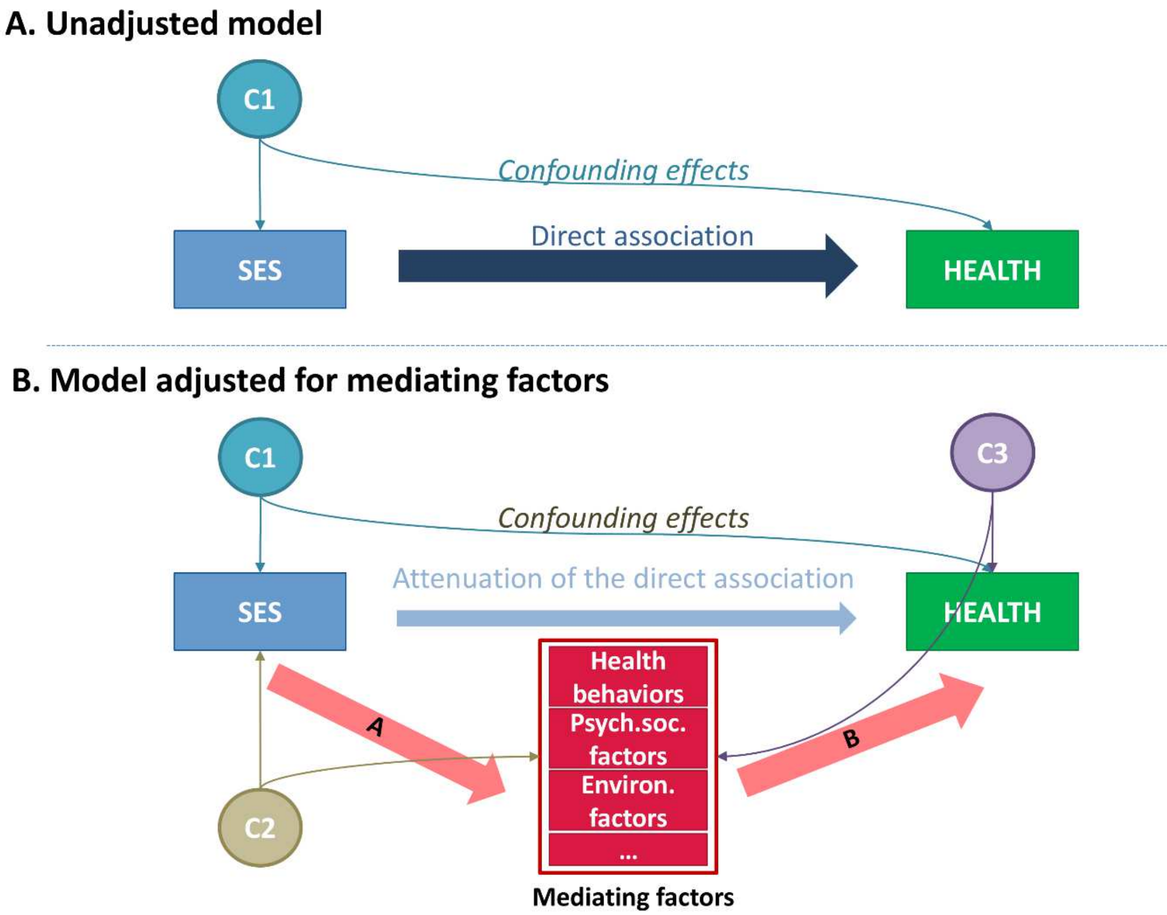
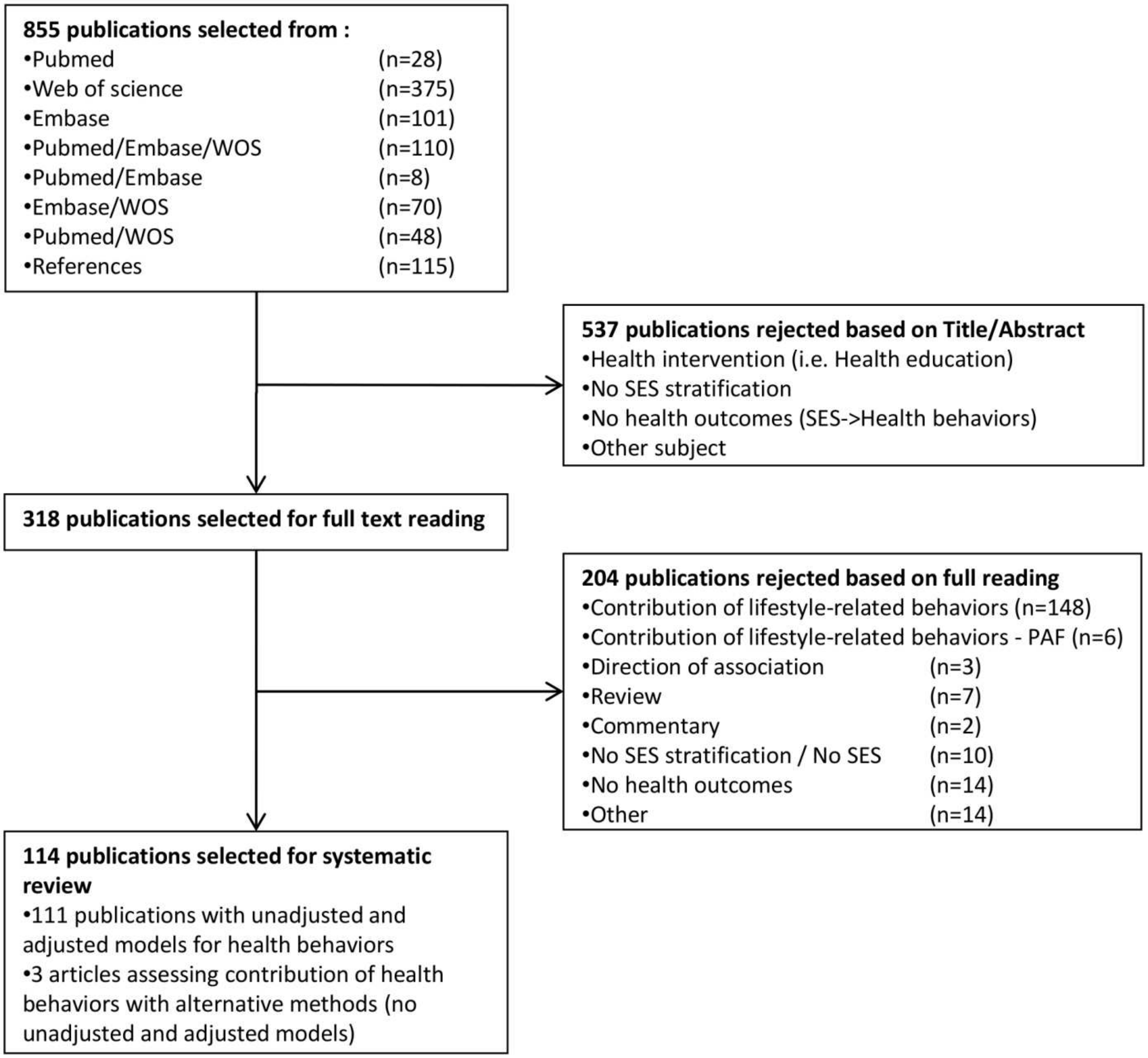
The contribution of health behaviors to socioeconomic inequalities in health: a systematic review



