Smoking and Obesity in a Social Context: What Is the Role of Stress?

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SMOKING AND OBESITY IN A SOCIAL CONTEXT:
WHAT DOES STRESS HAVE TO DO WITH IT?

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A Dissertation Submitted to the Faculty of
The Harvard T.H. Chan School of Public Health
in Partial Fulfillment of the Requirements
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Smoking and obesity in a social context:

What does stress have to do with it?

Abstract

**Background:** Smoking and obesity are the leading causes of preventable death in the United States and known cancer risk factors, yet the patterning of these conditions within low-income and immigrant populations is not well understood. The distribution of social-environmental stressors is also poorly understood in these populations. Furthermore, the relationship between socioeconomic status (SES) and stress is understudied. Therefore, this dissertation explores the association between SES, psychosocial stress and social-environmental stressors, self-reported smoking, and measured obesity.

**Methods:** Papers 1 and 2 used cross-sectional data from the Health in Common study of racially/ethnically diverse adults living in low-income housing in the Boston metropolitan area (n=828). Paper 1 examined associations between SES, chronic stress, and smoking while paper 2 explored the relationship between SES, chronic stress, and obesity. In papers 1 and 2, SES and chronic stress were conceptualized as latent variables where chronic stress was represented by perceived stress and physical characteristics of the neighborhood and internal home environment. Analyses were conducted using structural equation modeling (SEM) adjusting for sex, age, and nativity. For paper 3, we performed a targeted and systematic review of the literature on the relationship between SES and perceived stress and then conducted a meta-analysis.

**Results:** The meta-analysis found a one unit standard deviation change in education resulted in a -0.13 change in perceived stress. SEM results suggest residents with higher SES had significantly lower odds of being a current smoker (standardized coefficient=-0.31, p<0.05), but not of being obese (standardized coefficient=0.01, p=0.80). Furthermore, residents demonstrating higher chronic stress had significantly higher odds of being a current smoker (standardized coefficient=0.24, p<0.05) and being obese (standardized coefficient=0.13, p<0.05). SES was not associated with chronic stress in either model.
Conclusion: SES impacts stress and stress impacts health and health behavior in vulnerable populations. More research is needed to explore the complex and multifactorial relationships between SES, stress, and health, particularly among different population segments. This dissertation work is significant because identifying stress/stressors that act as structural barriers, exacerbating inequities, could result in interventions demonstrating population health impact.
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At my core, I remain a grateful sharecropper’s granddaughter. I started on this journey not only for intellectual pursuits, but to give a name to my experience of losing loved ones too soon because of an environment that systematically harmed their health. I’d like to dedicate this to the memory of family members who are not with me today, and in particular those that I witnessed struggle with cancer: Uncle
Albert, Uncle Tracey, and those who were taken suddenly by cardiovascular disease: Uncle Secret, Uncle Perry, and my dear 37 year-old Cousin Keedo just last year. They did not make it to see this day, but I’d like to imagine they were my guardian angels guiding me to and through this process. I love you.
“The dominant policy discussions remain centered more on individuals than on populations, more on cure than on prevention, and more on seeking to change individual behavior and lifestyles than on seeking to modify the community structures, norms, and incentives that induce people to behave as they do.”

Introduction

Theoretical framework: Socioeconomic status, stress, and health

Socioeconomic and racial and ethnic disparities in mental and physical health exist such that minorities and those of lower socioeconomic status (SES) generally experience a disproportionate burden of death and disease. Modifiable health behaviors (e.g. smoking) and conditions (e.g. obesity) that could potentially prevent this patterning are also unequally distributed where population segments at higher risk of morbidity and mortality generally engage in riskier behavior and experience a higher prevalence of high-risk conditions. Yet, little is known about the mechanisms that explain this relationship between SES and health behaviors.

Stress is one pathway that could partially explain the link between SES and health given that stress affects health directly by changing a person’s biology and indirectly by possibly triggering participation in health risk behaviors as a form of coping. Stress is an imbalance that occurs when demands outweigh a person’s adaptive capacity resulting in a negative emotional and biological response. Demands that can induce a stress response are stressors and can take the form of any unpleasant stimulus. Unfortunately, in health disparities there is a tendency to discuss stress as an individual process that prompts individual coping strategies frequently leading to conversations around personal responsibility and victim blaming. However, as Pearlin (1989) states, “many stressful experiences, it should be recognized, don’t spring out of a vacuum but typically can be traced back to surrounding social structures and people's locations within them” (p.242).

To understand people’s location within social structures in the United States (U.S.), it is critical to understand that due to the experience of social marginalization, oppression, and discrimination, differences in health and health behavior are often ramifications of historical and social systems. These systems are related to socioeconomic status (SES) and race and inextricably linked to structures of power, privilege, and access to resources and opportunities. Specifically, those of low SES (e.g. those with low educational attainment and who earn little), are more likely to experience financial strain, a stressor that has implications for mental and physical health.
In addition to greater exposure to financial strain, those of low SES often live in neighborhoods that are a reflection of institutional disinvestment. This manifests as neighborhoods that often lack adequate services and lead to higher exposure to physical and social disorder- often associated with public deviance, toxic chemicals, and poorer quality homes. Therefore, it makes sense that stress is a socially patterned response to the unequal distribution of power and privilege in an environment without adequate resources and opportunities to cope sufficiently.

Understanding health differences in terms of power and privilege require a healthy equity lens. To address the fundamental causes of health inequities then, it will be necessary to examine how SES patterns stress as well as physical and social structures (e.g. neighborhoods and environmental exposures) and assess their relationship to health and health behavior to inform interventions to address SES. This thinking informed the conceptual model (Figure 0.1) that guided my dissertation research and the subsequent aims for my three papers.

**Conceptual model**

![Conceptual model](image)

Figure 0.1. Dissertation conceptual model showing links between socioeconomic status, chronic stress, and health

The aim of my first 2 papers were closely linked and two-fold. Specifically, the aim of paper 1 was to 1) assess the relationships among SES, chronic stress as measured by several indicators, and smoking and 2) assess whether chronic stress mediates the relationship between SES and smoking among racially/ethnically diverse adults living in low-income housing in the Boston metropolitan area. The aim
of my second paper was to examine these relationships relationship with obesity as the outcome. I chose
to focus on tobacco smoking and obesity, the two leading causes of preventable death.

Both papers used structure equation modeling (SEM) methodology. SEM was used because it:
allows you to concurrently analyze latent and manifest variables, runs simultaneous regression equations
reducing the risk of type I error, and models measurement error directly without assuming observed
variables are measured without error--an assumption of multiple regression.

In papers 1 and 2 of my
dissertation, socioeconomic status was conceptualized as a latent variable, or a construct that is not
directly measurable. This latent variable represented material goods, skills, and abilities as well as
some reflection of a social hierarchy or degree of access to power, privilege, and other resources. SES
was represented by employment status, educational attainment, weekly income, and car ownership.

Similarly, chronic stress was characterized as a latent variable in dissertation papers 1 and 2.
Chronic stress was conceptualized as a latent variable because it was thought to capture stress that was
consciously attributed as overwhelming. It was also hypothesized to capture physical constraints and
environmental exposures that are both vestiges of institutional disinvestment and can act as stressors that
may or may not have contributed to attributions of perceived stress. I used chronic to symbolize how low-
income populations such as those I’m studying, might have sustained exposure to several stressors.

In the first two papers, chronic stress was a second order latent variable represented by three first
order latent variables: perceived stress as measured by Cohen’s 4-item Perceived Stress Scale; psychosocial stress which was ascertained by asking about financial hardship and food insecurity; and
environmental stress which was assessed by neighborhood incivilities, perceived safety, and presence of
pests in the home. I consciously chose indicators that were amendable to change for both the SES and
chronic stress latent variables.

While developing the first two papers, I became particularly intrigued by the global measure of
perceived stress. It seemed that relying solely on a specific measure of perceived stress (e.g. job strain,
perceived safety, and discrimination) implies that each type of stress exerts an independent effect, which
might not be the case in vulnerable populations where chronic stress tends to cluster. Additionally, it
implies people can correctly attribute feelings of lack of control and being overwhelmed (perceived stress) or ambiguous stressors (e.g. micro aggressions) correctly and to one specific stressor, when in fact it may be the presence of multiple stressors that induces this feeling. It seemed like a promising measure of non-specific stress that might be patterned by SES and exert its effects on health though there was a dearth of research examining the association of SES and perceived stress. To address this gap in the literature, the aim of my final paper was to narratively and quantitatively summarize the literature on the effects of SES indicators and perceived stress.

Overall, the goal of my three proposed papers was to understand the social patterning of stress in vulnerable populations and identify structural barriers that act as chronic stressors and can constrain health behaviors and/or damage health. This research is significant because identifying neighborhood structures and environmental exposures that are often the result of the unequal distribution of opportunities and resources could inform interventions that could contribute to larger population health impact. Furthermore, identifying the social structures that produce these barriers provides an added opportunity for organizational and policy change solutions that address the root causes of inequities. It also must be stated that race/ethnicity are not variables used in this work. However, we know that SES and race are highly correlated, yet independently impact for health; therefore, the potential contribution of race/ethnicity in addition to SES should not be overlooked. Next steps should include examining these associations within different racial/ethnic groups in the sample to understand the interaction of these two important factors.
REFERENCES

Paper 1: Smoking in a social context: What does stress have to do with it?

Kia L. Davis, MPH, Laura D. Kubzansky, PhD, MPH, Ichiro Kawachi, MD, PhD, Glorian Sorensen, PhD, MPH
ABSTRACT

Background: Despite decreases in smoking prevalence overall, smoking remains the leading cause of preventable death in the United States. Inequities in smoking outcomes persist such that those of low socioeconomic status (SES) are more likely to be smokers and less likely to quit. Psychosocial and socio-environmental stressors are thought to explain inequities in smoking, but there is little research examining the relationship between SES, various stressors, and smoking. As a result, this paper examines these relationships and whether chronic stress as represented by several types of stress/stressors mediate the relationship between SES and smoking.

Methods: We used data from the Health in Common study of adult, low-income housing residents (n=828) in the Boston metropolitan area. We conceptualized SES and chronic stress as latent variables with financial strain, physical neighborhood disorder, and perceived stress as some of the chronic stress indicators. We conducted structural equation modeling adjusting for nativity, age, and sex.

Results: Higher SES was associated with a decreased probability of smoking (standardized coefficient= -.31, p<0.05) and higher chronic stress was associated with a higher probability of being a current smoker (standardized coefficient=0.24, p<0.05). However, SES was not significantly associated with chronic stress and there was no evidence for mediation.

Conclusion: Smoking is partially patterned by social structures related to SES and chronic stress though they might exert their impact through different pathways. More research should be done in different population segments to understand the role of stress in the SES-smoking relationship.
INTRODUCTION

Public health’s tobacco control efforts in the United States (U.S.) have more than halved the smoking rate over the past 50 years; yet, tobacco smoking remains a public health problem as a leading cause of preventable death and disability. It impacts nearly every organ of the body, contributes to the increased risk of cancers and chronic diseases, and accounts for approximately 480,000 deaths annually while three times that number live suffering from smoking-related illness. Equally worrisome, the dramatic decline of tobacco smoking has been unequal across population segments resulting in a noticeable socioeconomic status (SES) gradient for tobacco outcomes including initiation, prevalence, intensity, and cessation. This gradient exists across individual- and neighborhood or area-level SES measures.

Many individual-level SES indicators alongside markers for material deprivation such as housing tenure and car ownership have been linked to poor smoking outcomes, see reviews by Fagan (2007) and Hiscock (2012). For instance, a cross-sectional study of Finnish adults found that multiple SES indicators--education, occupation, income, and housing tenure--were all independently and significantly associated with being a current smoker in a graded fashion. When concurrently controlling for all SES indicators among men, only renter status remained significant even though the trend remained evident across indicators. Among women, all SES indicators remained significant except for income.

Longitudinally, each additional year of an individual’s own educational attainment was associated with decreased odds of current use and increased odds of cessation among adults from the Rhode Island cohort.

Area-level SES measures are said to be associated with smoking behavior as well. They measure the social class of a neighborhood by reporting the percentage of people in the area who: have income below the poverty line, have less than a high school degree, etc. These measures tap into potential resources, support, and social standing a person has access to beyond their individual-level means. The observed relationships among area and individual level measures are complex due to variability in results and measures used across studies, inconsistency in variables that are adjusted for, and challenges with
defining SES or area boundaries. Perhaps due to these complexities, the mechanisms underlying this SES-health relationship are unclear.

The role of stress

Stress is often posited as a potential mechanism to explain why individuals with lower SES are more likely to engage in harmful health behaviors including smoking. Stress is an imbalance that occurs when demands outweigh an individual’s coping capacity, resulting in an emotional, psychological, or biological response. Any demands that have the potential to evoke a stress response are stressors and health damaging stressors can take many forms from financial strain to structural constraints. Many health damaging stressors are socially patterned and should be considered in context, and particularly in relation to a person’s position within existing social structures.

