Neighborhood environment, stress, and obesogenic behavior among adults

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ABSTRACT

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Background: Socio-ecologic models convey a conceptualization of how levels of environment surrounding individuals impact health behaviors and subsequent health outcomes. Neighborhood context, defined as area-level social or physical systems or structures, has been recognized as an important social determinant of many health outcomes across the lifespan. The overall goal of this dissertation was to evaluate the effects of worksite and home neighborhood contexts on biobehavioral pathways associated with stress. In particular, this dissertation evaluates whether workplace neighborhood context contributed to obesity-related behaviors, as most research to date has been in relation to the home neighborhood. It also examines how neighborhood contexts of the home and workplace influence levels of stress, a hypothesized pathway for the embodiment of contextual effects on chronic disease processes.

Methods: Chapters 1 and 2 used Promoting Changes in Activity and Eating (PACE) data, which included approximately 2400 individuals at follow-up within randomly selected smaller worksites in Seattle, to evaluate associations. Chapter 3 evaluated associations among 510 non-Hispanic white women in Seattle who represented a broad range of individual and neighborhood-level socioeconomic status (SES). Chapter 4 evaluated associations among 541 older professional white men and women within the British civil service. To evaluate neighborhood and individual-level associations, all analyses used models that

accounted for multiple sources of variance (i.e. random effects models, generalized estimating equations (GEE)) and included relevant covariates.

Results: We found in chapter 1 that higher worksite-level SES was significantly associated with more walking for at least 10 minutes in the previous week among employees. Built environment attributes were also significantly and independently associated with obesity-related behaviors. Specifically, higher residential density around the worksite was significantly associated with walking and eating 5 or more servings of fruits and vegetables, independent of worksite-level SES. More food and activity destinations as well as more intersections around the worksite were also significantly associated with more walking before accounting for worksite-level SES. We also found that higher residential density mediated the association of higher worksite-level SES with eating 5 or more servings of fruit and vegetables and with walking. Chapter 2 evaluated associations between social and built environment attributes surrounding worksites, perceived global and work-related stress, and C-Reactive Protein (CRP), a biomarker of inflammation that is associated with stress. We concluded that worksite context was not significantly associated with perceived stress or CRP in these data.. Worksite contextual variables were associated with work demands and worker social support, however, and these relationships varied by gender. Specifically, work demands varied significantly by both worksite-level SES and surrounding residential density among men. White-collar worksite class was also associated with fewer work demands and greater social support. Among women, a significant linear trend between higher residential density and greater work demands was demonstrated. Worker social support also varied significantly by residential density. Chapter 3 evaluated associations between home neighborhood SES and general perceptions of stress and found relationships which depended on individual-level SES. Specifically, measures of higher neighborhood SES were associated with lower stress among lower educated women whereas the opposite was suggested for higher educated women. Similar relationships were suggested when using family income as a measure of individual-level SES, albeit not as consistent. Strong associations between perceived neighborhood characteristics and stress were exhibited for all women. Specifically, greater neighborhood problems and dissatisfaction as well as lower perceived walkability were all highly significantly associated with greater stress. Chapter 4 evaluated associations between home neighborhood SES (i.e. income and employment deprivation), perceived neighborhood characteristics (i.e. social control, neighborhood threat, fear of crime), and stress reactivity (i.e. cortisol). Income and employment deprivation were significantly associated with lower social control, higher neighborhood threat and greater fear of crime after accounting for individual demographic characteristics. Fully adjusted models also indicated that higher levels of socioeconomic deprivation were associated with cortisol non-response, an indicator of a “blunted” cortisol profile which has been associated with chronic disease risk. Perceived

neighborhood characteristics were also significantly associated with cortisol non-response independent of individual-level demographic covariates. Mediation analyses indicated that the association between neighborhood SES and cortisol non-response was partially mediated by social control and neighborhood threat.

Conclusion: These studies contribute to the collective understanding of how environments may impact health behaviors and subsequent risk of disease among adults through the stress process. Importantly, findings indicate that multiple neighborhood contexts may be salient to biobehavioral processes associated with stress. Perceived measures of the neighborhood are important determinants of stress which not only work independently, but also mediate relationships between neighborhood-level SES and the stress process. These more modifiable factors may provide targets for addressing neighborhood disparities in health associated with stress.

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DEDICATION

To my family: Marc, Marlowe, and Jagger.

Chapter 1:
Worksite context and individual obesogenic behaviors among adults

ABSTRACT

Background: Understanding how area socioeconomic status (SES) affects the physical environment to influence health behaviors may provide additional avenues through which interventions can increase the probability of adopting and maintaining healthy behaviors. Most research has focused on relating aspects of the home neighborhood to obesogenic behaviors while less is known about how the neighborhood surrounding the workplace might impact these behaviors.

Objective: This study examined associations between worksite neighborhood context at baseline and obesogenic behaviors at follow-up among healthy working adults randomized to participate in Promoting Activity and Changes in Eating (PACE), a worksite-randomized trial of an intervention to prevent weight gain.

Methods: The main exposure examined was a worksite neighborhood measure of SES derived from worksite property values. Built environment attributes including residential density, food destinations, fitness destinations, and intersections were evaluated as mediators in relationships with self-reported activity and diet behaviors. Density measures were enumerated within a 0.5 mile buffer of worksites (N=26) via geocoded address at baseline. Behavioral data were collected at follow-up from n=1,100 employees who were present at baseline. Multi-level linear and logistic models were constructed adjusting for relevant covariates and accounting for clustering within worksites. Product-of-coefficients methods were used to assess mediation.

Results: Higher worksite-level SES was associated with walking for more than 10 minutes in the previous week (OR=1.15; 95% CI: 1.03, 1.29; p=0.010). This association remained for higher density of residential units surrounding worksites after accounting for differences in worksite-level SES (OR=1.84; 95% CI: 1.02, 3.33; p=0.043). Higher density of residential units surrounding worksites predicted eating 5+ daily servings of fruits and vegetables (OR=2.50; 95% CI: 1.27, 4.46; p=0.008) adjusted for worksite-level SES as well. Residential density surrounding worksites appeared to have a small mediating effect on the relationships between worksite-level SES and fruit and vegetable consumption as well as walking behavior. Other selected dietary and physical activity-related variables were not influenced by worksite contextual variables.

Conclusions: Worksite-level SES was directly associated with walking as well as indirectly associated with both fruit and vegetable intake and walking through increased residential density surrounding the

worksite. Residential density around worksites could be considered a measure of land-use mix in urban areas and may therefore be an important indicator of access to dietary and physical activity-related infrastructure. If verified by additional studies, this may represent a modifiable feature of the physical environment that could be manipulated to promote behavior change.

INTRODUCTION

Obesity is a major threat to the public's health because it has a substantial prevalence in the U.S. population and is associated with increased risk for chronic diseases including cardiovascular disease and cancer[1]. The body of evidence exploring links between obesity and obesity-related behaviors, such as physical activity and diet, and the social and physical (e.g. "built") environmental contexts in which those behaviors occur has increased substantially over the past decade. Most epidemiologic studies have assessed the impact of the social environment as defined by area socioeconomic status (SES) on obesity and related behaviors[2]. By aggregating socioeconomic information of individuals into geographic clusters, relationships between broader area-level SES and obesity[3-6] and weight gain[7] have also been demonstrated. Such analyses have drawn needed attention to economic and racial disparities in obesity, yet further work to uncover potential mechanisms explaining areal effects on obesity is needed to guide efforts to reduce such disparities. Evaluation of a possible mediating role of built environment attributes in the relationship between area-level SES and obesity-related behaviors is lacking. Filling this gap may suggest ways to address socioeconomic disparities in obesity via policy-level changes[8]. Understanding some of the processes underlying these associations may, therefore, further the evidence-base that suggests land-use practices may be promising obesity intervention strategies[9,10]. Such knowledge would help guide urban development and renewal programs toward "healthy public policy" while also identifying the degree to which land-use decisions associated with dietary and physical activity behaviors may impact health disparities.

Establishing causal relationships between the social and built environment (generally defined as structures and/or systems resulting from human activity) and obesity-related behaviors is challenging for several reasons. Many different constructs of the environment using various metrics have been associated with obesity-related outcomes. In the built environment literature, for example, "walkability" refers to the relative ease of walking to destinations based on proximity and directness of available routes[11,12]. However, many attributes of an area may influence walkability[13] and consensus as to which ones should be included and how they should be measured to score walkability has yet to be reached. Additionally, the type and scale of data used to compile these measures can vary by area and may influence the strength of association under study[14,15]. It is therefore likely that walkability measures in studies of different areas are not directly comparable. Increased specificity when making associations is also needed via more selected matching of built environment attributes to specific types of behavior to improve power to detect what may be small area-level effects[10,16]. Most studies to date have focused on the home built environment (i.e. area around household residence), although it is clear that individuals are regularly exposed to more environments, such as the workplace, with relevant environmental attributes[17]. Finally, and arguably most importantly, most studies of the built environment and health have been cross-sectional in nature, thereby barring any ability to draw inferential conclusions[10].

In spite of these limitations, we have learned much from previous studies of the built environment and health. For example, people who live in areas of low SES tend to eat fewer fruits and vegetables[18], eat more fast food meals as well as be less active than individuals in high SES areas[19,20]. This may be due to a lack of access to healthy food and opportunities for physical activity; low-income and minority neighborhoods have access to fewer chain supermarket stores and more fast food outlets[21,22]. This is likely to have behavioral consequences on healthy eating choices as chain grocery stores tend to offer a broader selection of products including fresh produce at the lowest cost[23] whereas fast food restaurants offer energy-dense nutrient-poor foods at a very low price[24,25]. In general, individuals who live in areas with greater density of supermarkets have a higher frequency of eating fruits and vegetables[26] and this effect was found to be even stronger among African-Americans[27], a group that experiences both socioeconomic and obesity-related disparities. A review of built environment influences on health behaviors among African-Americans found that the presence of supermarkets was consistently associated with meeting fruit and vegetable guidelines[28]. The presence of fast food restaurants in areas has been associated with higher energy and percent fat intake, higher consumption of fast food and sugar-sweetened beverages as well as lower intake of fruits and vegetables in some[29-31], but not all studies[22].

With respect to the built physical activity environment, several attributes have emerged which have repeatedly been linked to physical activity behaviors including: greater street connectivity (i.e. greater gridding of streets), more diverse land-use mix (i.e. a combination of retail, commercial, and residential units), as well as greater access to recreational facilities[32]. Scoring neighborhoods based on these some aspect of these characteristics is what has generally defined the "walkability" of the neighborhood. Importantly, built environment features may have differential effects on specific domains of physical activity. For example, the number of fitness centers in an area was more strongly related to moderate and vigorous physical activity than walking per se[33-35] although some studies have still made these links[36-38]. In contrast, walking for transportation has been more strongly related to traffic, street connectivity, and proximity to multiple retail, commercial, and residential destinations while walking for exercise has been found to be more associated with the number of parks in an area [13,39].