Supplementary Figure 1: Conceptual framework representing the association between SEP, mediating factors, health outcomes and confounders (C1-3: i.e. sex, age, pre-existent diseases, genetic predisposition,…). In panel A, the crude or unadjusted model is represented with the direct association leading from SEP to health. In panel B, the model comprises mediating factors, which are thought to be located on the causal pathway between SEP and health. According to this framework, mediating factors are socially patterned (arrow A) and are at the same time associated with health (arrow B). This figure was realized with MO Power Point.



Supplementary Figure 2: Flow chart representing the selection of studies to be included in the systematic review. 740 were identified in Pubmed, Web of Science and Embase electronic databases and 115 studies were retrieved from reference lists. 537 studies were rejected based on Title/Abstract reading. 318 studies were selected for full text reading, of which 204 were rejected, yielding 114 studies to be included in the systematic review. Out of the 114 included publications in the systematic review, 111 publications included the SEP-health model unadjusted for health behaviors, and a model additionally adjusted for health behaviors, while three publications did not include these two models and assessed the contribution of health behaviors according to alternative methods. This figure was realized with MO Power Point.

Supplementary Table 1: Computed contribution by health behaviors for the association between SEP and health outcomes.

Study	Country	Stratification of analyses	Regression parameter	Attenuation by health behaviors
Notkola et al., 1985(1)	Finland		Relative risk	Childhood SEP-CVD - Unadjusted β = 1.63 (smoking: 14%)
Jacobsen et al., 1988(2)	Norway	Stratified by sex	Mean difference	M: Education-CVD - Unadjusted β = 132.1 (full: 0%) W: Education-CVD - Unadjusted β = 124.6 (full: 0%)
Jeffery et al., 1991(3)	US	Stratified by sex	Other	
Stamler R. et al., 1992(4)	International	Stratified by sex	Beta coefficient	M: Education-CVD - Unadjusted β = -1.30 (full: 47%) W: Education-CVD - Unadjusted β = -4.47 (full: 35%)
Helmert et al., 1994(5)	Germany	Stratified by sex	Odds ratio	M: SEP score-Diabetes - Unadjusted β = 1.69 (smoking: 10%) SEP score-CVD - Unadjusted β = 1.88 (smoking: -11%) W: SEP score-Diabetes - Unadjusted β = 2.82 (smoking: 24%) SEP score-CVD - Unadjusted β = 2.86 (smoking: 4%)
Gliksman M.D. et al., 1995(6)	US	Women only	Relative risk	
Pekkanen et al., 1995(7)	Finland	Stratified by sex	Hazard ratio	M: Occupation-ACM - Unadjusted β = 1.86 (smoking: 24%; full: 38%) Occupation-CVD - Unadjusted β = 1.54 (smoking: 36%; full: 54%) W: Occupation-ACM - Unadjusted β = 1.49 (smoking: -5%; full: 17%) Occupation-CVD - Unadjusted β = 1.74 (smoking: -13%; full: 9%)
Brancati et al., 1996(8)	US		Odds ratio	SEP score-Diabetes - Unadjusted β = 4.09 (full: 11%)
Lynch et al., 1996(9)	Finland	Men only	Relative risk	M: Income-ACM - Unadjusted β = 3.14 (full: 24%) Income-CVD - Unadjusted β = 2.66 (full: 38%) Income-CHD - Unadjusted β = 4.34 (full: 21%)
Suadicani et al., 1997(10)	Denmark	Men only	Relative risk	M: Occupation-CVD - Unadjusted β = 1.44 (full: 69%)
Wannamethee SG et al., 1997(11)	UK	Men only	Relative risk	M: Occupation-ACM - Unadjusted β = 1.80 (smoking: 31%; full: 43%) Occupation-CVD - Unadjusted β = 1.80 (smoking: 31%; full: 43%)
Chandola et al., 1998(12)	UK	Stratified by sex	Odds ratio	
Lantz et al., 1998(13)	US		Hazard ratio	Income-ACM - Unadjusted β = 3.22 (full: 13%)
Schrijvers et al., 1999(14)	Netherlands		Relative risk	
Hart C.L. et al., 2000(15)	UK	Stratified by sex	Hazard ratio	M: Wealth-CVD - Unadjusted β = 2.29 (smoking: 11%) W: Wealth-CVD - Unadjusted β = 2.27 (smoking: 15%)
Kilander L et al., 2001(16)	Sweden	Men only	Relative risk	M: Education-CVD - Unadjusted β = 1.67 (smoking: 25%; diet: 34%)
Suadicani P. et al., 2001(17)	Denmark	Men only	Risk ratio	M: SEP score-CHD - Unadjusted β = 1.59 (smoking: 13%; alcohol: 43%; PA: 27%)
Egeland GM et al., 2002(18)	Norway	Men only	Risk ratio	
Van Lenthe et al., 2002(19)	Netherlands		Hazard ratio	Education-CHD - Unadjusted β = 1.85 (smoking: 22%; alcohol: 19%; PA: 8%)
Aslanyan et al., 2003(20)	UK		Hazard ratio	Area-CVD - Unadjusted β = 1.06 (smoking: 0%)
Osler et al., 2003(21)	Denmark	Stratified by sex	Hazard ratio	M: Income-CVD - Unadjusted β = 1.74 (full: 7%) W: Income-CVD - Unadjusted β = 2.01 (full: -6%)
Stamler et al., 2003(22)	US		Beta coefficient	Education-CVD - Unadjusted β = -0.264 (alcohol: 2%; PA: -5%; diet: 29%)
Woodward et al., 2003(23)	UK	Stratified by sex	Hazard ratio	M: Wealth-CVD - Unadjusted β = 1.48 (smoking: 27%; alcohol: -2%; PA: 3%; full: 69%) W: Wealth-CVD - Unadjusted β = 2.64 (smoking: 31%; alcohol: 6%; full: 68%)
Agardh et al., 2004(24)	Sweden	Stratified by sex	Risk ratio	M: Occupation-Diabetes - Unadjusted β = 2.90 (smoking: 14%; PA: 10%; full: 30%) W: Occupation-Diabetes - Unadjusted β = 2.70 (smoking: 35%; PA: 4%; full: 53%)
Lawlor D.A. et al., 2004(25)	UK	Women only	Odds ratio	W: Childhood SEP-CHD - Unadjusted β = 1.35 (full: 26%)
Strand et al., 2004(26)	Norway	Stratified by sex	Relative risk	M: Education-CVD - Unadjusted β = 1.33 (smoking: 48%; PA: 0%) W: Education-CVD - Unadjusted β = 1.72 (smoking: 16%; PA: 2%)