Stress is hypothesized as a mediator because of the social patterning of lived experiences. For example, those of low SES often face stress related to material deprivation like not having enough money to cover basic expenses (financial hardship) or having to go without food (food insecurity) resulting in a person being overwhelmed and without sufficient resources to cope. What’s more, low SES limits an individual’s housing, job, and educational opportunities resulting in increased exposure to physical constraints and environmental risks. Consequently, people characterized by low SES are more likely to live in poorer neighborhoods with higher crime, incivilities, and concentration of fast food places, and without access to healthy grocery stores. These neighborhoods tend to have or be located near more environmental risks exposures such as hazardous wastes, substandard housing, air pollution, or indoor environmental which have a deleterious impact on health. Interestingly, one study indicates that low area-level SES might impact health through perceptions of disorder, lack of safety, and a resulting fear.

Stress can have health damaging effects whether it is perceived as stressful or not. For example, perceived stress is when the demands one faces are assessed and attributed as being beyond one’s adaptive capacity and there are many domains (e.g. job strain, perceived safety, discrimination). Relying exclusively on specific measures of perceived stress implies people can correctly attribute their feelings of lack of control and ambiguous stress-inducing experiences (e.g. micro-aggressions). What’s more,
structural barriers can produce a confluence of factors that might not be captured by measuring specific stressors or might be misattributed to a stressor, increasing the risk of under reporting. As an alternative, it might be important to assess a global measure of perceived stress when exploring differential exposures to stress and smoking since people might not always know exactly what is troubling them. Non-specific measures of perceived stress such as Cohen’s Perceived Stress Scale (PSS) identify to what extent things are piling up, uncontrollable, and unpredictable. This is significant since the unpredictable and uncontrollable nature of stress is considered the most problematic for health.

However, the literature linking SES to perceived stress is inconsistent. For instance, in cross-sectional studies, lower education and income was significantly associated with higher perceived stress among Mexican-American women and in nationally representative samples of adults in the U.S. Yet, there was no association of income and education with perceived stress in a cross-sectional study of low-income South African adults or high SES immigrants across the U.S. In a two-year longitudinal study of adult women in Iceland, only mid-level education and income were associated with higher odds of perceived stress after the economic recession.

All of the studies measured perceived stress with PSS. The null studies of low-income South African adults and high-SES Asian immigrants in the U.S. suffered from limited variability in the SES exposure, potentially attenuating any associations. The cohort study has similar study design issues since about 50% of the sample had only a basic education and 50% had a middle level income. Additionally, the author dichotomized perceived stress potentially reducing power to detect differences. Overall, there appears to be some evidence of an association between SES and perceived stress with potential differences by race/ethnicity and sex, more research is needed to fully elucidate these relationships.

**Stress and smoking**

In order for stress to be a mediator, SES and stress must be related, but so must stress and smoking. The literature generally supports that individuals with higher perceived stress, measured in a variety of ways, smoke more and quit less though there is some debate over the directionality of this stress and smoking relationship due to the lack of longitudinal studies. In one longitudinal study, 211
adult smokers who maintained a high PSS level over 6 months were less likely to quit compared to those whose PSS decreased over the same time frame.\textsuperscript{72} The Midlife in the U.S. (MIDUS) study showed that respondents reporting higher stress at baseline and follow-up on specific stressor domains such as perceived inequality and financial strain resulted in persistent smoking and double the odds of failure to quit at the 9-10 year follow-up.\textsuperscript{77} Yet, of the eight stressor domains assessed, some were not significantly associated with smoking or quitting at all. Among respondents from the American Changing Life Study, the occurrence of adverse financial events within 3 years was associated with a greater likelihood of relapse and persistent smoking particularly among women.\textsuperscript{74}

**Evidence for mediation**

The evidence demonstrating stress as a mechanism linking other SES indicators and smoking is sparse though there is one longitudinal study of note. Businelle (2010) assessed whether social support, neighborhood disadvantage, negative affect/stress, agency, and craving- all conceptualized as latent variables- were on the pathway between socioeconomic status and smoking status four weeks after enrolling in a smoking cessation study in Texas.\textsuperscript{75} SES was characterized by education, income, employment, and insurance status. Neighborhood disadvantage was measured by neighborhood problems (e.g. traffic, vandalism, and litter), neighborhood vigilance, and social cohesion. Negative affect/stress was measured by the Center of Epidemiologic Studies Depression Scale (CES-D), Cohen’s PSS, and the Negative affect subscale of the Positive and Negative Affect Scale (PANAS). He found that all four latent variables had significant direct and indirect effects on smoking status after four weeks.

**The present study**

Our study is intended to fill several current gaps in the literature. First, many of the studies documenting the impact of SES on smoking were conducted in a European context and whether findings hold in the U.S. has not been assessed. Second, methodologically, previous studies mostly investigate the independent contribution of SES indicators on smoking while assuming these constructs are measured without error. In structural equation modeling (SEM), the error of the observed variables is modeled directly.\textsuperscript{76} The source of this error is random error and non-random error that normally arises from
measurement error. Therefore, unlike multiple regression, SEM does not assume correct measurement and this direct modeling of error can serve as a test of how well your underlying factors are measuring your construct. Since we are still understanding the role of different types of stress and measures of stressors, it will be useful to understand how well we are measuring our proposed constructs within different population segments.

Third, the literature to date has not considered the impact of some potentially potent stressors such as food insecurity, perceived safety, and pests in the home in relation smoking. Fourth, no studies have directly assessed whether the combined variance of these different types of stressors and perceived stress mediate the relationship between SES and smoking in adults. Finally, there is a dearth of evidence 1) documenting whether SES indicators lead to measures of perceived and 2) examining if specific stressors and perceived stress are along the pathway between SES, and smoking.

As a result, the aim of this paper is to assess whether several types of stress/stressors mediate the relationship between SES and smoking among low-income housing residents in the Boston metropolitan area. We are interested in perceived stress, psychosocial stressors, environmental stressors, and hypothesized physical stressors in the neighborhood and housing environment. Hereinafter this grouping of stress and stressors will be referred to as chronic stress because of their potential to persist in this population over time. We will use SEM to conduct the analysis.

We hypothesize that the proposed indicators of chronic stress co-vary and this shared variance is patterned by SES indicators which has implications for health behavior, particularly smoking. As shown in Figure 1.1, we hypothesized that low socioeconomic status is linked directly to being a current smoker (direct association) and that low SES is linked to high chronic stress which in turn is linked to being a current smoker (indirect association).
Figure 1.1 Initial conceptual model of socioeconomic status, chronic stress, and smoking status

The exposure, socioeconomic status, was conceptualized as a latent variable to represent material and financial goods in addition to skills and abilities while accounting for an individual’s location within a social hierarchy. The mediator, chronic stress, was conceptualized as a latent variable to represent stress that is consciously attributed as well as psychosocial and environmental stress exposures that could persist over time, are usually indicators of institutional disinvestments, and may or may not contribute to attributions of perceived stress. For both latent variables, we have deliberately chosen to identify indicators that are amenable to change and could be targeted by community-based organizational and policy change strategies that would reduce cancer health inequities at the population level.

METHODS

All research protocols were approved by the institutional review boards at the Dana Farber Cancer Institute and the Harvard T. H. Chan School of Public Health.

Data source

Data for this secondary analysis are from the Health in Common Study (HIC), a cross-sectional study whose original study goal was to ascertain the social and physical determinants of cancer risk behaviors among low-income housing residents in Boston. Approximately 828 residents were surveyed
across 20 public and private housing developments in the Boston, MA metropolitan area (Cambridge, Somerville, and Chelsea). A multi-stage cluster sampling method was used where households were selected within developments and one adult aged 18+ was selected from recruited households to be interviewed. Data were collected from February 2007 to June 2009 from housing developments with a minimum of 40 units and whose low-income housing classification was based on guidelines established by the Department of Housing and Urban Development (HUD). The response rate was 49% across all developments. Prior manuscripts should be referenced for further details.  

**Data collection**  
There were multiple data collection methods. Individual-level information on cancer risk behaviors, social status, stress, environmental exposures, and sociodemographic information were obtained from resident surveys. Trained bilingual research assistants conducted these 45-60 minute surveys in the residents’ household in English (53.7%), Spanish (26.7%) and Haitian Creole (19.6%).  

Data on environmental exposures were obtained from direct household environmental assessments. These 15-20 minute assessments were conducted in each resident’s household by staff trained to identify elements of the household environment that might result in indoor environmental exposures including signs of pest debris, live pests observed, and adequate ventilation of the bathroom fan. Lastly, data on the physical and social disorder of the neighborhood were derived from systematic social observations. Trained study staff conducted systematic social observations at each housing development to record features specific to the development such as measures of conditions of interior hallways, and lighting, and physical and social disorder. To complete these assessments, the staff member used a checklist to record observations on people’s activities, the physical environment, and social interactions during a 15-20 minute walkthrough. All assessments were performed during daylight hours.  

**Measures**  
Current smoking status. The outcome, current smoking status, was assessed by ascertaining if an individual had ever smoked 100 cigarettes in their lifetime and whether (s)he was currently smoking cigars, pipes, or cigarettes. These questions from the National Cancer Institute’s nationally represented
survey were cognitively tested. People who responded yes to currently smoking cigars, pipes, or cigarettes and who smoked at least 100 cigarettes in their lifetime were categorized as current smokers. Former smokers were designated if individuals reported smoking at least 100 cigarettes in their lifetime, but were not currently smoking; never smokers were defined as people not currently smoking and who also had not smoked 100 cigarettes in their lifetime. For this analysis and consistent with other research in this area smoking status was dichotomized (current smokers versus former and never smokers).

Socioeconomic status. The socioeconomic status indicators included: education; weekly income; poverty status; employment; and car ownership. For education, residents who attended school in the U.S. reported grades attended while those who attended school outside of the U.S. reported years of school attended. These values were combined to create response categories: less than high school, some high school, high school graduate, more than high school. Residents indicated their weekly household income before taxes and the interviewer marked the appropriate response category from the following options: $0-$100, $101-$250, $251-$500, $501-$750, >$750. There were four response categories above the $501-750 range, but these were collapsed to $750+ due to insufficient cell sizes.

In an effort to account for household size, income and household composition were compared to the U.S. Census Bureau’s 2008 definition and residents were deemed not in poverty if they were above the threshold and in poverty if they were below the threshold. Residents who responded that they did not work at a job for pay were categorized as unemployed and residents who responded they did work at a job for pay were employed. Car ownership was ascertained by asking if anyone in the household owns a car, van, truck, or motorcycle that runs (yes/no). All SES indicators were adapted from the Moving to Opportunity Study (MTO), coded similarly to previous analyses of this work, and coded so that higher values signified higher SES.

Chronic stress. Chronic stress was derived by combining information from measures of perceived stress, psychosocial stress (financial hardship and food insecurity) and environmental stress (low perceived safety, neighborhood incivilities, and presence of pests). Perceived stress was ascertained on the resident survey by Cohen’s abbreviated 4-item perceived stress scale, which asked: In the last month
how often have you 1) Felt you were unable to control the important things in your life? 2) Felt confident about your ability to handle your personal problems? 3) Felt that things were going your way and 4) Felt difficulties were piling up so high that you could not overcome them? The response categories ranged from 1-4 corresponding with options: never, rarely, sometimes and often. Questions 2 and 3 were reverse coded so that for each item, a higher number meant more stress.

Psychosocial stress was assessed by asking about food insecurity and financial hardship. For financial hardship residents were asked “in general, how do you find your household’s finances usually work out at the end of the month? Is there… some money left over, just enough to make ends meet, or not enough to make ends meet?” (Some money/just enough money versus not enough to make ends meet). This item categorized in the same way has performed as expected where it was significantly associated with self-rated health. Food insecurity was assessed by asking if in the past 12 months, there was ever at time when there wasn’t enough food (yes/no). The food insecurity question was adapted from the Household Food Security Scale.

Environmental stress was ascertained according to measures of perceived safety, neighborhood incivilities, and exposure to mold and pests. Perceived safety questions were adapted from the MTO study asked whether residents felt very safe, safe, unsafe, or very unsafe on the streets around the complex during the day, at night, and in common area of the apartment complex. Very safe and safe responses were coded as 0 and safe and unsafe responses were coded as 1. Responses were summed and dichotomized to represent residents who felt very safe and safe vs those who felt unsafe in 1 or more areas in or near the housing development. The three perceived safety items had a standardized Cronbach’s alpha of 0.83.