While much research has been performed relating the neighborhood where people live to healthy eating and physical activity behaviors, a significant gap in the literature exists surrounding what is known about these relationships with respect to the neighborhood where people work. Limited evidence suggests that a significant proportion of variance in objectively measured moderate-to-vigorous physical activity levels were explained by the built environment surrounding the worksite[40]. This is important as approximately 60% of adults are employed and spend over half of their waking hours at work and worksites are an increasingly popular venue for health promotion efforts[41]. Understanding these effects on individual behaviors may inform the development of a comprehensive intervention to promote healthy weight that addresses the surrounding environment.

The purpose of this study was to determine the relationship between worksite-level SES and individual-level obesity behaviors within among adults. We hypothesized that worksite-level SES was independently associated with individual-level fruit and vegetable intake, fast food meals, soft-drink intake, physical activity and walking and that these associations were mediated by specific built environment attributes of worksites including: residential density, food outlet density, density of physical activity destinations, and intersection density.

METHODS

Study Design and Participants

The Promoting Activity and Changes in Eating (PACE) study is a group-randomized trial of an intervention to prevent weight gain. It included 34 worksites with approximately 2,900 employees in the Seattle metropolitan area. Worksites were identified using select U.S. Standard Industrial Classification (SIC) codes and were required to have between 15 and 350 employees. Eligibility criteria included: having a high proportion of sedentary employees (>25%), low turn-over rate during the previous 2 years (<30%), low proportion of non-English speaking employees (<30%), no more than 2 worksite locations, a 3-year history of being in business, and a willingness to be randomized to either intervention or comparison group. Efforts were made to include a number of blue-collar worksites also. Eligible worksites also could not have had recently administered health promotion efforts or have an on-site cafeteria. Surveys were administered at baseline (2005-2007) and follow-up (2007-2009) to all employees for worksites between 15 and 150 employees while a random subsample of 125 employees were invited to complete the survey among worksites with greater than 150 employees. Built environment attributes of PACE worksites were assessed based on baseline reported worksite address and related to individual-level dietary behaviors, physical activity, and self-efficacy at 2-year follow-up among a population of adult workers. All study participants were asked to provide self-reported dietary and physical activity behaviors, self-efficacy, height, weight, and demographic information. Study methodology and initial analyses are detailed elsewhere[42].

Of the 34 worksites randomized, 33 continued and provided follow-up information at 2 years. Of those, 7 worksites were not included due to lack of available built environment attribute data. Analyses in this paper were restricted to employees within worksites who contributed both baseline and follow-up data to thereby ensure a similar level of exposure to the worksite neighborhood resulting in a total sample of 1,100 employees within 26 worksites.

Measures

Worksite SES. Worksite-level SES was constructed using the appraised worksite property value, a combination of bare land value and improved property onsite[43], adjusted for differences in land parcel size. Using this disaggregated worksite-specific measure of wealth may reduce the modifiable areal unit problem (MAUP), common in many area SES measures, where differences in geographies with varying spatial extents can influence both the magnitude and direction of associations with health outcomes[44]. The use of this metric when relating SES effects to health outcomes is fairly recent[43,45]. Our study uses it in a different way, however, since the appraised property value was attributed to the worksite rather than the home. In this way it could be used as an area-level value for each employee nested within the worksite. Although specific to the land parcel of the worksite, assessed property value also generally represents values of properties with similar characteristics in the same area location[46]. Assessed property value and the square footage of the land parcel were linked to worksites via address using tax data available from the King County Office of the Assessor. All worksites were situated on a single land parcel. Data from the 2006 tax year was selected to correspond to the timing of PACE baseline data collection.

Built Environment Attributes. Food destinations, physical activity destinations, and other density variables were calculated as follows: Worksite neighborhood was characterized by geocoding the worksite address and forming a buffer (i.e. a concentric circle with radius 0.5 miles) surrounding the worksite. The density of intersections and food and physical activity destinations were enumerated within this buffer using geospatial data from University of Washington's Urban Form Lab (UFL). The UFL provided data on food establishments based on food permit data from the Seattle King County Health Department. Categorizations of food destinations extracted included: food stores (including broad-selection groceries and specialty produce markets), convenience stores, dine-in restaurants (e.g. where food is made to order and table-service is available), and fast food or "quick-serve" restaurants (e.g. where food is already prepared and packaged)[47,48]. Other selected built environment attribute density measures provided by the UFL included the number of: 3- or 4-way street intersections (data from King County Street Network), residential units (data from King County Assessors), parks (data from 39 jurisdictions in King County), fitness destinations (e.g. tennis courts, community centers, pools, golf courses, private gym facilities) (data from INFOUSA). All destinations were geocoded by address and verified via cross-checking with online business directories.

Dietary Behaviors Related to Obesity. Average fruit and vegetable servings, number of fast food meals, and soft drink intake were the dietary outcomes of interest because they have been used in several previous studies and have been associated with estimated energy intake and obesity[49-53]. The average number of fruit and vegetable servings eaten per day by participants was assessed via the initial National Cancer Institute 5-A-Day seven question fruit and vegetable assessment tool[49]. The number of servings derived was then dichotomized using a threshold set at the 75%ile of intake which coincided with adherence to current dietary guidelines of eating 5 or more servings of fruits and vegetables per day and as defined in other studies in the built environment literature[21,27]. Frequency of fast-food meals was assessed using a single question similar to other studies (i.e. "Thinking about how often you eat out, how many times in a week or month do you eat breakfast, lunch, or dinner in a place such as McDonald's, Burger King, Wendy's, Arby's, Pizza Hut, or Kentucky Fried Chicken?")[51]. The response was open-ended and could be answered as number of times per week or number of times per month. This measure was then dichotomized at 75%ile, equivalent to about 1 serving per week, which was similar to other studies relating fast food outlets and fast food intake[22,54-56]. Average weekly soft-drink intake was also assessed by a single question (i.e. "How often do you drink soft drinks or soda pop (*regular or diet*)?"). Response options were: "Never", "Less than once a week", "About once a week", "2-5 times per week", "About once a day", and "2 or more times per day"[29]. This measure was also dichotomized at the 75%ile representing between 3 and 4 sodas per week[56,57].

Physical Activity Behaviors Related to Obesity: A physical activity score reflecting free-time physical activity of at least 10 minutes in duration was derived from the Godin Leisure-Time Exercise Questionnaire[58]. The questionnaire provides direct estimates of frequency of vigorous, moderate, and light exercise and summing these components creates an intensity-weighted score that corresponds to a metabolic equivalent frequency per week [58]. To capture moderate and vigorous physical activity, a score based on these two intensity categories was created and dichotomized at the 75%ile, a score of 38 in this dataset, which is equivalent to a frequency approximately 2.5 times greater than the score defined as “sufficient” moderate and vigorous activity according to current recommendations[59]. This alternate measure restricting to moderate and vigorous activity has also been endorsed by Godin[60]. The Godin physical activity score (including the mild intensity category) has acceptable validity and reliability [α:0.69 to 0.80 for total activity in adults] [58,61-63] . Total walking was assessed using a single-item (i.e. “During the last 7 days, on how many days did you walk for at least 10 minutes at a time?”) based on the International Physical Activity Questionnaire (IPAQ) walk question. The IPAQ walk question has acceptable validity and reliability[64]. This measure was dichotomized to represent any walking (i.e. yes or no) as is used in other studies of the built environment literature[17,46,59,65,66].

Efficacy for Behavior Change. Self-efficacy for a particular behavior is both a determinant and a consequence of change in that behavior [67]: the relevant measure has been associated with fruit and vegetable consumption[68], the ability to make healthier choices about weight[69], and with uptake and maintenance of physical activity behaviors[70] in adults. Self-efficacy in the dietary and physical activity realms was assessed via a single-item (i.e. “How sure are you that you can stick to a plan to monitor your eating choices on a regular basis?” and “How sure are you that you can increase your level of physical activity on a regular basis?”, respectively). Response options ranged from “1=Extremely sure” to “5=Not sure”. Self-efficacy measures were adapted from single-item self-efficacy measures specific to eating 5 or more servings of fruit and vegetables per day [71,72]. Measures were dichotomized with “extremely sure” and “very sure” responses indicating high self-efficacy.

Statistical Analyses

Descriptive statistics, including means and standard deviations for continuous variables and proportions for categorical variables, were calculated. Mediation analyses were performed in steps to estimate the various paths. First, the association between worksite-level SES and dietary and physical activity behaviors (i.e. the total effect *c* of worksite SES on obesity-related behaviors) was assessed using multi-level logistic models adjusted for: individual-level outcome measure at baseline, age, sex, race, education, and income as well as for worksite-level intervention group and parcel size as fixed effects and for a worksite random effect (see Figure 1). We refer to this as Model 1. Models of walking behavior were also adjusted for individual-level manual occupation defined as those who worked as machine operators, mechanics/technicians, service workers or within building trades or in construction and labor. Successive models were generated as groups of covariates were added. The number of models fitted was kept to a minimum by introducing groups of variables at a time. We then identified potential mediators of these relationships by using linear regression models to assess area-level associations between worksite-level SES and built environment attributes (i.e. path *a* in mediation analyses (Figure 2). Models were adjusted for worksite parcel size as the specified buffer radius was measured from the parcel centroid. Multi-level logistic models were then used to evaluate associations between neighborhood attributes of worksites and dietary and physical activity behaviors (i.e. path *b* in mediation analyses). Fully adjusted models included individual-level and worksite-level variables in Model 1as well as worksite-level SES. The rationale for adjusting for individual-level income and education for models using worksite-level SES as the predictor of interest was to ascertain whether behavior was impacted by worksite-level SES above and beyond individual-level SES. In addition to following mediation methodology, adjusting for worksite-level SES in models using worksite-level attributes as predictors was done to ascertain whether these structural characteristics influenced behavior above and beyond the overall contextual effect of worksite SES.

To test for mediation, we employed currently recommended product-of-coefficients methods involving biased-corrected bootstrapped 95% confidence intervals[73], also applicable to multilevel models[74] with a continuous mediator and dichotomous outcome[75]. Essentially, the equation for the indirect effect takes the form of:

$$\mathbf{OR \approx exp[\mathit{a}*\mathit{b}]}$$

where *a* is the coefficient resulting from the linear regression equation relating the predictor and mediator and *b* is the coefficient resulting from the multilevel logistic regression equation relating the mediator to the outcome while adjusting for the predictor. The indirect, or mediating, effect is considered statistically significant if the bootstrapped bias-corrected 95% confidence intervals do not include one. This study used bootstrapping within worksites due to the hierarchical structure of the data. All statistical analyses were performed via Stata SE, version 11.0 (Stata Corp., College Station, TX, USA).