van Oort et al., 2004(27)	Netherlands		Hazard ratio	Education-ACM - Unadjusted β = 1.66 (smoking: 10%; alcohol: 10%; PA: 17%)
Blakely et al., 2005(28)	New Zealand	Stratified by sex	Rate/prevalence ratio	M: Education-ACM - Unadjusted β = 1.31 (smoking: 17%) Education-CVD - Unadjusted β = 1.33 (smoking: 19%) W: Education-ACM - Unadjusted β = 1.42 (smoking: 10%) Education-CVD - Unadjusted β = 1.66 (smoking: 10%)
Khang et al., 2005(29)	South Korea		Risk ratio	Income-ACM - Unadjusted β = 2.33 (full: 13%)
Maty S.C. et al., 2005(30)	US		Hazard ratio	Education-Diabetes - Unadjusted β = 1.51 (full: 15%)
Power C. et al., 2005(31)	UK	Women only	Hazard ratio	W: Occupation-ACM - Unadjusted β = 1.75 (full: 35%) Occupation-CVD - Unadjusted β = 2.12 (full: 36%) Occupation-CHD - Unadjusted β = 2.74 (full: 32%) Childhood SEP-ACM (Unadjusted β = 1.19 (full: 30%; Childhood SEP-CVD (Unadjusted β = 1.37 (full 19%) Childhood SEP-CHD (Unadjusted β = 1.47 (full 18%)
Silventoinen et al., 2005(32)	Finland	Stratified by sex	Odds ratio	M: Education-MS - Unadjusted β = 0.39 (full: 10%) W: Education-MS - Unadjusted β = 0.40 (full: 13%)
van Oort et al., 2005(33)	Netherlands		Hazard ratio	Education-ACM - Unadjusted β = 2.57 (full: 17%)
Avendano et al., 2006(34)	US		Hazard ratio	
Kittleson et al., 2006 (35)	US Doctors (all age groups)		Hazard ratio	
Kittleson et al., 2006 (35)	US Doctors (<50y)		Hazard ratio	Childhood SEP-CVD - Unadjusted β = 2.40 (smoking: 7%; PA: -33%)
Rathmann et al., 2006 (36)	Germany	Stratified by sex	Odds ratio	M: SEP score-Diabetes - Unadjusted β = 1.40 (full: 13%) W: SEP score-Diabetes - Unadjusted β = 1.78 (full: 30%)
Yan et al., 2006 (37)	US		Odds ratio	Education-CVD - Unadjusted β = 4.14 (full: 32%)
Agardh et al., 2007 (38)	Sweden	Stratified by sex	Relative risk	M: W: Education-Diabetes - Unadjusted β = 2.50 (smoking: 14%; PA: 9%)
Feinglass et al., 2007(39)	US		Hazard ratio	Education-ACM - Unadjusted β = 0.79 (full: -16%) Income-ACM - Unadjusted β = 1.40 (full: 13%)
Gorman et al., 2007(40)	US		Odds ratio	Education-CVD – Unadjusted β =0.73 (full: 56%)
Kivimäki M. et al., 2007(41)	Finland	Stratified by sex	Odds ratio	M: Income-CVD - Unadjusted β = 2.24 (full: 22%) W: Income-CVD - Unadjusted β = 2.12 (full: 9%)
Kuper et al., 2007(42)	Sweden	Women only	Hazard ratio	W: Education-CVD - Unadjusted β = 2.10 (smoking: 21%; alcohol: 21%; PA: 7%)
Loucks et al., 2007(43)	US	Stratified by sex	Odds ratio	M: Education-MS - Unadjusted β = 1.33 (full: 16%) W: Education-MS - Unadjusted β = 2.25 (full: 24%)
Prescott et al., 2007 (44)	Denmark		Odds ratio	Education-MS - Unadjusted β = 0.35 (full: 8%)
Ito S et al., 2008 (45)	Japan		Hazard ratio	Education-ACM - Unadjusted β = 1.31 (full: 26%) Education-CVD - Unadjusted β = 1.53 (full: 14%)
Laaksonen et al., 2008(46)	Finland	Stratified by sex	Hazard ratio	M: Education-ACM - Unadjusted β = 1.64 (smoking: 24%; alcohol: -6%; PA: 11%; diet: 25%; full: 39%) Education-CVD - Unadjusted β = 1.46 (smoking: 27%; alcohol: -2%; PA: 13%; diet: 50%; full: 50%) W: Education-ACM - Unadjusted β = 1.32 (smoking: 20%; alcohol: -11%; PA: 8%; diet: 17%; full: 34%) Education-CVD - Unadjusted β = 2.16 (smoking: 4%; alcohol: -2%; PA: 5%; diet: 6%; full: 17%)
Laszlo et al., 2008(47)	Sweden	Women only	Hazard ratio	Income-CVD – Unadjusted β = 0.39 (smoking: 13%; alcohol: 24%)
Marmot et al., 2008(48)	UK	Men only	Hazard ratio	M: Occupation-CVD - Unadjusted β = 2.17 (smoking: 19%; full: 30%)
Maty S.C. et al., 2008 (49)	US		Hazard ratio	Childhood SEP-Diabetes - Unadjusted β = 1.60 (full: 0%)
McFadden et al., 2008(50)	UK	Stratified by sex	Relative risk	M: Occupation-ACM - Unadjusted β = 2.21 (smoking: 16%) W: Occupation-ACM - Unadjusted β = 1.64 (smoking: 6%)
Panagiotakos et al., 2008(51)	Greece		Hazard ratio	