Neighborhood incivilities were derived based on systematic observations of whether the following was visible on the interior grounds, foot paths, yards, and/or parking lots: 1) empty beer containers or liquor bottles 2) trash, litter, junk, or broken glass 3) cigarette or cigar butts or cigarettes or cigars 4) needles, syringes, condoms, or drug-related paraphernalia, and 5) graffiti on buildings, sidewalks and signs on the building grounds or in the parking lots with response categories: none, very little, some,
and a lot. For each item, a response of none or very little was coded as 0 and some, while a lot was coded as 1. Because of the near universal presence of trash and cigarette butts, these items were summed and dichotomized to people who indicated there were two or fewer incivilities versus more than two. These incivilities were selected and measured consistent with previous research on which indicators of physical disorder impact health. The five neighborhood incivilities items had a standardized Cronbach’s alpha of 0.81.

Exposure to pests was determined according to whether individuals reported (a) seeing rats or bedbugs a few times a year or more or (b) seeing cockroaches, ants, mice a few times a month or more. Exposure to mold was determined according to whether (a) individual residents reported seeing or treating mold or (b) study staff reported seeing mold during the environmental assessment at the time of the survey. These mold and pests exposure measures were derived from research designed to consider the impact of indoor environmental exposures on health. They have performed as expected in prior work.

For example, pest exposure was associated with a chemical exposure index (not used in this analysis) suggesting that pesticide usage was high to get rid of pests. Further, an inadequate ventilation index (not used in this analysis) was also associated with mold exposure which is consistent with prior findings that poor bathroom ventilation results in mold growth. For a more in-depth discussion of indices see Adamkiewicz and Sorensen. Chronic stress indicators were coded so that increasing values signified more chronic stress.

Covariates. We adjusted for age (split into normally distributed categories of 18-29, 30-39, 40-49, 50-59, 60+); sex (male/female); and nativity (U.S. born/Born outside of continental U.S.). We decided to use the two category nativity as it was highly associated with race/ethnicity in the sample and would make the model less complicated than a 4 category race variable. Future studies should conduct intersectional analysis, examining this association within difference racial/ethnic/native groups.

Analytic strategy

Descriptive statistics were evaluated. Chi square tests were conducted to determine if there were differences in smoking prevalence by group. Spearman correlations were obtained for dichotomous and
ordinal variables to examine inter-correlation of all indicator variables and the outcome variable for non-linear data. All of these analyses were conducted using SAS version 9.3. An SEM framework was used to simultaneously evaluate the hypothesized relationships between latent and manifest variables using MPlus version 7.1.

Each latent variable was first evaluated separately in a measurement model that related the indicators (measures) to the latent variable. Theory and conceptual model guided any changes made to improve model fit. Once both measurement models showed good fit, they were brought together in a structural model that related the latent variables to each other and the smoking status outcome, a manifest variable. To determine if the model was well fitting traditional fit indices such as the Chi-square, Bentler Comparative Fit Index (CFI), and the Root Mean Square Error of Approximation (RMSEA) goodness of fit indices were used. Though a non-significant $\chi^2$ is desired, this value is highly sensitive to large sample sizes (over 400) and multivariate non-normality. Generally CFI values of 0.90 or above indicate good model fit though this is also sensitive to large sample sizes. The RMSEA is less sensitive to sample size with an ideal estimate less than or equal to 0.05, and a tight confidence interval with an upper bound less than 0.10.

Weighted least squares with robust standard errors (WLSMV) was used to estimate the free parameters because of the categorical indicators. The “CLUSTER” and “TYPE=COMPLEX” commands were used to account for the clustering of residents within housing developments. This statistical approach uses a “sandwich estimator” correction to compute robust standard errors in the face of non-independence of observations. By default, MPlus calculates probit regression estimates when WLSMV estimation is used with a dichotomous outcome, predicting probabilities of smoking status.

Most residents had less than or equal to 1% missing information for all study variables (n≤5) except for 7% who were missing income information and 11% (n=92) who were missing data on education. Of the 92 missing education information, 88% were more likely to identify as female and 77% were more likely to be born outside of the continental U.S. For missing variables, MPlus assumes missing
at random with respect to x and uses a methodology that estimates missing values using all available information in the dataset, for further details see Asparouhov (2010).

RESULTS

Sample characteristics

Table 1 shows the sociodemographic characteristics of HIC residents (n=828) by smoking status. Residents were more likely to be women (80%) and 52% owned cars. Age was nearly evenly distributed though more residents were 30-39 years of age (26%). The residents were mostly Hispanic (41%), 38% were Non-Hispanic Black, 11% were Non-Hispanic white, and 9% were some other race or ethnicity. About 32% were born in the continental U.S. while 24% were born in Haiti and 20% were born in Latin America. Most residents were food secure (63%), did not face financial hardship (61%), were confident about handling their problems (53%) and lived in neighborhoods were there was some or a lot of neighborhood incivilities (78%). Compared to never and former tobacco users, current users were more likely to be employed, non-Hispanic White men who were born in the continental U.S. They were more likely to be food secure and marginally more likely to live in neighborhoods with a lot of neighborhood incivilities.
Table 1.1. Characteristics of low-income housing residents in the Health in Common Study by smoking status (n=828)

<table>
<thead>
<tr>
<th></th>
<th>Current Smoker</th>
<th>Former/Never smoker</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>% of sample</td>
<td>%</td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
<td>21.38</td>
</tr>
<tr>
<td>18-29 years</td>
<td>825</td>
<td>&lt;0.05</td>
<td></td>
</tr>
<tr>
<td>30-39 years</td>
<td>218</td>
<td>26.42</td>
<td>13.30</td>
</tr>
<tr>
<td>40-49 years</td>
<td>169</td>
<td>20.48</td>
<td>23.67</td>
</tr>
<tr>
<td>50-59 years</td>
<td>145</td>
<td>17.58</td>
<td>29.66</td>
</tr>
<tr>
<td>60+ years</td>
<td>140</td>
<td>16.97</td>
<td>16.43</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>659</td>
<td>79.59</td>
<td>19.88</td>
</tr>
<tr>
<td>Male</td>
<td>169</td>
<td>20.41</td>
<td>27.22</td>
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<td>Race/Ethnicity</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Hispanic</td>
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<td>41.38</td>
<td>18.77</td>
</tr>
<tr>
<td>Non-Hispanic Black</td>
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<td>38.35</td>
<td>13.92</td>
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<tr>
<td>Non-Hispanic White</td>
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<td>11.29</td>
<td>51.61</td>
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<tr>
<td>Other</td>
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<td>8.98</td>
<td>25.68</td>
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<tr>
<td>Nativity</td>
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<td></td>
<td></td>
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<tr>
<td>Born in continental US</td>
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<td>31.52</td>
<td>46.15</td>
</tr>
<tr>
<td>Born outside continental US</td>
<td>565</td>
<td>68.48</td>
<td>9.91</td>
</tr>
</tbody>
</table>

**Socioeconomic status indicators**

<p>|                                | Current Smoker | Former/Never smoker | p-value |
|                                | N  | % of sample | %    | %    |         |
| Employment Status              |    |             | 51.27 | 13.21 | &lt;.0001  |
| Employed                       | 424 |             | 13.21 | 86.79 |         |</p>
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<th></th>
<th>N</th>
<th>%</th>
<th>Current</th>
<th>Former</th>
<th>P-value</th>
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<td>30.02</td>
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<tr>
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<tr>
<td>$0-$100 weekly</td>
<td>75</td>
<td>9.70</td>
<td>29.33</td>
<td>70.67</td>
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<tr>
<td>$101-$250 weekly</td>
<td>236</td>
<td>30.53</td>
<td>27.12</td>
<td>72.88</td>
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<td>$251-500 weekly</td>
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<td>33.51</td>
<td>21.24</td>
<td>78.76</td>
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<td>$501-$750 weekly</td>
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<td>&gt;$750 weekly</td>
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<td>Unable to control important things</td>
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<td>0.001</td>
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<td>Never</td>
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<tr>
<td>Rarely</td>
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<tr>
<td>Sometimes</td>
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<tr>
<td></td>
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<td>Current</td>
<td>Former</td>
<td>P-value</td>
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<td>Table 1.1. (Continued)</td>
<td>N</td>
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<td>Current</td>
<td>Former</td>
<td>p-value</td>
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<td>-----</td>
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<td>--------</td>
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**Bivariate analyses**

Correlations between all observed variables are presented in table 2. The social status indicators are all significantly correlated with each other as expected, but not significantly correlated with the indicators of chronic stress. In fact, not all of the chronic stressor indicators are significantly intercorrelated. Surprisingly, some indicators have a weaker correlation than expected (e.g. financial hardship and car ownership \( r=0.013 \)).
Table 1.2. Spearman correlation coefficients of observed study variables

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<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
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<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Not in poverty</td>
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<td>--</td>
<td>--</td>
<td>--</td>
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<td>--</td>
</tr>
<tr>
<td>2. Income</td>
<td>0.635*</td>
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<tr>
<td>3. Employed</td>
<td>0.239*</td>
<td>0.399*</td>
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<tr>
<td>4. Education</td>
<td>0.167*</td>
<td>0.205*</td>
<td>0.213*</td>
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<tr>
<td>5. Car ownership</td>
<td>0.239*</td>
<td>0.264*</td>
<td>0.312*</td>
<td>0.188*</td>
<td>--</td>
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<table>
<thead>
<tr>
<th>Chronic stressors indicators</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
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<tbody>
<tr>
<td>6. Perceived stress</td>
<td>-0.054*</td>
<td>-0.120*</td>
<td>-0.016</td>
<td>0.010</td>
<td>-0.019</td>
<td>--</td>
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<tr>
<td>7. Food insecurity</td>
<td>-0.083*</td>
<td>-0.117*</td>
<td>-0.057</td>
<td>-0.060</td>
<td>-0.054</td>
<td>0.301*</td>
<td>--</td>
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<tr>
<td>8. Financial hardship</td>
<td>-0.022</td>
<td>-0.132*</td>
<td>0.068*</td>
<td>0.045</td>
<td>0.013</td>
<td>0.306*</td>
<td>0.324*</td>
<td>--</td>
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<tr>
<td>9. Perceived Safety</td>
<td>0.015</td>
<td>0.061*</td>
<td>-0.018</td>
<td>0.010</td>
<td>-0.030</td>
<td>0.120*</td>
<td>0.068*</td>
<td>0.021</td>
</tr>
<tr>
<td>10. Neighborhood Incivilities</td>
<td>-0.041</td>
<td>-0.085*</td>
<td>-0.036</td>
<td>-0.157*</td>
<td>-0.067*</td>
<td>0.024</td>
<td>0.070*</td>
<td>-0.053</td>
</tr>
<tr>
<td>11. Pests</td>
<td>0.012</td>
<td>0.014</td>
<td>0.071*</td>
<td>0.004</td>
<td>0.004</td>
<td>0.120*</td>
<td>0.133*</td>
<td>0.036</td>
</tr>
<tr>
<td>12. Mold</td>
<td>0.057</td>
<td>0.096*</td>
<td>0.063*</td>
<td>0.100*</td>
<td>0.100*</td>
<td>0.028</td>
<td>0.089*</td>
<td>0.095*</td>
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<tr>
<th>Health behavior Outcome</th>
<th>13</th>
</tr>
</thead>
<tbody>
<tr>
<td>13. Current smoking status</td>
<td>-0.105*</td>
</tr>
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*p-value < 0.05, *p-value = 0.10
Model building

Alone, the SES factor indicated good model fit ($\chi^2 (4, \text{N}=828) = 4.42, \text{p}=0.35; \text{CFI}=1.00; \text{RMSEA}=0.01 \text{ 90\% CI:0.00-0.06}$) and each indicator had a factor loading of 0.40 or higher. Income and poverty status were allowed to co-vary in the model since the income variable directly informed the coding of the poverty status variable.

For the chronic stress latent variable, the initial model was not a good fit to the data. As shown in Figure 1.1, the initial 2nd order factor model was hypothesized to have three first order factors including a: psychological factor with indicators perceived stress as a scale where the individual items were added, financial hardship, and food insecurity; an external environment factor with neighborhood incivilities and perceived safety as indicators; and an internal environment factor with pests and mold as indicators. In this model, the mold indicator had a loading below 0.30. Additionally, perceived stress was parcelled, or included as a scale, as some methodologists recommend, but had a high residual variance. The poorly fitting indicator, high residual variance and two first order factors with only two indicators made the model slightly unstable.