RESULTS

Baseline worksite built environment attributes as well as individual-level demographic characteristics and mean activity and dietary behaviors at follow-up are summarized in Table 1. On average, worksites parcel size was about 149,982 ± 249,354 ft^2 with a mean 2006 assessed property value of $26,697,496 ± $60,102,598. Although, on average, the number of residences around worksites was high, density of food and activity destinations was relatively low in comparison with many worksites having close to zero non-residential destinations in the surrounding 0.5 mile buffer. Employees tended to be of younger or middle age, mostly white, and of higher income and educational status. Approximately one third of employees reported eating 5 or more daily servings of fruits and vegetables and 1 fast food meal a week whereas reported soda consumption was slightly lower. Employees were relatively inactive with less than 30% reporting regular engagement in moderate or vigorous physical activity and about 12% reporting no walking of 10 minutes or more in the previous week. High self-efficacy in both dietary and physical activity domains was also low.

Associations of worksite SES with selected physical activity and dietary behaviors (path *c* or the total effect of SES on obesity-related behaviors)

Table 2 reports associations between worksite-level SES and individual obesity-related behaviors. To explore how confounding may have influenced point estimates, a series of models with successively added covariates are presented. Model 1 adjusts for worksite parcel size and intervention group (both area-level variables) as well as individual-level behavior at baseline. Model 2 also includes measures of individual-level age, sex, and race while model 3 additionally evaluates whether worksite-level SES is associated with these behaviors above and beyond individual-level measures of SES (i.e. household income and educational attainment). Worksite-level SES was only statistically significantly associated with no walking of 10 minutes or more in the past week in the fully adjusted model. Among worksites in the 75%ile of worksite-level SES compared to worksites in the 25%ile of worksite-level SES, walking was about 15% greater among employees (OR=1.15; 95% CI: 1.03, 1.29; p=0.010).

Associations of worksite built environment attributes with individual obesity-related behaviors (path *b* of mediation analyses)

Associations of built environment attributes with select diet-related variables (e.g. fruit and vegetables, fast food meals, soft-drinks, self-efficacy to monitor eating) were evaluated (Table 3). Residential density was only significantly associated with eating 5 or more servings of fruit and vegetables per day after adjustment for worksite-level SES. Among worksites in the 75%ile for residential density compared to worksites in the 25%ile for residential density, the odds of eating 5 or more servings of fruit and vegetables per day was 2.5 times higher (OR=2.5; 95% CI: 1.27, 4.95; p=0.008) independent of worksite-level SES. There were no significant associations between worksite built environment attributes and other dietary behaviors. Associations between built environment attributes and physical activity-related variables (e.g. walking, MVPA, self-efficacy to increase activity) are shown in Table 4. All four measures of the worksite built environment were significantly associated with not walking 10 or more minutes in the past week. A change in built environment attribute equal to each attribute's interquartile range (IQR) resulted in an increase in the odds of walking between a 61% to over a 2-fold increase in the odds of walking. Residential density, however, was the only attribute still significantly associated, albeit attenuated, with walking behavior after adjustment for worksite-level SES (OR=1.84; 95% CI: 1.02, 3.33; p=0.043). There were no significant associations between worksite built environment attributes and other physical activity-related measures.

Associations of worksite-level SES with built environment attributes (path *a* of mediation analyses)

Associations of worksite-level SES with built environment attributes hypothesized to mediate relationships with physical activity and dietary behaviors are presented in Table 5. Worksite-level SES was positively associated with all built environment measures examined. Comparing worksites in the 75%ile for worksite-level SES to worksites in the 25%ile of worksite-level SES, there was a difference of approximately 293.7 residential units (95% CI: 42.9, 544.4 590.0; p=0.024), 21.1 food destinations (95% CI: 10.8, 31.5; p<0.0001), 1.1 activity destinations (95% CI: 0.5, 1.7; p=0.001), and 12.1 intersections (95% CI: 4.2, 19.9; p=0.004) . In other words, higher worksite-level SES was associated with greater walkability and access to physical activity and food-related services.

Potential mediators of the relationship between worksite SES and selected dietary and physical activity behaviors (exp[*ab*] or the indirect effect of SES on obesity-related behaviors)**

Table 6 presents the product of coefficients for the hypothesized mediating relationships. The indirect effects presented relate to how much the predictor is associated with the outcome through the mediating variable only. As expected, only built environment attributes with statistically significant path *a* and *b* relationships were shown to statistically mediate the effect of worksite-level SES on individual obesity-related behaviors. Positive associations of worksite-level SES on fruit and vegetable consumption and walking behavior were partially explained through residential density. All else being equal, respondents who worked in worksites in the 75%ile of worksite-level SES had a 3.2% increased odds (95% CI: 1.1, 5.3) of eating 5 or more servings of fruit and vegetables per day as well as a 2.6%

increased odds (95% CI: 0.1, 5.2) of walking compared to respondents who worked in worksites in the 25%ile of worksite-level SES.

DISCUSSION

A new finding from this study is that worksite-level SES was associated with more walking -- important to consider during evaluation of obesity-prevention strategies as it is one of the most common forms of physical activity[56]. Worksite-level SES was also positively correlated with built environment attributes associated with neighborhood walkability. Providing environments that support walking may be key to more widespread adoption of physical activity behaviors through active living (e.g. walking to and from work, stores, and parks)[76]. Our findings are consistent with other studies linking higher SES of home neighborhoods with higher frequency of walking[10] and now extends those findings to the worksite neighborhood. Other literature suggests that higher SES of home neighborhoods may influence walking levels through better neighborhood perceptions, greater numbers of walking destinations, and better pedestrian infrastructure than lower SES home neighborhoods that together create an environment supportive of walking[10,77]. It is likely that many of these relationships translate to the context surrounding the worksite as well.

Although some studies have found that higher SES of home neighborhoods is associated with doing other forms of recreational activity besides walking[34,36], we did not find any significant associations with respect to the worksite neighborhood and other activity outcomes in our analyses. In contrast to other studies, area-level SES around worksites was not significantly associated with any dietary behaviors examined. For example, findings from at least two studies have demonstrated that area-level SES of the home neighborhood is associated with fruit and vegetable intake measured by 24-hour recall[18] as well as by biomarkers of fruit and vegetable intake[78].

In mediation analyses, we determined that the statistically significant association between worksite-level SES and walking was mediated by residential density. Yet, there was no demonstrated direct association between worksite-level SES and any other obesity-related behavior in these analyses.

Although it has been thought that mediation may only be assessed when there is a significant direct effect between the predictor and outcome, recent methodological research suggests that mediation analyses are still valid even when this is not the case[57]. This is especially salient when assessing mechanisms for area-level factors on behaviors as competing associations may exist which result in an overall null effect. Residential density, however, was found to also mediate the relationship between worksite-level SES and fruit and vegetable consumption. The presence of mediation by residential density given a lack of a total association between worksite-level SES and fruit and vegetable consumption may be explained by the presence of another mediator that results in a negative association between SES and fruit and vegetable consumption. This may manifest through a mediator that is positively associated with SES, but negatively associated with fruit and vegetable consumption or vice-versa.

To support the relationships between worksite SES and our hypothesized mediators, positive associations are evidenced in the literature between area-level SES and neighborhood components of walkability. Availability of high quality food and fitness-related destinations as well as the presence of infrastructure that is compatible with walking and biking tends to occur in higher SES areas[79]. Of interest, studies conducted in large metropolitan cities have found that area SES is positively associated with components of walkability including residential density and access to services, especially within central business districts[79]. Such districts are characterized by high-rise residential buildings, numerous shops and services, as well as gridded streets while the cost of housing in these areas is generally affordable to residents with higher incomes[79]. The association between lower area-SES and higher density of fast food outlets evidenced in the literature[43,60,80,81] was not demonstrated in our study of King County, Washington. The association between low area-SES and fast food was also not found in Detroit and, instead, it was found that lower socioeconomic areas also had less access to food outlets of any type[60] . Interestingly, a recent investigation of built environment attribute clusters (i.e. supermarket, retail, and fitness destinations) indicated a racial gradient, a phenomena highly correlated with socioeconomic status, in the location of these clusters in three metropolitan areas[18]. That is, those of minority status (i.e. groups that tend to be of lower SES) had less access to commercial and retail services. Along these lines, worksites in lower SES areas of Seattle, therefore, also appear to be "underserved" in that they are removed from central business districts, characterized by clusters of services, where access to food and fitness-related infrastructure is greater.

To support the relationships between our hypothesized mediators and behavioral outcomes, many linkages have been made between built environment attributes and both diet and physical activity behaviors. Higher walkability, specifically mixed land-use, has consistently been associated with higher walking while evidence for associations with moderate and vigorous exercise are mixed[10]. Greater access to parks and fitness destinations has also been associated with more physical activity, including walking[34]. In this regard, we also found evidence linking more walking with working in areas with high residential density. While the worksite itself is a non-residential land-use, when coupled with the zoning of the worksite parcel, the accompanying residential units indicates multiple (or mixed) uses within the 0.5 mile buffer studied. We did not find an association between walking behavior and selected food or physical activity destinations. A possible reason for this lack of association is that we measured total walking behavior and did not differentiate between transport-related and recreational walking. It has been suggested that each type of walking may have specific environmental correlates themselves[76,82]. A review of the walking literature in which the purpose for walking was defined suggests that only mixed land-use, population density, and proximity to nonresidential destinations have been consistently associated with transport-related walking whereas findings for recreational walking were less clear[76]. However, findings are consistent with another study of built environment correlates of walking among King County adults[13].

Most studies of free-time physical activity have focused on relating these behaviors to the proximity or density of recreational facilities (including parks, pools, tennis courts, private and public gyms).[11,32,83] Interestingly, evidence is emerging which suggests that the walkability of a neighborhood affects more than just walking behavior among residents.[11] In the U.S., Frank and colleagues found that walkability was also associated with increased minutes of moderate activity measured via accelerometer.[37] This work was later replicated in studies in Belgium[36] and Sweden[38] in which minutes of moderate and vigorous physical activity performed in the neighborhood was related to the walkability of the neighborhood. While components of walkability of the workplace were not associated with other forms of self-reported physical activity in these data, our lack of findings may be due to our use of a more biased self-reported measure of physical activity in our study whereas the aforementioned associations were found in studies using accelerometer or interviewer-collected data. Our findings mesh with a review of built environment correlates (including proximity to fitness destinations) of exclusively self-reported physical activity which found no strong or consistent associations[35]. More precise and comprehensive measures of physical activity are likely needed to detect associations with smaller area-level effects. However, collecting this type of data in large-scale cohort studies is often not feasible. Work to “correct” these self-reported physical activity measures using calibration equations derived from regression analyses in a subset of participants collecting accelerometer would be of interest.