Ramsay S.E. et al., 2008 (52)	UK	Men only	Odds ratio	
Schulz A.J. et al., 2008(53)	US		Beta coefficient	
Silva et al., 2008(54)	Netherlands	Women only	Odds ratio	W: Education-CVD - Unadjusted β = 5.12 (smoking: -15%; alcohol: 3%)
Singh-Manoux et al., 2008(55)	UK	Men only	Relative risk	M: Occupation-CVD - Unadjusted β = 1.66 (smoking: 15%)
Khang/Selmer et al., 2009(56)	South Korea		Relative risk	Education-ACM - Unadjusted β = 2.83 (full: 11%) Occupation-ACM - Unadjusted β = 1.92 (full: 12%)
McFadden et al., 2009(57)	UK		Hazard ratio	Occupation-Stroke - Unadjusted β = 2.62 (full: 3%)
Münster E et al., 2009(58)	Germany		Odds ratio	Wealth-Obesity - Unadjusted β = 2.91 (smoking: 12%)
Rosengren et al., 2009(59)	International		Odds ratio	Education-CVD - Unadjusted β = 1.56 (full: 39%) Occupation-CVD - Unadjusted β = 1.33 (full: 73%) Income-CVD - Unadjusted β = 1.28 (full: 47%) Wealth-CVD (Unadjusted β = 0.79 (full: 87%)
Rostad et al., 2009(60)	Norway	Women only	Hazard ratio	W: Education-ACM - Unadjusted β = 1.21 (full: 18%) Education-CVD - Unadjusted β = 1.21 (full: 13%)
Skalicka et al., 2009(61)	Norway		Hazard ratio	Education-ACM - Unadjusted β = 1.67 (full: 32%) Income-ACM - Unadjusted β = 2.03 (full: 14%)
Beauchamp et al., 2010(62)	Australia		Hazard ratio	Education-CVD - Unadjusted β = 1.66 (smoking: 20%; alcohol: 5%; PA: 9%; diet: 2%; full: 32%)
Chaix et al., 2010(63)	France		Beta coefficient	Education-CVD - Unadjusted β = 3.96 (full: 30%) Area-CVD - Unadjusted β = 2.39 (full: 64%)
Chapman et al., 2010(64)	US		Odds ratio	SEP score-ACM - Unadjusted β = 1.34 (full: 55%)
Kavanagh et al., 2010(65)	Australia	Stratified by sex	Beta coefficient	M: Education-Diabetes - Unadjusted β = 0.41 (full: 12%) W: Education-CVD - Unadjusted β = 4.47 (full: 26%) Income-Obesity - Unadjusted β = 3.09 (full: 36%)
Krishnan S. et al., 2010(66)	US	Women only	Risk ratio	W: Education-Diabetes - Unadjusted β = 1.28 (full: 26%) Income-Diabetes - Unadjusted β = 1.57 (full: 60%) Area-Diabetes - Unadjusted β = 1.65 (full: 54%)
Lantz et al., 2010(67)	US		Hazard ratio	Education-ACM - Unadjusted β = 1.40 (full: 43%) Income-ACM - Unadjusted β = 2.12 (full: 25%)
Manuck S.B. et al., 2010(68)	US		Odds ratio	SEP score-CVD - Unadjusted β = 0.76 (full: 14%) SEP score-Obesity - Unadjusted β = 0.74 (full: 4%)
Maty et al., 2010(69)	US White		Hazard ratio	Education-Diabetes - Unadjusted β = 1.60 (full: 0%) Childhood SEP-Diabetes - Unadjusted β = 1.60 (full: 0%)
Maty et al., 2010(69)	US Black		Hazard ratio	Education-Diabetes - Unadjusted β = 0.50 (full: 0%)
Schreier et al., 2010(70)	Canada		Beta coefficient	Education-CVD - Unadjusted β = -0.434 (smoking: 2%; PA: 1%)
Steptoe A. et al., 2010(71)	UK		Mean difference	Occupation-CVD - Unadjusted β = 0.824 (full: -7%)
Stringhini et al., 2010(72)	UK		Hazard ratio	Occupation-ACM - Unadjusted β = 1.60 (smoking: 31%; alcohol: 12%; PA: 21%; diet: 17%; full: 72%) Occupation-CVD - Unadjusted β = 3.05 (smoking: 12%; alcohol: 18%; PA: 12%; diet: 7%; full: 45%)
Williams et al., 2010(73)	Australia		Odds ratio	Education-Diabetes - Unadjusted β = 2.10 (full: 21%)
Brummett B.H. et al., 2011(74)	US		Unstandardized path weights	Income-CVD - Unadjusted β = -0.590 (smoking: 136%; alcohol: 261%; PA: 34%)
Demakakos et al., 2011(75)	UK		Hazard ratio	Education-Diabetes - Unadjusted β = 2.09 (full: 26%) Occupation-Diabetes - Unadjusted β = 1.48 (full: 47%) Income-Diabetes - Unadjusted β = 1.63 (full: 40%) Wealth-Diabetes (Unadjusted β = 2.65 (full: 22%; Childhood SEP – Diabetes Unadjusted β = 2.05 (full 20%)
Dinca et al., 2011(76)	Canada	Stratified by sex	Odds ratio	M: Education-Diabetes - Unadjusted β = 1.19 (full: 61%) Income-Diabetes - Unadjusted β = 1.90 (full: -3%) W: Education-Diabetes - Unadjusted β = 1.24 (full: 64%) Income-Diabetes -