Therefore, we created a new 2nd order factor model that did not parcel perceived stress and included it as its own factor where each individual item was an indicator, psychological remained a factor with financial hardship and food insecurity as indicators and the final factor was renamed environment to reflect the outside and inside factors. It included neighborhood incivilities, perceived safety, pests, and mold. Mold ultimately was removed from this factor as well because of a factor loading below 0.30. The final chronic stress higher order factor was a good conceptual fit and good fit to the data ($\chi^2 (24, \text{N}=828)=74.51, \text{p}<0.001; \text{CFI}=0.93; \text{RMSEA}=0.05 \text{ 90\% CI:0.04-0.06}$). Figure 1.2 shows standardized estimates of the final conceptual model, note that all indicators resulted in statistically significant factor loadings above 0.30 and most much higher ($\lambda=0.31$-0.85).
Structural Equation Model

These two latent variables (socioeconomic status and chronic stress) were brought together into a structural equation model with smoking status as the observed binary outcome. The structural model fit reasonably well ($\chi^2$ (122, N=823)=226.84, p<0.001; CFI=0.91; RMSEA=0.03 90% CI:0.03-0.04). Figure 1.2 shows that SES was significantly and inversely related to smoking status (standardized structural coefficient= -0.31, p<0.001) and inversely but not significantly related to chronic stress (standardized structural coefficient= -0.09, p=0.21) controlling for age, nativity, and sex. Chronic stress was significantly and positively associated with smoking status (standardized structural coefficient= 0.31, p<0.001). However, the indirect path was not statistically significant overall (standardized structural coefficient= -0.02, p=0.25; Table 1.3. All analyses controlled for age, nativity, and sex.
Table 1.3. Direct and indirect effects of the association of SES, chronic stress and smoking status.

<table>
<thead>
<tr>
<th></th>
<th>Estimate</th>
<th>S.E.</th>
<th>p-value</th>
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<tbody>
<tr>
<td>Total direct Status → Current smoking</td>
<td>-0.31</td>
<td>0.06</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Total indirect Status → Stress → Current smoking</td>
<td>-0.02</td>
<td>0.02</td>
<td>0.251</td>
</tr>
<tr>
<td>Total effect</td>
<td>-0.33</td>
<td>0.05</td>
<td>&lt;0.001</td>
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DISCUSSION

Within this sample of low-income housing residents, we found that chronic stress did not significantly mediate the relationship between SES and smoking status though it might prove to be a significant mediator with slightly more variability in SES. We did find a moderate inverse association between SES and smoking consistent with the tobacco literature. Additionally, chronic stress was positively associated with smoking status as expected and consistent with previous studies that lend credence to the idea that multiple types of stressors (objective, subjective, individual, neighborhood, environmental) impact health-related behavior, particularly smoking.

What’s more, some of our findings are similar in magnitude to Businelle’s (2010) longitudinal study which reported that those of low SES have an increased probability of smoking at week 4 follow-up (standardized coefficient= -0.38) as compared to our observed standardized coefficient= -0.31. Worth noting is that while not statistically significant the magnitude of our indirect association of SES on smoking through stress is identical to the statistically significant indirect effect of SES on smoking Businelle identified as traveling through the joint effects of social support, neighborhood disadvantage, negative affect/perceived stress, agency, and craving (standardized coefficient= -0.02).

Finally, although literature suggests that there is variation among the relationship between SES indicators and any one health outcome, we found it surprising that car ownership was so weakly related to financial hardship. This might be a testament to the extensive public transportation system in Boston or a challenge to public health practitioner’s assumptions of what constitutes socioeconomic status and stress in underserved communities.
Overall, research supports our results. There is evidence from a cross-sectional study that financial stress was associated with a 13% decrease in the odds of cessation among Australian adults (OR=0.87 95% CI=0.79-0.96) adjusting for age, income, education, and occupation. Moreover, respondents of the MIDUS study reporting higher stress at baseline and 10-year follow-up had higher odds of being a persistent smoker for 6 of 9 psychosocial stressors independently investigated, including financial stress (OR=1.64 (95% CI=1.19-2.25). Interestingly, in the MIDUS study, neighborhood stress as measured by a 4-item scale evaluating safety and trust in the neighborhood was not significantly associated with persistent smoking or quitting.

In our HIC study, our environmental factor capturing neighborhood indicators had the lowest association of the three chronic stress factors ($\lambda_{\text{environmental}}=0.45$ vs. $\lambda_{\text{PSS}}=0.80$ and $\lambda_{\text{psychosocial}}=0.91$). This suggests they may not be tightly linked to decisions to continue smoking or to quit or that qualitative work might be needed to identify more salient indicators of neighborhood stress. Unlike MIDUS and the cessation study, HIC did not limit respondents to English speakers allowing for a greater understanding of how these constructs work in a racially and ethnically diverse sample and as such it makes great contribution to the literature.

Limitations

This study has limitations that should be considered. First, it is cross-sectional data, therefore we are unable to infer causality. While we impose a temporal ordering of events in mediation studies, this is largely conceptual in cross-sectional studies and reverse causation is always possible. However, considering this is an adult sample, it is reasonable to assume that some of the static variables that compose the SES latent variable (e.g. education) are operating prior to development of psychosocial stress. There is also some evidence that the strongest potential for reverse causation among income and health is for the elderly.

In addition, this study focused on current tobacco use status, and did not examine the relationship of SES and stress to other indicators of tobacco use, such as amount smoked or success with quitting, which may be more temporally related to these variables than current smoking status. In a post hoc
analysis, we found that neither SES nor chronic stress were significantly related to number of cigarettes per day. This might be due to the fact that 50% of smokers in the HIC study smoke 10 or less cigarettes per day.

Furthermore, a restricted range among the SES indicators might pose a threat to the internal validity of the study. For instance, only 13% of residents reported being in the highest income category, making roughly $39,000+ annually. This figure, is much lower than $87,317, the median family income for the Boston metro area, an area where utilities and medical care are over 20% higher than the national average. Moreover, there might not be qualitative differences between education categories if a resident who dropped out of grade school has a similar experiences as a resident who dropped out in high school. In this instance, our results would be a conservative estimate of the relationships seen since they would be attenuated.

Another possible limitation is the 49% response rate. However, participation in surveys can vary based on nature of the actual building and geographical location. Additionally, in clusters such as housing developments it can vary based on number of families in each building. For our study, this response was typical of other Boston metro area public housing interventions using similar sites.

Lastly, we did not examine all of the mediators that could possibly lie on the path between SES and smoking and there may be a potential for unmeasured confounding and as a largely female, immigrant population of low-income residents these findings might not be generalizable to communities outside of Boston.

**Strengths**

Despite these methodological challenges, this study has several important strengths. To our knowledge, this study is the first to examine how a range of stressors co-vary as a mediator in the relationship between socioeconomic status and smoking. Additionally, this is the first study seeking to understand smoking patterns among low-income housing residents as a function of the social context. This population is more likely to continue harmful smoking behaviors and it is important to understand
this might be more than a personal choice, and potentially a result of the patterning of SES and stress in underserved communities.

In addition, this study uses a variety of assessments including residents’ perceptions through self-report and systematic objective measures of the neighborhood and direct assessment of the housing environment allowing for data triangulation. These complicated constructs were also not assumed to be measured without error. Finally, we deliberately chose to identify socioeconomic indicators, psychosocial stressors, neighborhood and environmental stressors that could be targeted by community-based organizational and policy change strategies to reduce inequalities in cancer.

CONCLUSION

In this data, stress is a weak mediator between low SES and smoking. Nonetheless, stress proved to have a significant effect on smoking that supports its role patterning health behaviors. Stress is generally treated in the literature as an individual process and smoking as a poor behavioral choice. However, our results show that smoking is at least partially patterned by social structures related to SES and stress though they might act through different pathways.

The progress and potential of public health’s behavioral interventions have been well documented and extremely successful in reducing the number of current smokers by more than half. However, if we want to stop the marked inequities that are developing amongst those at the lowest levels of SES, public health practitioners will have to examine health and behaviors in their social context and directly address the social determinants that pattern health.

Next steps should: utilize an intersectional approach to examine how these relationships vary across different racial/ethnic/sex groups; identify if other neighborhood measures such as access to services or tobacco advertising are more suitable neighborhood indicators; qualitatively investigate what counts as psychosocial and perceived stress across communities; and ascertain if discrimination might also be a moderator of this relationship.

Study acknowledgements

The authors thank Cambridge, Somerville, and Chelsea Public Housing authorities for their assistance; the 20 low-income housing sites that participated in this research; and the administrative and
field staff at the Harvard School of Public Health and Dana-Farber Cancer Institute for their contributions to this project. A special thanks to the residents who patiently answered survey questions and allowed staff into their homes. They also thank Lorraine Wallace and Linnea Benson-Whelan for helpful and meticulous note and record keeping post study implementation. The authors declare they have no financial conflicts of interest.
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Paper 2: The social context of obesity among low-income housing residents: 
What is the role of stress?

Kia L. Davis, MPH, Laura D. Kubzansky, PhD, MPH, Ichiro Kawachi, MD, PhD, Glorian Sorensen, PhD, MPH
INTRODUCTION: Obesity is the second leading cause of death in the United States and takes a toll on human and economic capital. Evidence suggests that obesity is patterned by socioeconomic status (SES) indicators but the role of stress, an oft proposed mediator in SES health inequities, is unclear. Therefore, the aim of this paper was to assess the relationship between SES, chronic stress, and obesity status and ascertain whether chronic stress was a mediator in the SES-obesity relationship.

METHODS: Data were from a cross-sectional sample of racially/ethnically diverse adults from the Health in Common study in low-incoming housing in the Boston metropolitan area (n=828). We conducted structural equation modeling adjusting for age, sex, and nativity since SES and chronic stress were conceptualized as latent variables.

RESULTS: Residents with higher chronic stress had a higher probability of being obese (standardized coefficient=0.13, p<0.05). SES was not significantly associated with obesity or chronic stress resulting in no evidence for mediation.

CONCLUSION: Obesity is partially patterned by psychosocial stressors as well as stressors in the housing and neighborhood environment. Therefore, interventions that address obesity should consider some of the existing structural constraints that hinder weight loss or promote weight gain. More research needs to be done to identify the most salient stressors in this relationship.
INTRODUCTION

Obesity, a body mass index (BMI) greater than or equal to 30, continues to take a serious human and economic toll globally. It is associated with decreased quality of life (QOL), increased risk for diabetes, cardiovascular diseases, and some cancers, and is responsible for approximately 300,000 avoidable deaths in the United States (U.S.) each year. Additionally, there is a high economic impact including the estimated $147 billion spent in direct medical costs associated with obesity-related disorders in 2008. It affects a large portion of the population since more than two-thirds of U.S. adults were classified as overweight or obese and roughly 35% were obese in 2012.

Moreover, evidence suggests obesity is patterned by indicators of socioeconomic status (SES), sex, and race. A seminal review of the SES and obesity literature from the 1960s through the 1980s found that among women in developed societies, SES was inversely associated with obesity, regardless of the measure of SES or obesity used. Conversely, there was no consistent pattern between SES and obesity among men in developed societies. Almost 50 years after this review, this trend continues as the U.S. Centers for Disease Control reported that women without a college degree are more likely to be obese than women with college degrees; yet, education has no bearing on obesity status for men. Similarly, women with low-income are more likely to be obese than women with high-income; and interestingly, Hispanic and non-Hispanic Black men with higher incomes are more likely to be obese than their low-income counterparts and non-Hispanic black women have the highest prevalence of obesity at 48% overall.

Mechanisms influencing the relationship between SES and Obesity

Previous research has explored the factors that might explain the SES and obesity relationship. In their earlier review, Sobal and Stunkard proposed mechanisms for the relationships between SES and obesity including: attitudes towards obesity, diet, physical activity, social mobility, and values and beliefs around diet, exercise and obesity that are passed to younger generations. More recently research discusses energy balance, the idea that your body must find an equilibrium between energy intake (diet), expenditure (physical activity), and metabolism to impact obesity. There has also been attention...
showing that some of the differences seen in SES could be due to differences in social ties whether through social norms and perceptions of what is an ideal body size\textsuperscript{114} or behavioral imitation\textsuperscript{115}.

Although much attention has been given to how individual factors shape obesity, research has also explored a range of social determinants as well\textsuperscript{116}. These findings intersect with built environment studies because of overlaps in some of the measures. Socioeconomically disadvantaged and racially segregated neighborhoods have up to 2.5 times the density of fast food outlets\textsuperscript{117} and are a farther distance from the closest neighborhood store\textsuperscript{118} than more advantaged neighborhoods. Local food environments with higher densities of fast food outlets and convenience stores have a higher proportion of overweight and obese residents than neighborhoods with grocery stores and more healthy food options\textsuperscript{119, 120}.

In addition to food access, neighborhoods’ strongest link to obesity related risk factors have been shown in relation to plans for physical activity and safety\textsuperscript{121}. Evidence supports the association of built environment factors such as walkability and physical activity\textsuperscript{122}. Furthermore, neighborhood disorder, and neighborhood and housing quality affect residents’ perceptions of safety potentially creating another path to physical activity\textsuperscript{123, 124}. Indeed perceived neighborhood indicators such as perceived safety as well as objective indicators are linked to obesity, potentially through physical activity participation\textsuperscript{125}.