With respect to the food environment, the number and type of food outlets in an area have been the most highly investigated factors found to be associated with dietary behaviors[23,31]. Studies have generally found that individuals who live in areas with greater density of supermarkets have a higher frequency of eating fruits and vegetables and lower frequency of eating fast food meals whereas those who live in areas with greater density of fast food outlets tend to eat more fast food meals and fewer servings of fruits and vegetables.[30,31] Although the relationship between residential density and dietary behavior is understudied, Burgoine and colleagues have documented a positive relationship between residential density with both fruit and vegetable consumption[78]. Interestingly, a total effect was also not evidenced between fruit and vegetable consumption and their area measure of SES.[78].

These analyses are based on the assumption that proximity to destinations connotes access which, in turn, influences behavior. To justify the mediating relationship of residential density (i.e. a measure of physical access) in the relationship between SES and fruit and vegetable consumption[84], evidence must also support a plausible competing mediating relationship. Aggarwal and colleagues have found that cost, a measure of economic rather than physical access, is also an influential determinant of food choice that is positively related to SES.[85] In their studies, energy-adjusted cost of food consumed among study participants was found to increase linearly with both individual-level income and education.[85] Energy density as estimated via food frequency questionnaire (FFQ) was also found to decrease linearly over quintiles of energy-adjusted diet cost.[85] Both of these relationships (i.e. representing *a* and *b* paths in their hypothesized causal model) were found to be significant thereby indicating a likelihood that bootstrapped product-of-coefficients methods would also detect a significant mediating relationship.[86]

An important criterion for evaluating mediating relationships is that the temporal sequence of variables is correct[86]. For our study, the measure used to operationalize worksite-level SES was total appraised property value of the worksite in 2006. The dates of attribute data were extracted included 2006 (i.e. intersections), 2007 (i.e. residential units), 2008 (i.e. parks, food outlets), and 2009 (i.e. fitness destinations) while follow-up data on employees was collected between 2007 and 2009. It is possible that the attribute data may not accurately reflect the built environment around worksites at baseline (i.e. between 2005 and 2007), especially for earlier waves of the study. Attributes derived from parcel-level tax assessor's data (i.e. worksite-level SES, residential units, and parcel size) are likely exempt from this problem as data are updated for biannual property tax levies. Other area-level data (i.e. intersections, destinations) are updated less frequently thereby likely rendering the data extracted relevant to earlier time-points "on the ground." Both of these scenarios minimize the possible threat to temporality of proposed mediating relationships.

This study has several limitations. First, the outcomes were measured by self-report and are therefore subject to measurement error. It is possible that there are unmeasured confounders, and given the multilevel nature of the data, these confounders can therefore exist at both the individual- and worksite-level. Furthermore, simultaneously assessing predictor/mediator relationships as well as mediator/outcome relationships essentially provides twice the opportunity where confounding may influence inference of the mediated effect using the product of coefficients method. The potential interaction between the predictor and mediator should also be considered as its presence dramatically changes interpretation of hypothesized mediating relationships[75,86]. Post-hoc analyses per methods suggested by Knol and colleagues[87], however, suggest that no departures from additivity, and therefore no interaction, existed in either of our mediating relationships.

Not knowing the location of where participants performed reported dietary and physical activity behaviors is also problematic. Because we are measuring total behavior, it is possible that the behavior was actually being performed in a context outside of the worksite. However, when considering walking, if employees were mostly performing transport-related walking associated with active commuting, this may be less of an issue in that walking was likely occurring within the worksite buffer. Our positive findings may support such a notion[39]. This assumption is more problematic, however, when considering moderate and vigorous physical activity (MVPA). Troped and colleagues encountered this issue and found that when simply relating worksite neighborhood to total minutes of MVPA, no associations were found[40]. Utilizing GPS and accelerometer data, however, they were able to pinpoint exactly where activity was being performed by participants. For MVPA performed within the 1 km buffer surrounding the workplace, population and residential housing unit density around worksites were associated with minutes of MVPA and explained a significant portion of the variation[40].

Attributing dietary behaviors to the correct context is also likely an issue when considering the food environment. If most people grocery shop at food outlets near home, then the effect of the number of grocery stores around the worksite for people who do shop near work may be masked due to this lack of specificity. Additionally, if there are few food outlets surrounding the worksite, this might encourage employees to pack their lunch, thereby rendering the food environment of the home neighborhood more relevant. Also, the size of buffer around the worksite may be too large in that the destinations closer to the worksite (e.g. in 0.25 mile buffer) may actually be more influential on dietary and physical activity behaviors. This may be less of an issue for physical activity behaviors given previous findings[40], but may be more of an issue for the food environment. If employees are constrained in time (e.g. duration of lunch break), it is likely that the relevant food environment is in much closer to the worksite. Having information about who exercises or buys lunch or groceries around the worksite would have been invaluable to these analyses.

Using objectively measured BE attribute data, derived from city planning, transportation, tax assessment, or commercial sources, may be problematic in that the exact date for when data were recorded is uncertain (many times only the year is available) and, as mentioned, updates to databases are lagged due to the sheer magnitude of the task. This, of course, affects the validity of the measure if there is high turn-over of businesses or other change in built attribute information. Counts of parks, intersections, and residential units are likely less subject to such measurement bias whereas counts of food outlets and fitness destination may be more affected. We must also acknowledge that our findings could be influenced by multiple tests. Although we sought to minimize the number of comparisons by mapping built environment attributes to specific behaviors, both worksite-level SES and residential density were hypothesized to be related to all behaviors whereas the food environment, for example, was only related to dietary behaviors and walking (i.e. as a walking destination). Despite these limitations, which are also present in most studies using objective measures of the built environment, strengths of our study include its longitudinal nature as well as the use of mixed models when evaluating associations. In addition, our findings add to the notable paucity of evidence concerning worksite neighborhood effects as well as apply appraised property value of the worksite as a novel measure of area-level SES in a commercial context.

In conclusion, residential density was independently associated with some dietary and physical activity behaviors and also acted as a mediator between area-level SES of worksites and these same behaviors. Such information may be especially salient given the popularity of worksites as venues for delivery of health promotion activities. Consideration of contextual characteristics of worksites may be one refinement of workplace intervention strategies to increase the probability of fruit and vegetable consumption and walking among participating employees. For example, strategies to increase transport-related walking could be given to worksites located in more dense areas whereas establishing a neighborhood walking circuit to be used during work breaks might be more efficacious for worksites further from destinations. Additional studies are needed which directly relate worksite neighborhood context to behaviors performed within that context before firm conclusions can be drawn.

Figure 1. Total effect of predictor on outcome including all mediating pathways[88].

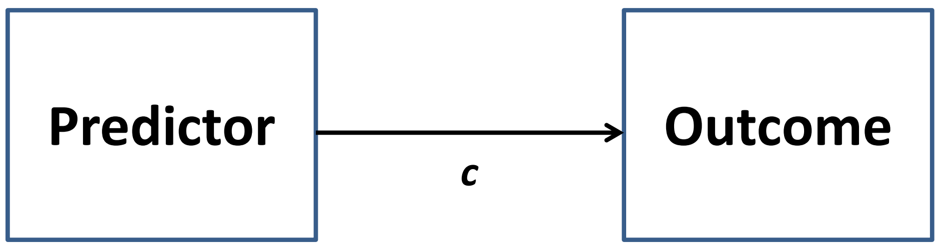

Figure 2. Direct (c') and indirect (a*b) effects of predictor on outcome where the indirect effect is the mediated effect and the direct effect is the total effect-indirect effect under study[88].

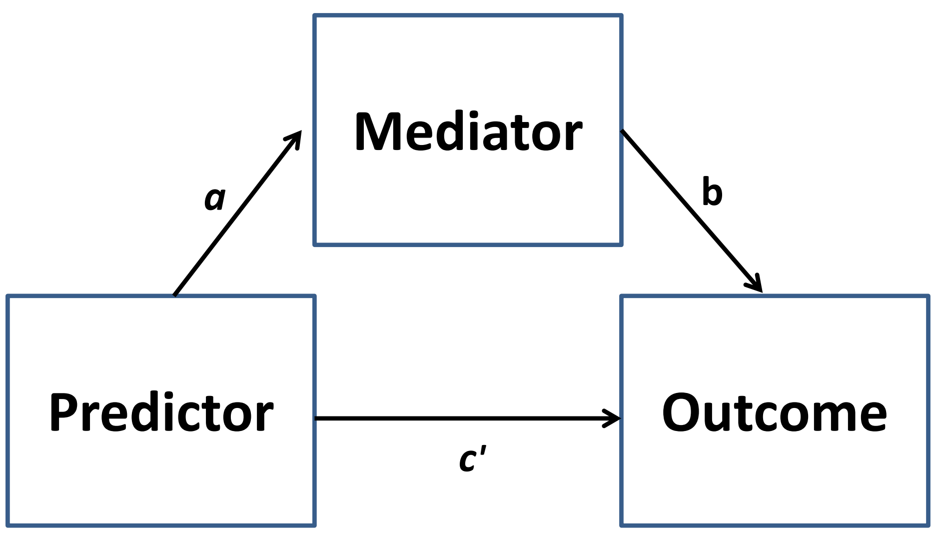

Table 1. Mean area- and individual-level demographic characteristics and behaviors of a subsample of PACE worksites[a] in King County, WA.

Area-level	Mean	SD
Worksite-level SES	$26,697,496	$60,102,598
Residential units	3,824.0	4,017.5
Food destinations	109.9	134.3
Fitness destinations	12.2	8.6
Intersections	193.5	113.8
Individual-level	**Percentage**	**n**
Age		
18-34	23.8	257
35-44	29.3	317
45-54	29.4	319
55-65	17.5	190
Male	43.2	499
Race		
White	76.3	781
African American	5.0	51
Hispanic/Latino	3.2	32
Asian	15.4	156
Education		
<HS, HS graduate or GED	17.9	193
Some college or technical college	32.9	356
College graduate	33.8	366
Professional degree	15.4	168
Household income		
<$50,000	23.1	190
$50,000 to $74,999	22.6	191
$75,000 to $100,000	21.1	177
>$100,000	33.1	270
Dietary behaviors		
High fruit and vegetable intake	34.5	375
High fast food intake	25.9	297
High soft-drink intake	27.9	270
High self-efficacy to monitor eating	14.1	128
Physical activity behaviors		
High MVPA	26.2	269
No walking for 10+ minutes	12.5	135
High self-efficacy to increase activity	15.9	142

[a] N = 26 worksites, n = 1,100 employees

Table 2. Social environment and obesogenic behaviors: baseline worksite SES, dietary behaviors, and physical activity at follow-up among 26 PACE worksites in King County, WA.