				Unadjusted $\beta = 3.24$ (full: 14%)
Franks et al., 2011(77)	US		Hazard ratio	SEP score-CHD - Unadjusted $\beta = 1.79$ (smoking: 21%)
Fu C et al., 2011(78)	China		Odds ratio	
Gustafsson et al., 2011(79)	Sweden	Stratified by sex	Odds ratio	M: SEP score-MS - Unadjusted $\beta = 1.79$ (full: 47%) W: SEP score-MS - Unadjusted $\beta = 2.05$ (full: 23%)
Niedhammer et al., 2011(80)	France		Hazard ratio	Occupation-ACM - Unadjusted $\beta = 1.88$ (full: 0%)
Silhol et al., 2011(81)	France		Hazard ratio	
Stringhini et al., 2011(82)	UK-Whitehall		Hazard ratio	Occupation-ACM - Unadjusted $\beta = 1.62$ (smoking: 32%; alcohol: 13%; PA: 20%; diet: 24%; full: 75%)
Stringhini et al., 2011(82)	France-Gazel		Hazard ratio	Occupation-ACM - Unadjusted $\beta = 1.94$ (smoking: 4%; alcohol: 7%; PA: 8%; diet: 4%; full: 19%)
Dinca et al., 2012(83)	Canada		Hazard ratio	Income-Diabetes - Unadjusted $\beta = 1.41$ (full: 11%)
Hagger-Johnson et al., 2012(84)	UK		Hazard ratio	
Ploubidis et al., 2012(85)	Kenya - urban population		Beta coefficient	
f et al., 2012(85)	Kenya - rural population		Beta coefficient	
Seligman H.K. et al., 2012(86)	US		Odds ratio	Wealth-Diabetes - Unadjusted $\beta = 1.46$ (diet: 11%)
Stringhini et al., 2012(87)	UK		Hazard ratio	Occupation-Diabetes - Unadjusted $\beta = 1.86$ (smoking: 5%; alcohol: 2%; PA: 6%; diet: 8%; full: 15%)
Tanaka et al., 2012(88)	UK	Stratified by sex	Odds ratio	M: Wealth-Diabetes - Unadjusted $\beta = 1.93$ (full: 32%) W: Wealth-Diabetes - Unadjusted $\beta = 3.15$ (full: 36%) Wealth-Obesity - Unadjusted $\beta = 2.98$ (full: 3%)
Williams E.D. et al., 2012(89)	Australia		Odds ratio	Area-Diabetes - Unadjusted $\beta = 1.53$ (full: 11%)
Woodside et al., 2012(90)	France and UK		Hazard ratio	Education-ACM - Unadjusted $\beta = 0.85$ (full: 42%)
Ni et al., 2013(91)	Taiwan	Stratified by sex	Odds ratio	M: W: SEP score-MS - Unadjusted $\beta = 0.85$ (full: 7%)
Shamshirgaran et al., 2013(92)	Australia		Odds ratio	Education-Diabetes - Unadjusted $\beta = 1.71$ (full: 43%) Income-Diabetes - Unadjusted $\beta = 1.42$ (full: 12%)
Dinwiddie et al., 2014(93)	US - Foreign born US Mexicans	Stratified by sex	Odds ratio	M: Education-Diabetes - Unadjusted $\beta = 1.22$ (full: 0%) Education-CVD - Unadjusted $\beta = 3.11$ (full: -0%) Education-Obesity - Unadjusted $\beta = 1.22$ (full: -20%) W: Education-Diabetes - Unadjusted $\beta = 0.90$ (full: -43%) Education-CVD - Unadjusted $\beta = 0.46$ (full: 0%) Education-Obesity - Unadjusted $\beta = 1.21$ (full: -4%)
Dinwiddie et al., 2014(93)	US - US born US Mexicans	Stratified by sex	Odds ratio	M: Education-Diabetes - Unadjusted $\beta = 1.13$ (full: 0%) Education-CVD - Unadjusted $\beta = 2.63$ (full: -0%) Education-Obesity - Unadjusted $\beta = 1.12$ (full: -31%) W: Education-Diabetes - Unadjusted $\beta = 0.32$ (full: 3%) Education-CVD - Unadjusted $\beta = 0.46$ (full: -3%) Education-Obesity - Unadjusted $\beta = 1.04$ (full: -24%)
Giesinger et al., 2014(94)	UK		Hazard ratio	Childhood SEP-ACM - Unadjusted $\beta = 1.97$ (smoking: 50%)
Hwang J et al., 2014(95)	South Korea		Odds ratio	Education-Diabetes - Unadjusted $\beta = 1.74$ (full: 11%) Income-Diabetes - Unadjusted $\beta = 1.37$ (full: 5%)
Lear S.A. et al., 2014(96)	International		Odds ratio	Wealth-Diabetes - Unadjusted $\beta = 1.38$ (full: 19%) Wealth-Obesity - Unadjusted $\beta = 1.43$ (full: 8%)
Lipowicz et al., 2014(97)	Poland	Men only	Odds ratio	M: Education-MS - Unadjusted $\beta = 1.30$ (full: -12%) W:
Nandi et al., 2014(98)	US		Risk ratio	SEP score-ACM - Unadjusted $\beta = 2.84$ (smoking: 13%; alcohol: 17%; PA: 17%; full: 41%)