Moreover, some material factors are associated with obesity. For example, poverty and food insecurity are examples of being without substantial resources and also direct products of low SES, including having little income and perhaps low education. An early case study first described the hunger-obesity paradox in a child where it was hypothesized that hunger was linked to obesity either through eating low-cost, energy dense foods to achieve satiety or as the body’s adaptive response to periods of no food\textsuperscript{126}. A review provided further evidence that food insecurity, or when the availability of nutritionally adequate food or the ability to secure such food is limited or impossible, leads to increased rates of obesity among adult women, particularly women of color\textsuperscript{127}.

These social, structural, and economic constraints act as structural issues that pattern obesity. It is important to note that these constraints are demands that could result in feeling overwhelmed. If the demands persist over time, they act as chronic stressors that systematically prohibit people from acting on
health information or result in an emotional or biological response. Identifying these structural constraints as stressors is in line with Pearlin’s (1989) stress theory that recommends locating individual behavior within the social structures that pattern and produce these behaviors. Research suggests this framing may be particularly salient for obesity where insecurity and stress have been found to increase the desire for high-fat and high-sugar foods that are readily available and usually low-priced.

The current study

This current study builds on previous research to examine the role of stress in the relationship of SES and obesity in a sample of low-income housing residents in the Boston metropolitan area. Specifically, we will examine how the latent variable of chronic stress mediates the relationship between SES and obesity (Figure 2.1). We will use structural equation modeling (SEM) methods to assess this relationship. We hypothesize that lower SES and higher stress will be positively associated with obesity.

![Figure 2.1 Initial conceptual model of socioeconomic status, chronic stress, and obesity](image)

METHODS

All research protocols were approved by the institutional review boards at the Dana Farber Cancer Institute and the Harvard T. H. Chan School of Public Health.
**Data source**

This is a secondary data analysis using the Health in Common Study (HIC), a cross-sectional study that investigated physical and social determinants of cancer risk among 828 low-income housing residents in the Boston, MA metropolitan area (Cambridge, Somerville, and Chelsea). Multi-stage cluster sampling was used where households were selected within developments and one adult aged 18+ was selected from recruited households to be interviewed. Data were collected from housing developments with a minimum of 40 units from February 2007 to June 2009. Low-income housing classification was based on the Department of Housing and Urban Development (HUD)’s guidelines. Across all developments, 49% of residents responded. For further study details see Adamkiewicz, Harley, and Sorensen.

**Data collection**

There were multiple data collections including individual level surveys, household environmental assessments, and neighborhood assessments. Resident surveys measured individual-level information on cancer risk behaviors, social status, stress, environmental exposures, and sociodemographics. Height and weight measurements were also recorded during the interview by study staff. Trained bilingual research assistants conducted these 45-60 minute surveys in the residents’ household in English (53.7%), Spanish (26.7%) and Haitian Creole (19.6%).

Environmental assessments were 15-20 minutes and conducted in each resident’s household to collect data on environmental exposures. Staff were trained to identify elements of the household environment that might result in indoor environmental exposures such as signs of mold or live pests. Lastly, neighborhood assessments collected data on the physical and social disorder of the neighborhood by systematic social observations. Trained study staff conducted systematic social observations at each housing development by using a checklist to record observations on people’s activities, the physical environment, and social interactions during a 15-20 minute walkthrough. All assessments were performed during daylight hours.
Measures

**Obesity.** Height and weight were measured directly. Body mass index (BMI) was calculated by dividing weight in pounds by height in inches squared and multiplied by a conversion factor of 703\(^{15}\). A BMI of 30 or above was considered obese.

**Socioeconomic status.** Socioeconomic status was conceptualized as a latent variable to represent a person’s socioeconomic position in a society. The social economic status indicators were measured by self-report and included: car ownership; education; weekly income; poverty status; and employment. For education, residents born outside of the continental United States (U.S.) reported years of school attended and those who attended school in the U.S. reported grades attended. These values were combined to create response categories: less than high school, some high school, high school graduate, more than high school. Residents indicated their weekly household income before taxes and the interviewer marked the appropriate response category from the following options: $0-$100, $101-$250, $251-$500, $501-$750, >$750. There were four response categories above the $501-750 range, which were collapsed to $750+ due to insufficient cell sizes. SES was coded so increasing values indicate higher status.

Household composition and income were used to determine poverty status by comparing to the U.S. Census Bureau’s 2008 definition and residents were deemed not in poverty if they were above the threshold and in poverty if they were below the threshold because of the lack of variability above the poverty threshold\(^{57}\). Residents categorized as unemployed responded that they did not work at a job for pay and residents who responded they did work at a job for pay were employed. Car ownership was ascertained by asking if anyone in the household owns a car, van, truck, or motorcycle that runs (yes/no). SES indicators were adapted from the Moving to Opportunity Study (MTO),\(^{82}\) coded similarly to previous analyses of this work\(^{63,78,79}\) and coded so that increasing values signified higher SES.

**Chronic stress.** Chronic stress was also conceptualized as a latent variable to represent socially patterned stress that could persist over time. Its indicators were perceived stress, psychosocial stress (financial hardship and food insecurity) and environmental stress (perceived safety, neighborhood incivilities, and presence of pests). Perceived stress was assessed by Cohen’s abbreviated 4-item
perceived stress scale on the resident survey. Residents were asked: In the last month: How often have you: 1) Felt you were unable to control the important things in your life? 2) Felt confident about your ability to handle your personal problems? 3) Felt that things were going your way and 4) Felt difficulties were piling up so high that you could not overcome them? The response categories were: never-coded as 1, rarely-coded as 2, sometimes-coded as 3, and often-coded as 4. Questions 2 and 3 were reverse coded so that for each item, a higher number meant more stress.

The psychosocial stress variables asked residents about their food availability and financial hardship. “In general, how do you find your household’s finances usually work out at the end of the month?” was used to ascertain financial hardship. Is there some money left over, just enough to make ends meet, or not enough to make ends meet. Similarly to other studies, response categories for this variable were dichotomized to some money/just enough money versus not enough to make ends meet. The food insecurity was adapted from the Household Food Security Scale and assessed if in the past 12 months, there was ever at time when there wasn’t enough food? (yes/no).

Environmental stress was determined by exposure to mold and pests, perceived safety, and neighborhood incivilities. Perceived safety questions were adapted from the MTO study that asked whether residents felt very safe, safe, unsafe, or very unsafe on the streets around the complex during the day, at night, and in common area of the apartment complex. Very safe and safe responses were coded as 0 and safe and unsafe responses were coded as 1.

Data collectors identified neighborhood incivilities by systematic observations where they indicated if the following was visible on the interior grounds, foot paths, yards, and/or parking lots: 1) empty beer containers or liquor bottles 2) trash, litter, junk, or broken glass 3) cigarette or cigar butts or cigarettes or cigars 4) needles, syringes, condoms, or drug-related paraphernalia, and 5) graffiti on buildings, sidewalks and signs on the building grounds or in the parking lots with response categories: none, very little, some, and a lot. Each answer of none or very little was coded as 0 and some and a lot was coded as 1. Because of the ubiquitous presence of trash and cigarette butts, these items were summed and dichotomized to people who indicated there were two or fewer versus all others. These incivilities
were selected and measured consistent with previous research on which indicators of physical disorder impact health. Residents were determined exposed to pests if (a) they reported seeing rats or bedbugs a few times a year or more or (b) they reported seeing cockroaches, ants, mice frequently a few times a month or more.

Residents were classified as exposed to mold if (a) mold was reported as seen or treated by the resident or (b) if mold was seen during the environmental assessment during the time of the survey. Mold, pests, and other indices were collected to consider the impact of indoor environmental exposures on health. For our study purposes we only use the mold and post index. They have performed as expected where for example, the pest index was associated with a chemical exposure index (not used in this analysis) where presumably pesticide usage was high in order to get rid of pests and where an inadequate ventilation index (not used in this analysis) was associated with the mold index which is consistent with knowledge around poor bathroom ventilation sometimes resulting in mold growth. For a more in-depth discussion of indices see Adamkiewicz et al and Sorensen et al. Chronic stress indicators were coded so that increasing values signified more chronic stress.

Covariates. We adjusted the model for sex (male/female); nativity (born in the continental U.S./not born in the continental U.S.); and age (split into normally distributed categories of 18-29, 30-39, 40-49, 50-59, 60+).

Analytic strategy

All descriptive statistics were evaluated in SAS version 9.3 (Cary, NC). Chi square tests were conducted to determine if there were differences in obesity prevalence by group. Spearman correlations were obtained for dichotomous and ordinal variables to examine inter-correlation of all indicator variables and the outcome variable for non-linear data. To simultaneously analyze the hypothesized relationships among study variables, we evaluated a structural equation model using MPlus version 7.1. Each latent variable was evaluated separately in a measurement model that related the indicators (measures) to the latent variable. Any modifications made to the model were driven by theory and conceptual model to improve fit. Once both measurement models showed good fit, they were brought
together in a structural model that related the latent variables to each other and the outcome, a manifest variable. Traditional fit indices used to determine model fit including; the Chi-square, Bentler Comparative Fit Index (CFI), and the Root Mean Square Error of Approximation (RMSEA).

Though a non-significant $\chi^2$ is desired, this value is highly sensitive to large sample sizes (over 400) and multivariate non-normality. Generally CFI values of 0.90 or above indicate good model fit though this is also sensitive to large sample sizes. The RMSEA is less sensitive to sample size with an ideal estimate less than or equal to 0.05, and a tight confidence interval with an upper bound less than 0.10.

Since using categorical indicators, weighted least squares with robust standard errors (WLSMV) was used to estimate the free parameters. The “CLUSTER” and “TYPE=COMPLEX” commands were used to account for the residents being clustered within housing developments. By default, MPlus calculated probit regression estimates since the outcome was dichotomous and WLSMV estimation was used.

The HIC data set had little missing data. Of the residents missing the largest amount of data, 11% (n=92) were missing data on education. Of the missing education information, 88% were more likely to identify as female and 77% were more likely to be born outside of the continental U.S. For missing variables, MPlus assumes missing at random with respect to x and uses a methodology that estimates missing values using all variables in the dataset, for further details see Asparouhov (2010).

RESULTS

Sample characteristics

The demographic characteristics of HIC residents (n=828) by obesity status are shown in Table 2.1. Residents were more likely to be food secure, Hispanic women who owned cars, did not face financial hardship and were born in the continental U.S. Age was nearly evenly distributed though more residents were 30-39 years of age (26%). A slight majority of residents were confident about handling their problems (53%) and most residents reported seeing some or a lot of neighborhood incivilities (78%). About 40% of the sample was obese and had a BMI greater than or equal to 30 while 75% were overweight or obese having a BMI of 25 or more. Those who were obese were more likely to be
unemployed, non-Hispanic white women born in the continental U.S. and feel that difficulties were piling up.
Table 2.1. Characteristics of low-income housing residents in the Health in Common Study by obesity status (n=828)

<table>
<thead>
<tr>
<th></th>
<th>Not Obese</th>
<th>Obese</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>% of sample</td>
<td>%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>59.54</td>
</tr>
<tr>
<td>Age</td>
<td>825</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18-29 years</td>
<td>153</td>
<td>18.55</td>
<td>65.36</td>
</tr>
<tr>
<td>30-39 years</td>
<td>218</td>
<td>26.42</td>
<td>61.93</td>
</tr>
<tr>
<td>40-49 years</td>
<td>169</td>
<td>20.48</td>
<td>56.21</td>
</tr>
<tr>
<td>50-59 years</td>
<td>145</td>
<td>17.58</td>
<td>51.72</td>
</tr>
<tr>
<td>60+ years</td>
<td>140</td>
<td>16.97</td>
<td>61.43</td>
</tr>
<tr>
<td>Gender</td>
<td>828</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>659</td>
<td>79.59</td>
<td>55.54</td>
</tr>
<tr>
<td>Male</td>
<td>169</td>
<td>20.41</td>
<td>75.15</td>
</tr>
<tr>
<td>Race/Ethnicity</td>
<td>824</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hispanic</td>
<td>341</td>
<td>41.38</td>
<td>58.94</td>
</tr>
<tr>
<td>Non-Hispanic Black</td>
<td>316</td>
<td>38.35</td>
<td>60.13</td>
</tr>
<tr>
<td>Non-Hispanic White</td>
<td>93</td>
<td>11.29</td>
<td>52.69</td>
</tr>
<tr>
<td>Other</td>
<td>74</td>
<td>8.98</td>
<td>66.22</td>
</tr>
<tr>
<td>Nativity</td>
<td>825</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Born in continental US</td>
<td>260</td>
<td>31.52</td>
<td>54.62</td>
</tr>
<tr>
<td>Born outside continental US</td>
<td>565</td>
<td>68.48</td>
<td>61.77</td>
</tr>
</tbody>
</table>