	Model 1[a]			Model 2[b]			Model 3[c]		
	OR	95% CI	Pvalue[d]	OR	95% CI	Pvalue[d]	OR	95% CI	Pvalue[d]
Dietary Behaviors									
Fruit and vegetables	1.03	(0.97, 1.09)	0.310	1.03	(0.97, 1.10)	0.288	1.03	(0.97, 1.10)	0.273
Fast food meals	0.95	(0.85, 1.06)	0.336	0.95	(0.85, 1.06)	0.340	0.97	(0.88, 1.08)	0.599
Soft-drinks	1.00	(0.96, 1.04)	0.960	0.99	(0.95, 1.04)	0.734	0.99	(0.94, 1.04)	0.640
Dietary SE	0.96	(0.91, 1.01)	0.141	0.96	(0.91, 1.02)	0.153	0.97	(0.91, 1.03)	0.276
Physical Activity Behaviors									
Walking[e]	**1.13**	**(1.03, 1.25)**	**0.010**	**1.14**	**(1.03, 1.26)**	**0.012**	**1.15**	**(1.03, 1.29)**	**0.010**
MVPA	0.98	(0.94, 1.03)	0.506	0.99	(0.95, 1.03)	0.674	0.99	(0.94, 1.03)	0.617
Physical activity SE	0.99	(0.95, 1.04)	0.797	1.00	(0.96, 1.05)	0.985	1.00	(0.95, 1.05)	0.983

[a] Difference in probability of outcome presented for increase of IQR of worksite SES; Slope between groups estimated by multilevel logistic model adjusted for measure at baseline, worksite parcel size, and intervention group as fixed effects and a worksite random effect
[b] Model 1 plus age (continuous), sex, race (collapsed into 4 categories)
[c] Model 2 plus education (collapsed into 4 categories), income (collapsed into 4 categories)
[d] Wald test
[e] Model 2 includes adjustment for individual-level manual occupation (blue collar v. not blue collar)
MVPA= moderate or vigorous physical activity; SE= self-efficacy

Table 3. Built environment and obesogenic behaviors: baseline residential and food outlet density and dietary behaviors among 26 PACE worksites in King County, WA.

	Fruits and Vegetables			Fast Food Meals			Soft-drinks			Dietary SE		
	OR[a]	95%CI	Pvalue[b]	OR[a]	95%CI	Pvalue[b]	OR[a]	95%CI	Pvalue[b]	OR[a]	95%CI	Pvalue[b]
Residential units												
Model 1[c]	**2.44**	**(1.34, 4.46)**	**0.004**	0.78	(0.52, 1.20)	0.259	1.25	(0.63, 2.49)	0.518	0.71	(0.40, 1.26)	0.237
Model 2[d]	**2.50**	**(1.27, 4.95)**	**0.008**	0.88	(0.55, 1.40)	0.586	1.30	(0.60, 2.83)	0.500	0.78	(0.41, 1.49)	0.456
Food destinations[e]												
Model 1[c]	1.40	(0.90, 2.17)	0.138	0.80	(0.59, 1.09)	0.155	1.03	(0.66, 1.60)	0.907	0.75	(0.51, 1.11)	0.147
Model 2[d]	1.39	(0.72, 2.70)	0.330	0.89	(0.58, 1.37)	0.595	1.02	(0.51, 2.02)	0.956	0.76	(0.43, 1.34)	0.348

[a] Slope between groups (presented for increase in IQR of worksite built environment attribute) estimated using multilevel logistic model

[b] Wald test

[c] Adjusted for age (continuous), sex, race (collapsed into 4 categories), education (collapsed into 4 categories), income (collapsed into 4 categories), measure at baseline, worksite parcel size, and intervention group as fixed effects and a worksite random effect

[d] Model 1 + worksite SES

[e] Includes all restaurant and grocery store types

Table 4. Built environment and obesogenic behaviors: baseline residential, food outlet, physical activity destination, and intersection density and physical activity among 26 PACE worksites in King County, WA.

	Walking[a]			MVPA			PA SE		
	OR[b]	95%CI	Pvalue[c]	OR[b]	95%CI	Pvalue[c]	OR[b]	95%CI	Pvalue[c]
Residential units									
Model 1[d]	**2.45**	**(1.41, 4.27)**	**0.001**	1.12	(0.66, 1.89)	0.672	0.99	(0.56, 1.72)	0.958
Model 2[e]	**1.84**	**(1.02, 3.33)**	**0.043**	1.26	(0.69, 2.28)	0.454	0.98	(0.52, 1.86)	0.961
Food destination[f]									
Model 1[d]	**1.72**	**(1.14, 2.60)**	**0.010**						
Model 2[e]	1.14	(0.65, 2.02)	0.640						
Activity destination[g]									
Model 1[d]	**1.99**	**(1.16, 3.40)**	**0.012**	1.07	(0.68, 1.71)	0.761	1.13	(0.70, 1.81)	0.618
Model 2[e]	1.26	(0.65, 2.45)	0.494	1.29	(0.70, 2.38)	0.411	1.24	(0.66, 2.31)	0.500
Intersections									
Model 1[d]	**1.61**	**(1.01, 2.60)**	**0.047**	0.95	(0.62, 1.44)	0.800	1.07	(0.69, 1.67)	0.755
Model 2[e]	1.07	(0.61, 1.87)	0.820	1.02	(0.60, 1.74)	0.948	1.12	(0.65, 1.95)	0.684

[a] Adjusted for individual-level manual occupation (blue collar v. not blue collar)
[b] Slope between groups (presented for increase in IQR of worksite built environment attribute) estimated using multilevel logistic model
[c] Wald test
[d] Adjusted for age (continuous), sex, race (collapsed into 4 categories), education (collapsed into 4 categories), income (collapsed into 4 categories), measure at baseline, worksite parcel size, and intervention group as fixed effects and a worksite random effect
[e] Model 1+ worksite SES
[f] Includes all restaurant and grocery store types
[g] Includes parks, trails, gyms, golf courses, pools, community centers
MVPA= moderate or vigorous physical activity; SE= self-efficacy

Table 5 . Social and built environment: baseline worksite SES and built environment attributes surrounding 26 PACE worksites in King County, WA

	β[a]	95%CI[b]	Pvalue
Residential units	293.7	(42.9, 544.5)	0.024
Food destination[c]	21.1	(10.8, 31.5)	<0.0001
Activity destination[d]	1.1	(0.5, 1.7)	0.001
Intersections	12.1	(4.2, 19.9)	0.004

[a] Slope between groups (presented for increase in IQR of worksite SES) estimated by linear regression model adjusted for worksite parcel size
[b] Wald test
[c] Includes all restaurant and grocery store types
[d] Includes parks, trails, gyms, golf courses, pools, community centers

Table 6. Mediation analysis: bootstrap estimates of indirect effect (product of coefficients) of worksite SES through built environment attributes on obesogenic behaviors among 26 PACE worksites in King County, WA.

	Residential units		Food destinations[a]		Activity destinations[b]		Intersections	
	exp(*ab*)[c]	exp(95%CI)[d]	exp(*ab*)[c]	exp(95%CI)[d]	exp(*ab*)[c]	exp(95%CI)[d]	exp(*ab*)[c]	exp(95%CI)[d]
Dietary Behaviors								
Fruit and vegetables	**1.032**	**(1.011, 1.053)**	0.998	(0.967, 1.024)				
Fast food meals	0.995	(0.997, 1.017)	0.988	(0.945, 1.036)				
Soft-drinks	1.011	(0.983, 1.054)	1.002	(0.934, 1.085)				
Dietary SE	0.998	(0.967, 1.024)	0.989	(0.934, 1.048)				
Physical activity Behaviors								
Walking[e]	**1.026**	**(1.001, 1.052)**	1.014	(0.960, 1.088)	1.015	(0.975, 1.060)	1.004	(0.971, 1.044)
MVPA	1.006	(0.982, 1.028)	0.993	(0.945, 1.034)	1.011	(0.975, 1.045)	0.993	(0.962, 1.021)
Physical activity SE	1.001	(0.973, 1.030)	1.002	(0.940, 1.059)	1.016	(0.977, 1.059)	1.007	(0.971, 1.047)

[a]Includes all restaurant and grocery store types
[b] Includes parks, trails, gyms, golf courses, pools, community centers
[c]Estimates obtained via antilogarithm of mean regression coefficient of indirect effect (product of coefficients *ab* presented for increase in IQR of worksite SES (path *a*) and 1 unit increase in mediator (path *b*))
[d]95% bias-corrected confidence intervals; effect is considered statistically significant if the BC confidence intervals do not overlap with 1.
[e] Adjusted for individual-level manual occupation (blue collar v. not blue collar)
MVPA= moderate or vigorous physical activity; SE= self-efficacy

Chapter 2:

Worksite context and measures of stress, social support, and systemic inflammation among employees

ABSTRACT

Introduction The stress process has been implicated in the etiology and progression of many chronic diseases such as cardiovascular disease (CVD) and cancer through both biological and behavioral pathways. Understanding the degree to which environment contributes to the stress process may suggest mechanisms linking neighborhood context and chronic disease outcomes. Home neighborhood context has been associated with measures of psychological distress, yet less is known about how other contexts such as the workplace may contribute to stress burden. As the workplace is one of the environments experienced by a majority of adults, the objective of this study was to evaluate associations between worksite neighborhood context and measures of global and work-specific stress.

Methods Promoting Activity and Changes in Eating (PACE) is a worksite-randomized study of an intervention to prevent weight gain. Worksites represented both white-collar and blue-collar businesses and employees tended to be older, mostly white, and college educated. Worksite neighborhood context was defined by worksite-level socioeconomic status (SES, measured as assessed property value), worksite class (white-collar vs. blue-collar), and neighborhood density (i.e. residential units) around the worksite. The Perceived Stress Scale (PSS) was included as a measure of global stress; other correlates of stress were also assessed: C-reactive protein (CRP, a biomarker of inflammation), work demands (an indicator of lower worker productivity), and social support at work. Linear mixed models adjusted for individual-level age, sex, race, education, manual occupation as well as worksite-level intervention group and parcel size were used to evaluate associations. Interaction by gender was tested.