Nordahl et al., 2014(99)	Denmark	Stratified by sex	Hazard ratio	M: Education-CVD - Unadjusted β = 1.55 (smoking: 7%; PA: 1%) W: Education-CVD - Unadjusted β = 1.65 (smoking: 4%; PA: 0%)
Nordahl et al., 2014 (100)	Denmark	Stratified by sex	Rate difference in additional death per 100'000 Person-Years	M: Education-ACM - Unadjusted β = 1277 (smoking: 22%) Education-CVD - Unadjusted β = 464 (smoking: 17%) W: Education-ACM - Unadjusted β = 746 (smoking: 23%) Education-CVD - Unadjusted β = 200 (smoking: 15%)
Stringhini et al., 2014(101)	Seychelles		Hazard ratio	Occupation-ACM - Unadjusted β = 1.80 (smoking: 16%; alcohol: 12%; full: 23%) Occupation-CVD - Unadjusted β = 1.95 (smoking: 6%; alcohol: 3%; full: 10%)
Tamayo T. et al., 2014(102)	Germany		Rate/prevalence ratio	
Dupre et al., 2015(103)	US elderly (low Hba1c)		Hazard ratio	
Dupre et al., 2015(103)	US elderly (high Hba1c)		Hazard ratio	Education-ACM - Unadjusted β = 1.62 (full: 11%)
Panagiotakos et al., 2015(104)	Greece		Relative risk	Education-CVD - Unadjusted β = 1.52 (full: 13%)
Robertson et al., 2015(105)	UK		Beta coefficient	Occupation-MS - Unadjusted β = -0.450 (smoking: 33%; alcohol: 2%; PA: 4%; diet: 11%; full: 24%)
Zhu et al., 2015 (106)	China		Odds ratio	Occupation-Diabetes - Unadjusted β = 9.04 (full: -6%) Income-Diabetes - Unadjusted β = 2.89 (full: -11%)
Bihan et al., 2016 (107)	Australia		Hazard ratio	Area-ACM - Unadjusted β = 1.27 (full: -3%)
Bonaccio et al., 2016 (108)	Italy		Hazard ratio	
Deere et al., 2016 (109)	US		Odds ratio	Education-CVD - Unadjusted β = 0.67 (full:-59%); Income-CVD Unadjusted β = 0.54 (full: -16%)
Floud et al., 2016 (110)	UK	Women only	Relative risk	W: Education-CVD - Unadjusted β = 2.46 (smoking: 15%; alcohol: 13%; PA: 11%; full: 40%) Area-CVD - Unadjusted β = 1.96 (smoking: 21%; alcohol: 11%; PA: 9%; full: 45%)
Houle et al., 2016 (111)	Canada		Other	Total effect of education : -0.35**; Direct effect : -0.29*; Indirect effect (smoking) : -0.05
Montez et al., 2016 (112)	US	Women only	Hazard ratio	W: Education-MS - Unadjusted β = 1.51 (full: 7%)
Montez et al., 2016 (112)	US	Women only	Odds ratio	W: Education-MS - Unadjusted β = 1.72 (full: 30%)
Poulsen et al., 2016 (113)	Denmark		Risk ratio	Occupation-Diabetes - Unadjusted β = 1.64 (full: 68%)
Stringhini et al., 2016 (114)	UK		Hazard ratio	Education-Diabetes - Unadjusted β = 1.53 (full: 67%) Wealth-Diabetes - Unadjusted β = 1.76 (full: 61%) SEP score-ACM - Unadjusted β = 2.10 (full: 45%) Childhood SEP-Diabetes (Unadjusted β = 1.55 (full: 45%)