**Socioeconomic status indicators**

<p>| | | | | |
|                           |            |       |       |     |
| Employment Status         | 827         |       |       |     |
| Employed                  | 424         | 51.27 | 61.08 | 38.92 |</p>
<table>
<thead>
<tr>
<th>Table 2.1. (Continued)</th>
<th>N</th>
<th>%</th>
<th>Not obese</th>
<th>Obese</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unemployed</td>
<td>403</td>
<td>48.73</td>
<td>58.06</td>
<td>41.94</td>
<td></td>
</tr>
<tr>
<td>Income</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$0-$100 weekly</td>
<td>75</td>
<td>9.7</td>
<td>62.67</td>
<td>37.33</td>
<td>0.0941</td>
</tr>
<tr>
<td>$101-$250 weekly</td>
<td>236</td>
<td>30.53</td>
<td>55.08</td>
<td>44.92</td>
<td></td>
</tr>
<tr>
<td>$251-$500 weekly</td>
<td>259</td>
<td>33.51</td>
<td>64.09</td>
<td>35.91</td>
<td></td>
</tr>
<tr>
<td>$501-$750 weekly</td>
<td>105</td>
<td>13.58</td>
<td>59.05</td>
<td>40.95</td>
<td></td>
</tr>
<tr>
<td>&gt;$750 weekly</td>
<td>98</td>
<td>12.68</td>
<td>50</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>Poverty status</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>In poverty</td>
<td>445</td>
<td>57.64</td>
<td>57.53</td>
<td>42.47</td>
<td>0.4488</td>
</tr>
<tr>
<td>Not in poverty</td>
<td>327</td>
<td>42.36</td>
<td>60.24</td>
<td>39.76</td>
<td></td>
</tr>
<tr>
<td>Education</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grade school</td>
<td>152</td>
<td>20.65</td>
<td>59.21</td>
<td>40.79</td>
<td></td>
</tr>
<tr>
<td>Some high school (HS)</td>
<td>123</td>
<td>16.71</td>
<td>52.85</td>
<td>47.15</td>
<td></td>
</tr>
<tr>
<td>HS graduate</td>
<td>200</td>
<td>27.17</td>
<td>56.5</td>
<td>43.5</td>
<td></td>
</tr>
<tr>
<td>&gt;HS</td>
<td>261</td>
<td>35.46</td>
<td>65.9</td>
<td>34.1</td>
<td></td>
</tr>
<tr>
<td>Car Ownership</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>430</td>
<td>52</td>
<td>61.16</td>
<td>38.84</td>
<td>0.3084</td>
</tr>
<tr>
<td>No</td>
<td>397</td>
<td>48</td>
<td>57.68</td>
<td>42.32</td>
<td></td>
</tr>
</tbody>
</table>

**Chronic stress indicator**

Perceived Stress Scale indicators

<table>
<thead>
<tr>
<th>Unable to control important things</th>
<th>N</th>
<th>%</th>
<th>Not obese</th>
<th>Obese</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Never</td>
<td>279</td>
<td>33.78</td>
<td>65.59</td>
<td>34.41</td>
<td></td>
</tr>
<tr>
<td>Rarely</td>
<td>136</td>
<td>16.46</td>
<td>60.29</td>
<td>39.71</td>
<td></td>
</tr>
<tr>
<td>Sometimes</td>
<td>265</td>
<td>32.08</td>
<td>58.11</td>
<td>41.89</td>
<td></td>
</tr>
<tr>
<td>Table 2.1. (Continued)</td>
<td>N</td>
<td>%</td>
<td>Not obese</td>
<td>Obese</td>
<td>p-value</td>
</tr>
<tr>
<td>--------------------------------------------</td>
<td>-----</td>
<td>-------</td>
<td>-----------</td>
<td>--------</td>
<td>---------</td>
</tr>
<tr>
<td>Often</td>
<td>146</td>
<td>17.68</td>
<td>49.32</td>
<td>50.68</td>
<td></td>
</tr>
<tr>
<td>Confident about handling problems</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Never</td>
<td>48</td>
<td>5.83</td>
<td>59.5</td>
<td>40.5</td>
<td>0.1134</td>
</tr>
<tr>
<td>Rarely</td>
<td>65</td>
<td>7.9</td>
<td>57.51</td>
<td>42.49</td>
<td></td>
</tr>
<tr>
<td>Sometimes</td>
<td>273</td>
<td>33.17</td>
<td>72.31</td>
<td>27.69</td>
<td></td>
</tr>
<tr>
<td>Often</td>
<td>437</td>
<td>53.1</td>
<td>52.08</td>
<td>47.92</td>
<td></td>
</tr>
<tr>
<td>Felt things were going your way</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.953</td>
</tr>
<tr>
<td>Never</td>
<td>95</td>
<td>11.5</td>
<td>60.26</td>
<td>39.74</td>
<td></td>
</tr>
<tr>
<td>Rarely</td>
<td>123</td>
<td>14.89</td>
<td>59.63</td>
<td>40.37</td>
<td></td>
</tr>
<tr>
<td>Sometimes</td>
<td>374</td>
<td>45.28</td>
<td>59.35</td>
<td>40.65</td>
<td></td>
</tr>
<tr>
<td>Often</td>
<td>234</td>
<td>28.33</td>
<td>56.84</td>
<td>43.16</td>
<td></td>
</tr>
<tr>
<td>Felt difficulties were piling up</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.0079</td>
</tr>
<tr>
<td>Never</td>
<td>231</td>
<td>27.93</td>
<td>63.2</td>
<td>36.8</td>
<td></td>
</tr>
<tr>
<td>Rarely</td>
<td>183</td>
<td>22.13</td>
<td>59.56</td>
<td>40.44</td>
<td></td>
</tr>
<tr>
<td>Sometimes</td>
<td>251</td>
<td>30.35</td>
<td>63.75</td>
<td>36.25</td>
<td></td>
</tr>
<tr>
<td>Often</td>
<td>162</td>
<td>19.59</td>
<td>48.15</td>
<td>51.85</td>
<td></td>
</tr>
<tr>
<td>Psychosocial indicators</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Food insecure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>307</td>
<td>37.48</td>
<td>62.11</td>
<td>37.89</td>
<td>0.0463</td>
</tr>
<tr>
<td>No</td>
<td>512</td>
<td>62.52</td>
<td>55.05</td>
<td>44.95</td>
<td></td>
</tr>
<tr>
<td>Financial Hardship</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.8294</td>
</tr>
<tr>
<td>Yes</td>
<td>318</td>
<td>39.07</td>
<td>59.12</td>
<td>40.88</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>496</td>
<td>60.93</td>
<td>59.88</td>
<td>40.12</td>
<td></td>
</tr>
<tr>
<td>Table 2.1. (Continued)</td>
<td>N</td>
<td>%</td>
<td>Not obese</td>
<td>Obese</td>
<td>p-value</td>
</tr>
<tr>
<td>------------------------</td>
<td>-------</td>
<td>------</td>
<td>-----------</td>
<td>-------</td>
<td>---------</td>
</tr>
<tr>
<td><strong>Environmental stress</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neighborhood incivilities</td>
<td>828</td>
<td></td>
<td></td>
<td></td>
<td>0.8009</td>
</tr>
<tr>
<td>Some/a lot (2+)</td>
<td>647</td>
<td>78.14</td>
<td>59.85</td>
<td>40.15</td>
<td></td>
</tr>
<tr>
<td>None/very little (1-2)</td>
<td>181</td>
<td>21.86</td>
<td>58.95</td>
<td>41.05</td>
<td></td>
</tr>
<tr>
<td>Perceived safety</td>
<td>816</td>
<td></td>
<td></td>
<td></td>
<td>0.7649</td>
</tr>
<tr>
<td>Unsafe in at least one area</td>
<td>584</td>
<td>28.54</td>
<td>58.62</td>
<td>41.38</td>
<td></td>
</tr>
<tr>
<td>Safe/very safe</td>
<td>232</td>
<td>71.46</td>
<td>59.76</td>
<td>40.24</td>
<td></td>
</tr>
<tr>
<td>Presence of mold</td>
<td>827</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>443</td>
<td>53.57</td>
<td>56.98</td>
<td>43.02</td>
<td>0.1906</td>
</tr>
<tr>
<td>No</td>
<td>384</td>
<td>46.43</td>
<td>61.49</td>
<td>38.51</td>
<td></td>
</tr>
<tr>
<td>Presence of pests</td>
<td>828</td>
<td></td>
<td></td>
<td></td>
<td>0.7172</td>
</tr>
<tr>
<td>Yes</td>
<td>358</td>
<td>43.24</td>
<td>58.92</td>
<td>41.08</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>470</td>
<td>56.76</td>
<td>60.16</td>
<td>39.84</td>
<td></td>
</tr>
</tbody>
</table>
Bivariate analyses

Correlations between all observed variables are presented in table 2.2. The indicators of chronic stress are not all significantly correlated with the indicators of social status and some are inter-correlated with each other. The social status indicators are all significantly correlated with each other as expected. However, the magnitude of correlation for some indicators was lower than expected.
Table 2.2. Spearman correlation coefficients of observed study variables

<table>
<thead>
<tr>
<th>Social Status indicators</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Not in poverty</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>2. Income</td>
<td>0.635*</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>3. Employed</td>
<td>0.239*</td>
<td>0.399*</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>4. Education</td>
<td>0.167*</td>
<td>0.205*</td>
<td>0.213*</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>5. Car ownership</td>
<td>0.239*</td>
<td>0.264*</td>
<td>0.312*</td>
<td>0.188*</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Chronic stressors indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>6. Perceived stress</td>
</tr>
<tr>
<td>7. Food insecurity</td>
</tr>
<tr>
<td>8. Financial hardship</td>
</tr>
<tr>
<td>9. Perceived Safety</td>
</tr>
<tr>
<td>10. Neighborhood Incivilities</td>
</tr>
<tr>
<td>11. Pests</td>
</tr>
<tr>
<td>12. Mold</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Health behavior Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>13. Obesity</td>
</tr>
</tbody>
</table>

*p-value <0.05, † p-value =0.10, p-value<0.10**
Model building

The SES factor indicated good model fit ($\chi^2 (4, N=828)=4.42, p=0.35$; $\text{CFI}=1.00$; $\text{RMSEA}=0.01$ 90% CI:0.00-0.06) and each indicator had a factor loading of 0.40 or higher. Income and poverty status were allowed to co-vary in the model since the income variable directly informed the coding of the poverty status variable.

The initial chronic stress latent variable was not a good fit to the data. As shown in Figure 2.1, the initial 2nd order factor model was hypothesized to have three first order factors including a: psychosocial factor with indicators perceived stress as a scale where the individual items were added, financial hardship, and food insecurity; an external factor with neighborhood incivilities and perceived safety as indicators; and an internal factor with pests and mold as indicators. In this model, the mold indicator had a loading below 0.30. Additionally, perceived stress was parceled, or included as a scale, as some methodologists recommend, but had a high residual variance. The poor fitting indicator, high residual variance and two first order factors with only two indicators made the model slightly unstable.

Therefore, the new 2nd order factor model did not parcel perceived stress and included it as its own factor where each individual item was an indicator, psychosocial remained a factor with financial hardship and food insecurity as indicators and the final factor was renamed environment to reflect the outside and inside factors. It included neighborhood incivilities, perceived safety, pests, and mold. Mold ultimately was removed from this factor as well because of a factor loading well below 0.30. The final chronic stress higher order factor was a good conceptual fit and good fit to the data ($\chi^2 (24, N=828)=74.51, p<0.001$; $\text{CFI}=0.93$; $\text{RMSEA}=0.05$ 90% CI:0.04-0.06). Figure 2.2 shows standardized estimates of the final conceptual model controlling for sex, age, and nativity status.
Figure 2.2. Final model of standardized coefficients linking socioeconomic status, chronic stress, and obesity among low-income housing residents.

**Structural Equation Model**

The SES and chronic stress latent variables were brought into a model with obesity as a dichotomous variable. The structural model was a good fit to the data. The final chronic stress higher order factor was a good conceptual fit and good fit to the data ($\chi^2 (121, N=823)=227.111, p<0.001; CFI=0.90; RMSEA=0.03 90\% CI:0.03-0.04$). Note that after adding all control variables, neighborhood incivilities had a factor loading below 0.30 ($\lambda=0.29$); however, we kept it for improved model stability. Figure 2.2 shows that chronic stress was significantly and positively related to obesity as expected (standardized structural coefficient= 0.13, $p=0.03$); however, none of the other relationships were significant and the total effect of SES on obesity was miniscule (standardized structural coefficient= -0.001, $p=0.98$; table 2.3).
DISCUSSION

We believe this is the first study to assess the relationship between SES, chronic stress as measured by several stressors and psychosocial stressors, and obesity. The goal of our study was to understand how SES and stress patterns health and we found that chronic stress does in fact pattern obesity since the two variables were positively and significantly associated. However, chronic stress was not a significant mediator in the relationship between SES and obesity as we hypothesized. In fact, SES was not significantly associated with chronic stress or obesity and the total model effect was .001.