Results Worksite context was not statistically significantly associated with global measures of perceived stress or CRP in these data and interaction by gender was not detected. A significant gender interaction was detected, however, for nearly all worksite contextual variables in relation to work demands and social support. Among men, work demands varied by worksite-level SES ($p<0.001$) and level of neighborhood density surrounding the worksite ($p=0.02$), although patterns were not linear. White-collar worksite class was also associated with fewer work demands (Diff=-2.68; 95% CI: -5.35, -0.01; $p=0.049$) and higher social support (Diff: 0.12; 95%CI: 0.01, 0.23; $p=0.034$) compared to blue-collar worksite class. Among women, worksite-level SES was not statistically significantly associated with work demands or social support at work. White-collar worksite class was associated with lower worker social support (Diff=-0.11; 95% CI: -0.22, -0.01; p=0.04) compared to blue-collar worksite class whereas higher neighborhood density around the worksite was more strongly associated with higher work demands (Diff =1.34; 95% CI: 0.65, 2.02; p<0.0001) compared to lower neighborhood density. Social support also varied by level of neighborhood density surrounding the worksite (p=0.02), although patterns were also not linear.

Conclusions Worksite context was not significantly associated with measures of global stress or chronic inflammation in these data. However, worksite context did significantly influence measures of work demands and worker social support, key factors of work stress, thereby suggesting a contributing role of worksite context in the stress process. In addition, these findings may have implications for organizational efforts targeting increased worker productivity.

INTRODUCTION

Neighborhood-level socioeconomic status (SES), especially measures related to aggregate income and education, is commonly used to measure of social context[89]. In turn, this has been linked to many chronic disease outcomes including obesity[21,43,90], diabetes[91], cardiovascular disease (CVD)[92-96] as well as to the progression and survivorship of some cancers[97-100]. Evidence is emerging to link attributes of the built environment (e.g. land-use mix which includes density measures of residential units, population, and commercial destinations) directly to the prevalence of obesity[10,101,102] as well as CVD risk[101,103]. Pathways which might explain these associations are likely biobehavioral in nature. That is, neighborhood attributes are associated with both behaviors and physiologic changes which might confer additional health risk at both the individual- and area-levels. For example, known modifiable chronic disease risk factors, such as smoking, physical inactivity, and obesity, are more prevalent among poorer persons and areas[30,101,104-106]. In addition, precursor physiologic changes associated with both CVD and cancer, such as systemic inflammation[93,107], have also been associated with individual[108] as well as neighborhood measures of poverty[30]. While individual-level measures of income have been consistently associated with inflammatory markers such as von Willebrand factor and C-reactive protein (CRP) [45,47,109,110] ,findings relating area-level poverty and inflammatory markers are emerging [48,111]. Predictors for these biobehavioral risk factors, such as social support, neighborhood walkability, and stress also vary by economic measures at both the individual- and area-level[36,112,113].

The stress process is of interest as a biobehavioral framework to link both individual and neighborhood factors to chronic disease risk[114] as it is determined in part by environment and affects both behaviors and physiologic changes implicated in the etiology of many chronic diseases. Accordingly, perceived stress has been associated with physical activity and obesogenic dietary behaviors in this same cohort[115]. Stress occurs when demands from the environment exceed the adaptive capacity of an individual resulting in both physical and psychological changes in order to maintain homeostasis[116]. Research has included multiple measures of the stress process including counts of stressors or stressful life events, perceptions of stress, as well as physiologic responses to stress (e.g. cortisol and pro-inflammatory output) in relation to health outcomes. The adult lifestyle in the U.S. is characterized by exposure to many types of environmental stressors experienced at various levels of the socio-ecological framework including those associated with home, family, work, and financial obligations which are likely augmented by one's socioeconomic position[117], including gender[118,119].

Previous research has found that persons living in poorer neighborhoods are more likely to have higher exposure to stressful life events such as crime victimization, loss of a loved one, and unemployment as well as have limited access to beneficial neighborhood social and material resources (e.g. social support, public services, commercial businesses, law enforcement, and public amenities)[120]. Although perceived stress has not been statistically significantly associated with living in poorer neighborhoods[121], abnormal diurnal cortisol secretion has been associated with living in poorer neighborhoods[122]. While neighborhood SES likely has a large impact on exposure to neighborhood stressors and beneficial resources, neighborhood density may also be an important driver by providing the population "critical mass" necessary for the provision of services[109]. Higher density may also be associated with increased social interactions leading to both positive and negative neighborhood issues[109].

For example, higher frequency of encounters with strangers outside the home has been associated with greater distress, depression, and anxiety among adults[123].

Literature evaluating the impact of neighborhood contextual characteristics of environments other than the home on stress levels is lacking. Clearly, individuals operate within multiple contexts throughout the day and further understanding of how these other places may impact health is needed. The workplace is a salient environment for many Americans as approximately 60% of the adult U.S. population is employed while over half of the waking hours for those individuals are spent at work[41]. Given the significant portion of time spent at work for employed individuals, it follows that the area around the workplace could influence health to some degree. As living in areas with higher levels of density or economic disadvantage contributes to the exposure, perception, and response to stress, we posit that exposure to similar characteristics of the workplace may also impact stress levels. Stressors associated with poor home neighborhoods (e.g. crime and other elements of social disorder, graffiti and garbage, poor building quality and failing infrastructure)[124] could conceivably overlap with those identified in reference to the workplace to impact stress levels[125] as well as health behaviors[89] of employees. As with poorer home neighborhoods, it is also possible that poorer working areas have fewer beneficial resources to buffer the effects of stressors[126] which could also influence stress levels and health behaviors.

Work stressors such as job demands and lack of social support at work are integral dimensions of isostrain models of work stress. These models define higher stressed workers as those who are socially isolated, have high physical and/or mental job demands, and have low control over how to meet those demands[65,127]. As with global measures of stress, these dimensions of work stress have also been associated with physical inactivity[128], poor dietary behavior, obesity[129], as well as chronic disease risk (e.g. CVD)[130,131]. Given that global stress measures and dimensions of work stress are similarly related to health outcomes, it is likely that these measures all tap the same underlying stress construct. Assuming that neighborhood stressors similarly occur in the workplace neighborhood as the home neighborhood with respect to neighborhood SES, workplace neighborhood could theoretically influence global stress in some way. Yet, it is also possible that stressors around the workplace are more salient to dimensions of work stress given they share the same measurement domain as compared to global measures of stress which measures stress from multiple domains.

Taken with the associations found between home neighborhood and stress, further understanding of how the neighborhood of the workplace may impact stress among workers could contribute to the overall picture of how environmental context affects the stress process and, in turn, biobehavioral pathways of chronic disease. This study builds on evidence relating worksite context to other behavioral risk factors among workers, namely dietary and physical activity behaviors (see Chapter 1). The objective of this study, therefore, was to relate elements of both the social and built environment of the worksite to measures of global stress and systemic inflammation as well as dimensions of work stress (i.e. work demands and worker social support). Specifically, we hypothesized that individuals who worked in poorer areas would have higher levels of global stress, higher levels of low-grade systemic inflammation, higher work demands, and lower social support at work than individuals who worked in more affluent areas. We also hypothesized similar relationships between higher neighborhood density around the workplace, global stress, inflammation, work demands, and social support at work. As exposure, appraisal, and responses to stressors may differ by gender[106], we decided *a priori* to test a gender interaction term for these relationships.

METHODS

Study Design and Participants.

The Promoting Activity and Changes in Eating (PACE) study was a large group-randomized intervention trial to prevent weight gain among the employees of 34 worksites in the Seattle metropolitan area. Worksites were selected using a subset of U.S. Standard Industrial Classification (SIC) codes and were required to have between 50 and 350 employees. Eligibility criteria included: having a high proportion of sedentary employees (>25% or >35% depending on blue or white collar occupations), low turn-over rate during the previous 2 years (<30%), low proportion of non-English speaking employees (<30%), no more than 2 worksite locations, a 3-year or longer history of being in business, and a willingness to be randomized to either intervention or comparison group. Eligible worksites also could not have had recently administered health promotion efforts or have an on-site cafeteria. Surveys assessing work demands, social support at work, and demographic information were administered at baseline (2005-2007) and follow-up (2007-2009), using serial cross-sectional samples of employees. For worksites between 50 and 150 employees, all current employees at the time of the survey were invited to respond, while a random subsample of 125 employees was drawn from worksites with greater than 125 employees. A total of 3054 individuals within 34 worksites completed baseline and 2398 individuals within 33 worksites at follow-up (one worksite was lost to follow-up). In addition, a random subsample of participating employees within all 34 worksites was invited to complete an intensive assessment including the Perceived Stress Scale (PSS-10), a 24 hour dietary recall, and a fasting blood draw; 676 employees in 34 worksites participated at baseline (78.2% of those invited) and 577 in 33 worksites participated at follow-up (79.5% of those invited). Only 26 worksites (78.8%) had environment attribute data, since this was only available for King County. Seven worksites were outside of King County. Analyses were then limited to those workers at follow-up who provided non-missing demographic information resulting in a sample of 1501 individuals with survey information and 508 individuals in the intensive assessment subsample. All study protocols and materials were reviewed and approved by the University of Washington and Fred Hutchinson Cancer Center Institutional Review Boards. Written informed consent was obtained from all study participants of the intensive assessment.

Measures.

Worksite neighborhood SES. Worksite neighborhood SES was constructed using the appraised property value, a combination of bare land value and improved property onsite adjusted for differences in land parcel size[43]. Using this disaggregated worksite-specific measure of wealth may reduce the modifiable areal unit problem (MAUP) common in many area SES measures where differences in geographies with varying spatial extents can influence the magnitude and direction of associations in health studies[44]. This metric has been used recently in studies of area-level SES and health.[43,45] In this instance, however, the appraised property value was attributed to the worksite thereby rendering it a common area-level value for each employee nested within the worksite. Although specific to the land parcel of the worksite, assessed property value also generally represents values of properties with similar characteristics in the same area location[46]. Assessed property value and the square footage of the land parcel was linked to worksites via worksite address at baseline using tax data available from the King County Office of the Assessor. All worksites were situated on a single land parcel. Data from the 2006 tax year was selected to correspond to the timing of PACE baseline data collection. A second measure of worksite SES was assessed using SIC codes for PACE worksites including: 1) manufacturing (SIC: 20-29); 2) transportation and utilities (SIC: 40-49); 3) distribution (SIC: 50-59); 4) personal services (SIC: 70-79); 5) legal services (SIC: 81); 6) social services (SIC: 83); 7) professional services (SIC: 87); and 8) services unclassified (SIC: 89). A dichotomous variable was created to differentiate “blue collar” worksites (SIC: 20-69) from “white collar” worksites (SIC: 70-89). Blue collar work is usually defined as involving physical labor or wearing a uniform and includes industries such as manufacturing, construction, mining, and maintenance as well as services such as law-enforcement and fire protection. White collar work is usually defined as not involving physical labor and includes managerial, professional, or administrative professions. Here, white-collar designation is used as an indicator of higher worksite class as individuals within these occupations generally command higher salaries.