ACM: All-cause mortality, CVD: Cardiovascular disease (including mortality, incidence, morbidity, prevalence, stroke, coronary heart disease), MS: Metabolic syndrome (including allostatic load), PA: Physical activity, M: Men, W: Women, Full: Adjustment was performed for all previously mentioned health behaviors (Table 1) or additional covariables added simultaneously to the adjusted model (2) (BMI, hypertension,…)

β1 : β coefficient for SEP → Health outcomes unadjusted for health behaviors

Contribution percentages were computed according to the absolute scale difference method (72)

Supplementary Table 2: Contribution of health behaviors according to the assessment method of SEP indicators (Questionnaire vs. Objective assessment)

Health behavior	**SEP assessment method**	**SEP indicator** **Education**	**Occupation**	**Other SEP indicators**
Multiple health behaviors	Questionnaire	16% [a] (-59%;67%) [b]; n=53 [c]	36% (-6%;73%); n=16	24% (-16%;69%); n=38
	Objective assessment	29% (26%;32%); n=3	35% (-7%;75%); n=12	22% (-6%;64%); n=12
Smoking	Questionnaire	17% (-15%;48%); n=25	15% (-13%;36%); n=9	16% (-11%;136%); n=14
	Objective assessment		22% (4%;33%); n=11	18% (0%;50%); n=5
Alcohol	Questionnaire	4% (-11%;21%); n=11	7% (3%;12%); n=2	50% (-2%;261%); n=7
	Objective assessment		10% (2%;18%); n=6	
Physical activity	Questionnaire	6% (-5%;17%); n=16	7% (4%;10%); n=2	10% (-33%;34%); n=6
	Objective assessment		14% (4%;21%); n=6	
Diet	Questionnaire	23% (2%;50%); n=7		
	Objective assessment		13% (4%;24%); n=6	11% (11%;11%); n=1

[a]: Median contribution

[b]: Minimum and maximum contributions for each association. Contribution percentages for each association were computed according to the absolute scale difference method (72)

[c]: Number of found associations (one study may contain several associations)

Supplementary Table 3: Median, minimum and maximum contribution of health behaviors according to the assessment method of health outcomes (Questionnaire vs. Objective assessment)

Health behavior	**Health outcome assessment method**	**Health outcome** **All-cause mortality**	**Cardiovascular disorders**	**Metabolic disorders**
Multiple health behaviors	Questionnaire	16% [a] (-59%;67%) [b]; n=53 [c]	36% (-6%;73%); n=16	24% (-16%;69%); n=38
	Objective assessment	29% (26%;32%); n=3	35% (-7%;75%); n=12	22% (-6%;64%); n=12
Smoking	Questionnaire	17% (-15%;48%); n=25	15% (-13%;36%); n=9	16% (-11%;136%); n=14
	Objective assessment		22% (4%;33%); n=11	18% (0%;50%); n=5
Alcohol	Questionnaire	4% (-11%;21%); n=11	7% (3%;12%); n=2	50% (-2%;261%); n=7
	Objective assessment		10% (2%;18%); n=6	
Physical activity	Questionnaire	6% (-5%;17%); n=16	7% (4%;10%); n=2	10% (-33%;34%); n=6
	Objective assessment		14% (4%;21%); n=6	
Diet	Questionnaire	23% (2%;50%); n=7		
	Objective assessment		13% (4%;24%); n=6	11% (11%;11%); n=1

[a]: Median contribution

[b]: Minimum and maximum contributions for each association. Contribution percentages for each association were computed according to the absolute scale difference method (72)

[c]: Number of found associations (one study may contain several associations)

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The contribution of health behaviors to socioeconomic inequalities in health: a systematic review

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