This was contrary to what was expected and not supported by the literature. Varying measures of the built environment and structural constraints will show varying association with the same outcome. However, since we used multiple indicators of each, it was surprising to see virtually no association. We would be remiss if we did not consider the limitation of our outcome, BMI is the most common measure of adiposity, but the actual distribution of body fat is highly variable where some people with high BMI don’t necessarily have the increased adiposity. There are other ways to determine body fatness such as skinfold thickness measurement and dual X-ray absorptiometry, but they are usually difficult to standardize the methodology or more expensive to conduct.

That said we considered two post hoc analyses to strengthen our methodological approach: 1) preserving power and using continuous BMI as an outcome, 2) using a dichotomous morbidly obese outcome since its prevalence in our sample is only 20% compared to the 40% of obese residents. Both these methods had similar null results. As a result, a study limitation is the lack of variability in the exposure and outcome which suggests this might be a type 2 error and not a true null finding.
Furthermore, the cross-section nature of this data prevents us from making any causal claims, it would not be prudent to state that the chronic stressors came before the obesity status. However, as a first of its kind analysis this is an interesting finding that is worth further study. While the association of chronic stress and obesity is significant, it is of substantially lower magnitude than a similar analysis I conducted with a different outcome (smoking) with similar paths from SES to chronic stress. Therefore, another potential limitation would be that differing measures of food insecurity lead to different relationships with obesity potentially attenuating the chronic stress obesity result that we found. It should also be noted that some would consider food insecurity as a mechanism by which material disadvantage impacts obesity and not psychosocial stress. Though we understand this point, we believe the inability to provide food for oneself could also lead to a stress response.

There are a number of strengths to our study as well. It occurred in a racially/ethnically diverse population allowing us to understand how stress patterns health in different communities. Another strength is the ability to execute SEM to simultaneously consider chronic stressors from multiple domains of influence such as psychosocial pathways, material deprivation, neighborhood (measured at the housing site level), and housing quality. This process allows me to explain the inter-relatedness of sociodemographic variables as opposed to just adjusting for an effect.

**CONCLUSION**

The latent variable chronic stress was significantly associated with measured obesity. However, the overall direct and indirect effects between other variables in the model were of modest magnitude and not significant. Though the obesity epidemic’s meteoric rise has seemingly halted, there is no sign of a reversal of trends as obesity prevalence has not significantly decreased over the past few years. This and the fact that no state met Healthy People 2010’s goal of obtaining a rate of obesity less than or equal to 15% suggests that obesity is a major problem and that continued monitoring and control efforts are warranted.

Furthermore, while the influence of individual level constructs related to obesity cannot be ignored, these factors largely frame obesity as an individual problem, ignoring social and physical
contexts in which behavioral decisions are made. It is important for public health practitioners to adopt a “health disparities perspective on obesity” examining multiple aspects of advantage and disadvantage at multiple levels to understand how these unfair differences are produced and understand their far reaching impact[17].

**Study acknowledgements**

The authors would like to thank each and every resident that answered our surveys and allowed the study team into their home. Additionally, we thank the 20 low-income housing sites that participated in this research; the Cambridge, Somerville, and Chelsea Public Housing Authorities for their assistance; and the administrative and field staff at the Harvard School of Public Health and Dana-Farber Cancer Institute. They also thank Lorraine Wallace and Linnea Benson-Whelan for helpful and meticulous note and record keeping post study implementation. The authors declare they have no financial conflicts of interest.
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Paper 3: A targeted systematic review and meta-analysis of the relationship between socioeconomic status and perceived stress: Is the evidence there?

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ABSTRACT

Introduction: In order for stress to be one potential mediator in the relationship between socioeconomic status and health it must be a consequence of SES. Yet, there is little literature explicitly testing this hypothesis, in particular as it relates to perceived stress.

Methods: We performed a targeted and systematic review of the literature and conducted a meta-analysis of the relationship between SES indicators education and income and perceived stress. We stratified analysis by SES indicator.

Results: Initial results yielded 100% heterogeneity for articles with estimates of the relationship between income and perceived stress. After we removed potentially problematic estimates for income, we found a 0.11 point difference in perceived stress score per standard deviation in income and a 0.13 point difference in perceived stress score per standard deviation difference in education.

Conclusion: Education is related to perceived stress and income is possibly related to perceived stress suggesting that it could be a mediator in the relationship between SES and health. More work needs to be done examining this relationship across population segments.
INTRODUCTION

Socioeconomic status (SES) whether measured by education, income, or occupation is often used interchangeably with social status and used in studies that aim to explain the distribution of death and disease in a society. The impact of SES on health has been formally studied since the 1800s; yet, the evidence supporting class effects on health dates back roughly to the 12th century. Earlier work focused at the lowest levels of SES indicating that those in poverty are at increased risk for infectious and chronic diseases, lower life expectancy, and higher mortality. Research in the 1980s shifted to how SES disparities exist across all categories of SES, revealing a gradient where stepwise decreases in SES generally correspond to incremental decreases in health.

The current phase of research focuses on the important task of understanding pathways that may account for the SES-health relationship. Exploring mediating mechanisms means that the proposed mechanism must 1) be a consequence of SES and 2) cause a health-related event. We know that physical and social environments partially explain how SES impacts health. For instance, physical and social environments are considered mediators since SES generally affects where people live, work, and play. Additionally, these environments determine the probability that individuals will be subjected to health damaging exposures from lead, carcinogens, and air pollution to violence, or a preponderance of fast food outlets with few, if any, grocery stores.

Another important hypothesized mediator of this relationship is psychosocial stress. Psychosocial stress is an imbalance between demands placed on a person and his or her ability to manage those demands. These demands, or stressors, act as a type of health damaging exposure that can be socially patterned and in turn, pattern population health and health behavior. Stressors can take the form of any unpleasant stimulus such as environmental demands, stressful life events, daily hassles, and can become sources of chronic stress if they persist over time.

Stressors exert their effect on health directly through biological alterations or indirectly through behavioral coping. Biologically, prolonged stress lowers immune functioning by activating the release of hormones. Immune system dysregulation increases the body’s susceptibility to infectious diseases, slows
wound healing, and could negatively impacting systems it interacts with including the central nervous system or endocrine system. Indirectly, stress operates through behavioral coping mechanisms that might lead people to consume food with high fat content or smoke as a way to alleviate the negative impact of stress.

In particular, perceived stress, or when a person assesses their demands and determines they are outside of his or her adaptive capacity, could be an important mediator. Research suggests it is the appraisal of stress as uncontrollable and unpredictable that has the most deleterious health effects. There are several measures of perceived stress including one of the most widely used, Cohen’s global perceived stress scale (PSS). Cohen’s PSS measures to what extent a person feels difficulties in general are piling up, they are able to control important things, and they are confident about handling problems among other things.

Yet, this important mediator remains understudied as demonstrated by a review examining how psychosocial factors mediate the relationship between SES and objective physical health outcomes (e.g. coronary artery disease, mortality). It found only 4 articles directly testing perceived stress as a psychosocial mediator and only 1 of the 4 studies saw a significant mediating effect. This South Korean cross-sectional study exploring the association of household income and excess mortality reported that controlling for a 1-item perceived stress measure and depression reduced excess mortality risk by 11%. More evidence is needed to directly evaluate the role of perceived stress as a mediator in the SES-health relationship.

Substantial literature supports the hypothesis that perceived stress causes poor health outcomes, linking perceived stress to a variety of mental and physical health outcomes. For instance, a cross-sectional study of over 12,000 individuals at worksites across Minnesota demonstrated that higher perceived stress was associated with poor health behaviors including a high-fat diet, being a current smoker, and a decrease in confidence to quit smoking. Next, a review showed that perceived stress precedes coronary heart disease in experimental animal models and longitudinal population health
Finally, another review demonstrated that stress-induced biological changes were associated with cognition and the development of mental health problems such as PTSD and depression.

More research needs to be done to show that stress can be a patterned response and a sequelae of some SES indicators since it is often discussed as an individual process which leads to proposed individualized solutions and victim blaming. Of the commonly used SES measures; occupation, education, and income; more evidence supports the relationship between SES, job stress, and health. Specifically, people from low SES backgrounds characterized by low educational attainment and blue collar work generally tend to have jobs characterized by heavy demands and low decisional latitude that result in more job stress or strain. Increased job stress has been directly linked to increased risk for poor cardiovascular outcomes and participation in poor health behaviors such as smoking.

Still, evidence elucidating the relationship between income and education with perceived stress is inconclusive and there has been little synthesis of available evidence, and no synthesis of direct measures of SES and perceived stress. Therefore, the aim of this paper is to conduct a targeted, systematic review of the literature on the relationship of education and income to perceived stress and to quantify this relationship. This review and meta-analysis will fill a void in the literature that presumes that lower levels of education and income lead to higher perceived stress and that this relationship is well documented.

**METHODS**

**Data sources and searches**

This meta-analysis protocol was developed and conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. It was not registered with any systematic review databases. A targeted, systematic review of the literature was conducted by searching PubMed and Sociological abstracts databases with key words: income or education or socioeconomic* AND perceived stress*. The asterisks represent multiple potential endings for the key words. The search results were not restricted by geographic location or start date. We did
restrict the search to population-based empirical studies and also manually searched the references lists of retrieved reviews. All articles published until March 2015 were included.

**Eligibility criteria and data extraction**

There was a sequential screening process based on standard meta-analysis and systematic review procedure. In the first phase of article screening, articles were included if they were peer-reviewed, quantitative articles in English, and had any of the keywords in the title. In the second screening phase, article abstracts were examined and articles were excluded if they did not directly assess: income or education as an exposure or covariate; or a measure of global stress as an outcome or intermediary. There were few adolescent studies (n=2) and the stress process for adolescents might be different than that for adults, so we restricted the population to adults. Additionally, special populations (e.g. pregnant women, clinical samples) whose reporting of stress might be situational were excluded. At each stage, all articles were screened consistently by one reviewer (K.L.D.). Studies also had to report standard errors and standardized regression estimates. No grey literature was included in this meta-analysis and no study authors were contacted.

The study team determined information to be extracted from each article for analysis. One study author extracted the following data from each article: study publication year, name of the first author, study design, geographical location where study was conducted, sample size and brief descriptive and demographic information about the sample. Information was also extracted related to: SES measure, stress measure, covariates adjusted for in the analysis, standardized regression coefficients, and standard errors. For studies reporting results for multiple models, only the results from the fully adjusted model were extracted. Similarly to previous studies, multiple estimates were extracted if separate effect sizes were reported within the same study for men and women or education and income. One study analyzed the association of education and income to perceived stress in three independent samples so a total of six estimates were obtained from this paper. Quality scores were not calculated for any study to avoid inducing bias due to the subjective nature of these assessments.
Data synthesis and analysis

We pooled standardized regression coefficients across all articles to be analyzed in order to have an estimate that was comparable in scale and units across studies. In the data used in Cohen’s study, an error of 0.00 was reported for all three of the income estimates. We substituted a small standard error, 1.00x10^-5, in order to use the estimated in the model. We then grouped and analyzed articles separately by SES measures education and income. There were not enough articles to analyze by sociodemographic variables of interest. Random effects modeling was utilized to account for within and between study differences. This analytic method employs inverse-variance weights to derive the overall effect estimate, giving higher weights to studies with increased precision as defined by larger sample sizes and more narrow confidence intervals. We obtained fixed effects estimates as well to qualitatively understand any observed heterogeneity.

Next, I² was calculated. It is a statistical test that determines if the observed differences across studies are true differences due to between study variation (heterogeneity of effect) or due to chance alone (homogeneity of effect). A non-significant p-value indicated homogeneity of effect or that differences across studies are more likely due to sampling error rather than a true difference in the effect of SES on perceived stress; I² values higher than 50% represent substantial heterogeneity. The test is robust in the face of a small number of studies. All analyses were conducted with STATA version 14.1 (StataCorp LP, College Station, TX)

RESULTS

A total of 962 unique articles were retrieved from our search, 909 were excluded based on a review of the title and abstract. Of the 53 that were selected for more detailed evaluation, the majority did not: provide the direct effect of SES on perceived stress (n=20), provide estimates for the SES measures (n=17), or include enough raw data to derive or transform effect estimates (n=6). Several studies included ineligible populations (n=7) and one used only a 1-item measure of stress which might not be comparable to the outcomes measured in the other studies. No unique articles were identified and coded based on reviews of citations. In total, 4 articles were retained for inclusion in the meta-analysis (Figure 3.1).
Figure 3.1. Flow diagram of studies included in meta-analysis of income and education and perceived stress through March 2015.