Worksite Neighborhood Density. Density is composed of multiple domains: density, perceived density, and crowding[109]. Density is generally defined as the number of units (e.g. people or dwellings) per unit area and is an objectively measured quantity. Area may be defined as the neighborhood, city, county, or areal quantity (e.g. km^2) and may include or exclude specific land-use types[132]. Net neighborhood density, for example, is defined as the number of units per land area devoted for residential facilities. Gross neighborhood density is defined as the number of units per total land area[132]. Evaluation of gross neighborhood density is relevant to neighborhood walkability, food accessibility, and opportunities for physical activity as this measure incorporates areas designated for those purposes[133]. Similarly, we would argue that this measure would be most related to stress as it incorporates all areas where neighborhood stressors may occur. Neighborhood density around the worksite was characterized by geocoding the worksite address at baseline and forming a buffer (i.e. a concentric circle with radius 0.5 miles) surrounding the worksite which is an area roughly equivalent to a Census blockgroup. Density of residential units was enumerated within this buffer using geospatial data sourced from University of Washington's Urban Form Lab.

Perceived Stress. The degree of stress due to life situations encountered by the participant during the past 30 days was assessed via Cohen's 10-item Perceived Stress Scale (PSS-10)[134]. Each item (e.g. "In the last month, how often have you been angered because of things that were outside of your control?") was answered on a five-point Likert scale ranging from "Never" to "Very Often". Possible total scores ranged from 0 to 40 with higher scores indicating greater perceived stress. The PSS has been used extensively in studies of human social stress and health outcomes and has good reliability [Cronbach's alpha: 0.84 to 0.86][134].

High-sensitivity C-reactive protein (hsCRP). C-reactive protein has been established as a biomarker of systemic inflammation with smaller elevations associated with obesity, heart disease, and cancer risk[93-95,107]. Inflammation has also been associated with the stress response and is a hypothesized mediator in psychobiological processes linking stress and chronic health outcomes[104,135]. Blood samples were collected from participants by trained study personnel at intensive assessment clinics held at worksites. Serum samples were stored at -80 degrees Celsius until analysis. The serum hsCRP was determined immunologically on a BN II nephelometer by Dade-Behring (Deerfield, IL, USA) with the use of kits from Diagnostic Systems Laboratories, Inc., (sensitivity 1.57 ng/mL). The assay was performed according to the manufacturer recommendations and quality was documented via agarose gel methods.

Work Stress. The isostrain model of work stress hypothesizes that workers with low social capital, high work demands, and low decision latitude (i.e. job control) are at increased risk for adverse health outcomes such as heart disease[136]. Information related to two dimensions of the isostrain model was collected. Worker social support was measured via 3 items based on perceived general support[137] including: 1) "I look forward to being with those on my shift or in my work group"; 2) " People take a personal interest in each other on my shift or in my work group"; and 3) "Members of my shift or work group really help and support one another"[138]. Responses were on a 4-point Likert scale anchored at "strongly agree" and "strongly disagree" and were averaged for all three items. Work demands were measured using the 8-item Work Limitations Questionnaire (WLQ) short-form[139]; domains assessed related to time-management (2 items), mental/interpersonal ability (2 items), physical ability (2 items), and work output (2 items). Items were scored according to recommendations with higher WLQ index scores indicating higher work demands. The WLQ score also produces a relative estimate of "presenteeism" which is defined as coming to work despite decrements in mental or physical health which often results in decreased productivity[111]. For example, a score of 20 relates to an approximate 20% decrease in productivity compared to a non-limited employee.

Statistical Analyses

We evaluated whether worksite-level SES and surrounding neighborhood density were associated with perceived stress, CRP levels, and dimensions of work stress of employees using linear mixed models to account for the hierarchical structure of the data. We also included robust standard errors to account for variable heteroskedasticity where appropriate. Log transformation of CRP values was performed to be consistent with reported literature. Tests for gender interaction were significant for work demands and worker social support, but not for perceived stress or CRP. Models were adjusted for: individual-level age, sex, race, and education as well as worksite-level parcel size and intervention group as fixed effects. A worksite-level random effect was also included in models to account for the hierarchical structure of the data. Models for work demands and social support were stratified by gender. All statistical analyses were performed via Stata SE, version 12.0 (Stata Corp., College Station, TX, USA*).*

RESULTS

Worksite- and individual-level demographic information is summarized in Table 7. Participants in the intensive assessment subsample appeared to be slightly older, more likely to be male, and of higher income and educational attainment compared to the full set of survey respondents. Additionally, the proportion of Asian participants was substantially smaller within the intensive assessment subsample compared to the larger cohort. Both subsample and the group from which it came were similar, however, with respect to reported work demands and social support.

Worksite context was not statistically significantly associated with employee perceived stress or CRP in these data and no significant interaction by gender was detected (Table 8). Significant gender interactions were present, however, in relationships of nearly all worksite contextual variables and work demands and worker social support. Worksite property value, class, and surrounding neighborhood density were associated with work demands among men (Table 9). Employee reported work demands varied by quartile of worksite-level SES ($p<0.0001$), although the pattern of association was not linear. Male employees of white-collar worksites reported lower work demands (Diff: 2.7; 95% CI: 0.01, 5.4; $p=0.049$) compared to blue-collar worksites. Employee reported work demands also varied by quartile of neighborhood density around worksites ($p=0.02$) although, again, the pattern of association was not linear. Reported social support of male employees was higher for white-collar worksites (0.12; 95%CI: 0.01, 0.23; $p=0.034$) than blue-collar worksites, but not significantly associated with SES or neighborhood density of the worksite.

Among women, a significant linear trend was observed in the relationship between neighborhood density of the worksite and reported work demands (Diff: 1.4; 95% CI: 0.7, 2.1; $p<0.0001$) whereas worksite-level SES and worksite class were not significantly associated (Table 9). Reported social support varied by quartile of neighborhood density around worksites (p=0.03) and was not significantly associated with worksite-level SES or worksite class.

DISCUSSION

We hypothesized that working in a poorer area would impact stress levels as workers would encounter social and physical cues indicative of neighborhood disorder and decay around the workplace. We also hypothesized that working in denser areas would be associated with higher stress. Worksite contextual variables, however, were not significantly associated with global perceived stress or CRP in these data. The literature pertaining to associations of social and built environment characteristics surrounding the home and perceived stress are mixed[121,140]. Studies of individuals in the U.S. and in the U.K., however, have found that those living in lower SES areas experience higher psychological distress as defined by domains of anxiety and depression[125,141-143] which are likely correlates of stress, especially among workers[144]. The association of neighborhood with stress has also been supported by findings with respect to cortisol response in that those in lower SES areas tended to exhibit a "blunted" diurnal profile, a hallmark of chronic stress exposure[122]. Factors associated with lower SES of the home neighborhood have also been associated with higher levels of CRP, a biomarker of systemic inflammation[145,146].

It is possible that the lack of findings in our study was due to no true association or we simply were not powered to detect it. We could only evaluate these relationships in the smaller intensive subsample with sample sizes of approximately 281 with non-missing perceived stress scale data and 447 with non-missing CRP data. Comparing our results to Everson-Rose and colleagues[121] is difficult as they use a 6-item version of the Perceived Stress Scale and present their final model adjusted for education, income, and marital status. Additionally, the aforementioned study had a large number of Black participants, a group demonstrated to report higher levels of stress[147,148]. The relationship between neighborhood SES and perceived stress was also not statistically significant in their fully adjusted models, although only a linear relationship was modeled. The previously published studies of stress and CRP were adjusted for gender, rather than stratified.

While we did not see significant linkages between worksite neighborhood context and global stress in these data, we did find differing associations with work-specific job demands and social support for both men and women. For men, working in areas characterized as white-collar was associated with fewer work demands and higher social support from co-workers whereas work demands significantly varied both for levels of SES and neighborhood density of the worksite. Interestingly, working in more densely inhabited areas was significantly associated with more work demands among women. Ascertaining correlates of work demands and worker social support is important as both are directly related to work productivity (an indicator of presenteeism) which has also been related to numerous chronic health outcomes including obesity[149,150]. While much has been reported on the effects of presenteeism and individual-level health outcomes, less is known about what environmental factors of a workplace might contribute to this decrease in productivity. In a review of workplace health promotion interventions, potential individual-level risk factors of presenteeism included: being overweight, a poor diet, a lack of exercise, high stress, and poor relations with co-workers and management[128,151]. This analysis suggests that being employed in certain types of worksites defined by SES or urbanicity also impacts worker productivity and social support. Workplace context, therefore, may impact domains of work stress and has also been associated with the individual-level correlates of presenteeism listed above (see paper 1). Worksite context, for example, was also associated with walking, free-time physical activity, fast-food and soft-drink consumption within this same cohort.

These findings, however, should be interpreted cautiously given their limitations and cross-sectional nature. We chose to evaluate associations at follow-up to address temporality as worksite context was measured at baseline, although it is possible that some workers may have been newly hired thereby lessening their exposure to the worksite neighborhood environment. Also, work-specific and global domains of stress were ascertained via self-report and may therefore be subject to some bias. In addition, study inclusion criteria selected worksites with a low turnover rate which may have placed limits on the variability of stress reported as turnover is a likely outcome associated with high stress work environments. Study strengths included accounting for the hierarchical structure imposed by study design as well as the use of robust standard errors when appropriate.

In conclusion, while worksite context did not significantly influence global perceived stress, it may still be salient to domains of work stress including work demands and social support. These more proximal associations do support a link between worksite context and the stress process as work is an important source of stressors encountered by many adults. Accounting for worksite contextual variables may also be important for organizational decisions to improve worker performance as well as guide worksite health promotion efforts aimed at reducing presenteeism. Intervening on presenteeism may also decrease risk for certain chronic diseases in the long-term as many of the individual-level risk factors are the same[152]. Additional studies are needed, however, before firm conclusions can be made.

Table 7. Worksite- and individual-level characteristics of 26 PACE worksites in King County, WA.

	Total Group		Intensive Assessment Subsample	
Worksite-level	N=26		N=26	
	Mean	SD	Mean	SD
Parcel size (sq.ft)	149,982.2	249,354.2	149,982.2	249,354.2
2006 Property value (USD)	$26,697,496	$60,102,598	$26,697,496	$60,102,598
Residential units	3,824.0	4,017.5	3,824.0	4,017.5
Individual-level	(n=1501)		(n=508)	
	%	n	%	n
Age				
18-34	30.0	450	13.7	60
35-44	27.1	406	26.5	116
45-54	25.9	388	32.5	142
55-65	17.1	257	27.2	119
Male	44.7	707	50.3	205
Race				
White	79.1	1123	86.7	429
African American	3.4	50	5.0	25
Hispanic/Latino	3.7	56	3.0	10
Asian	13.7	197	5.3	59
Education				
<HS, HS graduate or GED	16.9	254	20.9	106
Some college or technical	34.2	513	33.7	171
College graduate	34.5	519	27.3	139
degree	14.3	215	18.1	92
Household income				
<$50,000	26.6	345	22.8	95
$50,000 to $74,999	23.3	303	25.9	105
$75,000 to $100,000	20.1	262	21.0	85
>$100,000	30.0	395	30.2	121
	Mean	SD	Mean	SD
Work Demands (mean, sd)	1.7	1.1	1.8	1.0
Work Social Support (mean, sd)	3.2	0.5	3.1	0.5
Perceived Stress (mean, sd)	----	----	12.5	5.9
CRP[a] (mean, sd)	----	----	3.0	3.9

[a] mg/L

Table 8. Measures of social and built environment and domains of work stress at 2-year follow-up among men and women in 26 PACE worksites in King County, WA.