Study characteristics

Characteristics of the 4 included studies are presented in Table 3.1. One study was published in 1998 and the rest were published from 2008-2012. These studies are all cross-sectional and were conducted in the U.S. Sample sizes for the individual studies ranged from 124 to 2,387. The U.S. study
from San Diego focused on women aged 40-65 years old[67] and the other studies recruited respondents ages 18 or 19 and up and included both sexes.

Every included study measured perceived stress using Cohen’s Perceived Stress Scale (PSS); 2 articles used the 10-item PSS[67,69] one used the 4-item PSS[66] and another utilized a modified 11-item PSS[72]. All studies measured the exposures, income and/or education, as categorical variables and perceived stress as a continuous variable though the SES indicators were analyzed as continuous variables. Gallo (2013) only adjusted for age, Cohen (2012) adjusted for age and the other SES measure, Haritatos (2007) and Krannich (1998) adjusted for age and a host of other covariates.

The extracted estimates came mostly from middle to high income populations. Data from Cohen’s (2012) study examined nationally representative data from 1983, 2006, and 2009 where 38-56% earned over $50,000 annually and 46% of those in 1983 and more than 70% in 2003 and 2006 had some college education or more. Similarly, 54% of respondents had some college education or higher and 41% made $4,000 or more per month in Gallo’s (2013) study of Mexican-American women in San Diego. Participants from Haritatos’ (2007) community study of high SES immigrants were the most socio-economically advantaged where respondents reported that 82% were working on or had completed a professional degree and 51% had annual family incomes greater than $70,000. Conversely Krannich’s (1998) study of a 78% Mormon population in Utah reported that 40% made an annual income of less than $40,000. There was some racial/ethnic diversity with half the studies of mostly white populations and the rest of immigrants and Mexican-American women though this diversity did not reflect the racial/ethnic composition of the United States.
Table 3.1 Characteristics of cross-sectional studies that assessed the association between income and/or education and perceived stress through March 2015

<table>
<thead>
<tr>
<th>Study (Year)</th>
<th>Population (n)</th>
<th>Study Demographics</th>
<th>SES measure</th>
<th>Perceived stress measure</th>
<th>Covariates</th>
<th>Results</th>
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</table>
| Cohen et. al. (2012) | U.S. nationally representative 1983 telephone survey (n=2387) | Age: Mean=42.8, SD= 17.2  
Sex: 56% women  
Race/ethnicity: 81% White; 7% Black; 4% Hispanic; 2% Other; 6% missing  
Employment: 51% full time employed | Education and annual household income | Cohen's PSS-10 | 10 | age and education |
| | | | | | | B(edu)= -0.05*, se=0.13 adjusted for age and income  
B(income)= -0.12**, se=1.00E-4 adjusted for age and education |
| Cohen et. al. (2012) | U.S. nationally representative 2006 web-based survey (n=2,000) | Age: Mean=46.8, SD= 14.7  
Sex: 52% women  
Race/ethnicity: 86% White; 5% Black; 4% Hispanic; 3% Other; 3% missing  
Employment: 55% full time employed | Education and annual household income | Cohen's PSS-10 | 10 | age and education |
| | | | | | | B(edu)= -0.09**, se=0.18 adjusted for age and income  
B(income)= -0.05*, se=1.00E-4 adjusted for age and education |
| Cohen et. al. (2012) | U.S. nationally representative 2009 web-based survey (n=2,000) | Age: Mean=44.6, SD= 15.5  
Sex: 52% women  
Race/ethnicity: 85% White; 5% Black; 4% Hispanic; 4% Other; 2% missing  
Employment: 52% full time employed | Education and annual household income | Cohen's PSS-10 | 10 | age and education |
| | | | | | | B(edu)= -0.06*, se=0.18 adjusted for age and income  
B(income)= -0.12**, se=1.00E-4 adjusted for age and education |
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<tr>
<th>Table 3.1 (Continued)</th>
<th>Population (n)</th>
<th>Study Demographics</th>
<th>SES measure</th>
<th>Perceived stress measure</th>
<th>Covariates</th>
<th>Results</th>
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<tr>
<td><strong>Gallo et. al.</strong> (2013)</td>
<td>Mexican-American women aged 40-65 living in San Diego, CA, USA and able to read and write in English or Spanish (n=318)</td>
<td>Education: 54% Some college/college degree; Income: 41% &gt;$4,000/month</td>
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<td></td>
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<td>B(educ) = -0.20**, se=0.06</td>
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<tr>
<td><strong>Haritatos et. al.</strong> (2007)</td>
<td>First generation high SES Indian or Chinese immigrants living in the Midwestern, Western, Northeastern, or Southern U.S. (n=318)</td>
<td>Sex: 48% women; Race: 46% Chinese; 54% Indian; Education: 81.8% completed or working toward professional degree; Income: 51% $70,000+</td>
<td></td>
<td></td>
<td></td>
<td>B(educ) = -0.050, se=0.094</td>
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<tr>
<td>Study Demographics</td>
<td>SES measure</td>
<td>Perceived stress measure</td>
<td>Covariates</td>
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<td>Married or cohabitating adults living in 3 nonmetropolitan Utah communities (n=124)</td>
<td>Sex: 50% women</td>
<td>Annual household income</td>
<td>Age, religion, sex, unemployment, household size, life events, length of residence, town</td>
<td>B(income)= .003, se=.488</td>
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<td></td>
<td>Religion: 78% Mormon</td>
<td>modified version of Cohen's PSS (11 items)</td>
<td>economic satisfaction, health status</td>
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<tr>
<td></td>
<td>Income: 40% below $40,000</td>
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**p<0.001
*p<0.05
**Effect of education and income on perceived stress**

Based on 11 estimates from 4 studies, we found a small, statistically significant effect of SES on perceived stress such that on average, a one unit standard deviation change in SES was associated with a significant -0.11 change in perceived stress score (95% confidence interval (CI)=-0.12, -0.07; p<0.001) adjusting for various covariates (Figure 3.2). There was substantial and significant heterogeneity between studies ($I^2=100\%$, P for heterogeneity <0.001). When we stratified by SES measure, education remained significantly associated with perceived stress (standardized beta= -0.13, 95% CI=-0.22, -0.05; p<0.001) and there was no between study heterogeneity ($I^2=0\%$, P for heterogeneity =0.62). Income was significantly associated with perceived stress (standardized beta= -0.10, 95% CI=-0.14, -0.07; p<0.001) and between study variation was substantially and significantly large ($I^2=100\%$, P for heterogeneity <0.001).
Figure 3.2 Forest plot displaying overall effect estimates for education, income, and both socioeconomic status indicators on perceived stress
Sensitivity analyses

Large inverse variance weights were associated with the income estimates from Cohen’s studies, due to the large sample size and small error that was reported in his study. Since he reported 0.00, we decided to remove these three estimates and rerun the analyses. After removing the estimates: overall SES was significantly associated with perceived stress as measured by Cohen’s PSS (standardized beta= -0.11, 95% confidence interval (CI)=-0.13, -0.08; p<0.001) and there was so little heterogeneity between studies ($I^2=0\%$, $P$ for heterogeneity =0.625) the overall fixed and random effect estimates for education were the same (Figure 3.3). In the sensitivity analysis, income was significantly associated with perceived stress (standardized beta= -0.11, 95% CI=-0.15, -0.07; p<0.001) and between study variation was small and not significant ($I^2=9\%$, $P$ for heterogeneity =0.33).
Figure 3.3 Sensitivity analysis forest plot displaying overall effect estimates for education, income, and both socioeconomic status indicators on perceived stress
DISCUSSION

To our knowledge, this was the first review to directly assess the relationship between SES indicators, education and income, and perceived stress using meta-analysis methods. Based on a targeted review of the literature, we found that education and income separately and together are significantly and inversely associated with perceived stress controlling for sociodemographic variables. We also found that the magnitude of the relationship between education and perceived stress was slightly more than the magnitude of the relationship between income and perceived stress. These findings are consistent with the literature that suggest SES indicators may have different magnitudes of relationship with the same health outcome and potential inconsistent findings depending on type and level of measure used.

While these are significant findings, these estimates are of lower magnitude than expected and suggest that there may be other predictors of perceived stress that yield higher explanatory power. In the previous studies of low-income housing residents, the mean of perceived stress is 8.52 and the standard deviation is 2.67. Other studies show which variables might yield more explanatory power. For example, in one study, the extent to which race is one’s central identity and psychological distress were significantly and highly associated with perceived stress among young adults. Central showed a magnitude of twice that for the income-perceived stress relationship (standardized beta_{identity} = -0.24, p<0.05 and standardized beta_{distress} = 0.16, p<0.05). In another study perceived stress was determined to be a mediator in the relationship between HIV coping strategies and quality of life. Specifically, denial was positively and significantly associated with perceived stress (standardized beta= 0.29, p<0.05) and cognitive coping skills was negatively and significantly associated with perceived stress (standardized beta= -.32, p<0.001).

Furthermore, after observing substantial heterogeneity in the first analysis, we wanted to take extreme care in understanding the differences across studies. As a result, we removed three income estimates from the Cohen paper as potential sources of heterogeneity that were unlike the others since their standard errors were reported as zero. This action reduced the heterogeneity from 100% to 9% and the resulting estimates were of the same direction and similar magnitude as the first analysis. The
remaining studies are still quite different in terms of study size and demographics, but the applied weights are designed to help with some of those issues. The weighting process examines standard error and sample size to determine the more precise estimates and they are weighted more heavily.

Similar to previous studies, a sensitivity analysis demonstrated that substantial heterogeneity across studies does not necessarily lead to divergent results that would change the overall study conclusions. Results from both analyses provide evidence that perceived stress might mediate the SES-health relationship and support at least some of the study findings in Matthews (2010) review which reported an 11% reduction in excess mortality once perceived stress was controlled for in the study. They also provide a foundation for the idea that stress is not always an individual-level phenomenon and can be patterned in societies by sociodemographic characteristics among other things.

Limitations

A meta-analysis is only as strong as the articles included for analysis; therefore, there are some limitations worth mentioning. First, the majority of the studies were of high SES populations, reducing the range of variability among the exposure of interest. For instance, a great majority of respondents had college degrees, were employed, and had annual salaries of $50,000 or more. In the presence of this bias, our results are a conservative estimate of the true effect of education and income on perceived stress.

Next, all of the included studies are cross-sectional so we are unable to make conclusions about causality. However, all of the studies are of adults and most samples have mean ages of 30 or more indicating respondents achieved the bulk of their education before participating in the study and responding to questions about recent perceived stress.

A possible limitation is that the search terms were limited to try and delineate articles that would directly measure and report the associations of income and education with perceived stress, and might have missed some eligible articles as a result. To determine the degree to which this might be possible, study authors did a few searches using broader search terms and reviewed the first two pages of search results to determine if any relevant articles were overlooked and they found no relevant articles. This suggests that the likelihood of omitting relevant articles is low. Additionally, we did not formally test for
publication bias since we have only four articles. In order to be sufficiently powered, statistical tests of
symmetry, such as the funnel plot, should have at least 10 articles to perform the method.

Another possible limitation of the relatively high SES populations of mixed sex is that findings
might not be generalizable to the general public. Although this meta-analysis found that on average,
education and income are associated with a small change in perceived stress, these results might be
different with more samples that have more gender and racial/ethnic diversity. Though we are
underpowered to examine these differences, there is one study Gallo (2013) that reports estimates for
women only, the rest report estimates for women and men. For both education and income, the estimates
from the Gallo study are larger than any of the other studies and the overall effect estimate. This suggests
that women might report more perceived stress in men and is worth further investigation.

Finally, we must note the 100% heterogeneity that resulted when all articles with income
estimates were included in the analysis. This usually suggests that the articles and therefore their
estimates are so dissimilar, pooling estimates should not be attempted. After removing the three
potentially problematic estimates, the heterogeneity dropped to 9%; yet, with only three remaining
articles, we should interpret the results for income with caution.

CONCLUSION

Given that perceived stress has been shown to have deleterious health effects and this analysis
shows that changes in SES lead to miniscule changes in perceived stress it would appear that this is a
plausible mediator in the SES-health relationship, but perhaps with low explanatory power. More
intersectional analyses that examine this relationship within population segments that are diverse in terms
of socioeconomic status, racial and ethnic and sexual identities are needed to understand if and how
education and income influence perceived stress in populations more likely to experience a
disproportionate burden of death and disease. This is particularly important work to help develop
population health interventions and policies to reduce this unequal burden.

This study also shows the importance of reporting effect estimates for the relationship of “path a”
or in our case, SES on perceived stress in studies designed to examine if perceived stress mediates the
relationship between SES and perceived stress. This would have allowed the inclusion of several more studies in our analysis. These additional studies will increase the power for more thorough meta-analytic techniques where estimates can be summarized within and across multiple groups. Finally, we cannot underscore the importance of longitudinal studies to definitively establish temporality of the association.
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