	Perceived Stress			CRP (mg/L)[a]		
	Mean[b]	95% CI	Pvalue[c]	Mean[b]	95% CI	Pvalue[c]
Social Environment						
Property value (USD)[c]			0.33			0.82
1,580,400-3,326,100	11.2	(9.5, 12.9)		1.67	(1.26, 2.23)	
3,402,000-5,228,100	13.1	(11.6, 14.5)		1.36	(1.09, 1.69)	
5,846,900-12,700,000	11.8	(10.3, 13.2)		1.71	(1.35, 2.16)	
18,000,000-298,000,000	12.4	(11.1, 13.7)		1.40	(1.12, 1.76)	
Worksite Class			0.40			0.62
Blue collar	12.3	(11.2, 13.5)		1.54	(1.29, 1.83)	
White collar	12.1	(11.1, 13.1)		1.48	(1.26, 1.74)	
Built Environment						
Neighborhood density			0.97			0.54
1-236	11.8	(10.3, 13.3)		1.31	(1.01, 1.70)	
269-2286	11.8	(10.2, 13.5)		1.64	(1.31, 2.06)	
2613-7920	12.3	(10.8, 13.9)		1.40	(1.10, 1.78)	
8484-13805	12.8	(11.2, 14.3)		1.63	(1.30, 2.05)	

[a] CRP values log-transformed for analysis; back-transformed predicted mean values presented
[b] Slope between groups estimated by multilevel linear model adjusted for individual-level age, sex, race, education, and job type and worksite-level treatment arm (fixed effects) and worksite random effect
[c] Wald test

Table 9. Measures of social and built environment and domains of work stress at 2-year follow-up among men and women in 26 PACE worksites in King County, WA.

	Men						Women					
	Work Demands			Work Social Support			Work Demands			Work Social Support		
	Mean[a]	95% CI	Pvalue[b]	Mean[a]	95% CI	Pvalue[b]	Mean[a]	95% CI	Pvalue[b]	Mean[a]	95% CI	Pvalue[b]
Social Environment												
Property value (USD)[c]			**<0.0001**			0.17			0.78			0.06
1,580,400-3,326,100	**4.6**	**(3.1, 6.0)**		3.1	(3.0, 3.2)		4.6	(2.0, 7.2)		3.3	(3.2, 3.4)	
3,402,000-5,228,100	**6.2**	**(4.8, 7.6)**		3.1	(3.0, 3.2)		4.6	(2.2, 7.1)		3.2	(3.1, 3.3)	
5,846,900-12,700,000	**1.9**	**(1.2, 2.7)**		3.2	(3.1, 3.3)		5.6	(4.0, 7.2)		3.1	(3.0, 3.2)	
18,000,000-298,000,000	**5.5**	**(4.9, 6.1)**		3.2	(3.1, 3.3)		5.6	(4.0, 7.1)		3.2	(3.1, 3.3)	
Worksite Class			**0.049**			**0.034**			0.65			0.06
Blue collar	**5.8**	**(4.5, 7.0)**		**3.1**	**(3.0, 3.2)**		4.6	(2.5, 6.8)		3.3	(3.2, 3.3)	
White collar	**4.0**	**(2.9, 5.0)**		**3.2**	**(3.1, 3.3)**		5.4	(4.4, 6.4)		3.2	(3.1, 3.2)	
Built Environment												
Residential density			**0.02**			0.22			**0.001**			**0.03**
1-236	**5.0**	**(4.1, 5.9)**		3.1	(3.0, 3.2)		**3.2**	**(2.3, 4.1)**		**3.2**	**(3.1, 3.2)**	
269-2286	**4.3**	**(3.3, 5.2)**		3.1	(3.0, 3.2)		**3.3**	**(2.5, 4.1)**		**3.3**	**(3.2, 3.3)**	
2613-7920	**6.2**	**(4.6, 7.9)**		3.2	(3.1, 3.3)		**6.7**	**(4.7, 8.8)**		**3.2**	**(3.2, 3.3)**	
8484-13805	**3.0**	**(1.4, 4.6)**		3.2	(3.1, 3.3)		**6.4**	**(4.5, 8.2)**		**3.1**	**(3.0, 3.2)**	

[a] Predicted means by gender estimated by multilevel linear model adjusted for individual-level age, race, education, and job type and worksite-level treatment arm (fixed effects) and worksite random effect
[b] Wald test that coefficients are jointly equal to zero
[c] Also adjusted for parcel size

Chapter 3:

Context and perceived stress: the roles of individual SES and objective versus perceived neighborhood among middle-aged non-Hispanic white women

ABSTRACT

Introduction: Substantial evidence links neighborhood socioeconomic status (SES) to health outcomes. Explanatory pathways, including the stress process, are being pursued to explain these associations, yet few studies have examined the association of neighborhood SES with perceived stress. Furthermore, it has been noted that perceived neighborhood characteristics such as neighborhood problems (e.g. threats to property or personal safety, litter and vandalisms, noise and odors, lack of amenities), neighborhood dissatisfaction, and perceived walkability (i.e. the extent to which an area is supportive of walking) should also be accounted for in models of neighborhood SES and stress. This is because they may have a direct relationship with stress ratings since they are individual-level modifiable appraisals of stressors and resources in the neighborhood more directly related to stress ratings. Perceptions of neighborhood characteristics may provide more actionable intervention targets than neighborhood SES would provide. Perceived neighborhood characteristics may also account for important differences in the relationship between neighborhood SES and stress as appraisal of neighborhood stressors likely depends on individual-level characteristics (e.g. SES) which may vary within the same neighborhood. The objective of this study was to investigate the degree to which perceived stress varies in relation to neighborhood SES and perceived neighborhood characteristics and whether these relationships depended on level of education among middle-aged non-Hispanic white women in South King County, Washington. We hypothesized that lower SES would correlate with higher stressors in the neighborhood and that both would be associated with higher perceived stress. Furthermore, we hypothesized that this association would be strongest for women of lower educational attainment.

Methods: A multi-stage sampling design was employed to recruit women from blockgroups with a large range of neighborhood SES and above-average proportion of Hispanic residents (N=143 blockgroups). Both Hispanic and non-Hispanic white women were recruited and invited to complete questionnaires that included questions on perceived neighborhood characteristics (i.e. neighborhood problems, neighborhood dissatisfaction, neighborhood walkability), perceived stress (via Cohen's 10-item Perceived Stress Scale; score range 0-40), social capital, and demographic information (i.e. age, education, income). This paper is restricted to the non-Hispanic white cohort. Generalized estimating equations (GEE) were used to assess predicted mean differences and 95% confidence intervals and accounted for correlations within blockgroups. Models were adjusted for individual-level age, education, level of social capital, and number of years lived in the neighborhood.

Results: Of the block-groups sampled, 112 had one or more non-Hispanic white women agreeing to participate in the study. The baseline survey was completed by 510 non-Hispanic white women. Associations between perceived stress and objective measures of the neighborhood were dependent on individual-level education whereas no gender interaction was present in associations between perceived stress and perceived neighborhood characteristics. Irrespective of individual-level educational attainment, higher perceived stress was associated with more neighborhood problems (Diff=0.42; 95% CI: 0.26, 0.58; $p<0.0001$) and greater neighborhood dissatisfaction (Diff=1.97; 95% CI: 1.05, 2.89; $p<0.0001$). Conversely, lower perceived stress was associated with greater perceived walkability (Diff: -0.46; 95% CI: -0.73, -0.18; $p=0.001$). While higher neighborhood SES was associated with lower stress for women with low education, the opposite was true for women with high education.

Conclusion: Not only are objective and perceived measures of the neighborhood associated with levels of perceived stress, the degree of association may be different for women with lower versus higher education. Additional longitudinal data from this cohort study and other longitudinal studies are needed, to confirm these associations and evaluate whether or not these relationships may be causal.

INTRODUCTION

Evidence supporting the influence of neighborhood contexts on health continues to grow with many studies linking area-level socioeconomic status (SES), a fundamental aspect of the neighborhood social environment[153], and physical and mental health outcomes[89,125,154]. Lower neighborhood SES, for example, has been associated with higher prevalence of asthma[155], obesity[156], cardiovascular disease (CVD)[157], as well as cancer mortality[97-99]. Evidence is accumulating to link lower neighborhood SES to perceptions of social and physical problems of neighborhoods (i.e. neighborhood disorder and decay)[125,158] as well as psychological distress (i.e. depression and anxiety domains) [125,159-163]. It has been suggested that much of the neighborhood variation in physical and mental health outcomes is mediated by perceived stress [89,164].

Stress is defined as an individual's adaptive response to external challenges and has been implicated in both behavioral and physiologic processes involved in the etiology of many chronic diseases[116]. Measurement of stress can essentially be divided into quantifying exposure to stressors, self-appraisal (i.e. perceptions), and behavioral or physiologic response [165]. Theoretically, any adverse environment may contribute to stress[165]. In practice, lower SES neighborhoods may pose greater number and magnitude of stressors to individuals who live in those neighborhoods via neighborhood characteristics such as poorer housing quality, limited access to services and infrastructure, threats to property and personal safety, discrimination, as well as diminished social capital compared with higher SES neighborhoods[89,125,154,163,166]. Furthermore, it has also been hypothesized that lower SES individuals experience higher risk of stress exposure in their work and family lives as well as their local environments[125] such that there may be a synergistic effect between area and individual levels of SES. Despite evidence supporting relationships between neighborhood SES and exposure to neighborhood stressors and evidence linking exposure to neighborhood stressors and perceived stress[167] , findings are equivocal from the few studies of neighborhood SES and perceived stress [121,140,168,169] and from studies of neighborhood SES and elements of the physiologic stress response[48,122]. Identifying mechanisms which explain how contextual influences are embodied may provide evidence of biologic plausibility, thereby strengthening causal inference, for associations between neighborhood, behaviors, and chronic disease outcomes.

Several issues hinder our ability to summarize associations between neighborhood SES and stress including differences in: 1) size and method for neighborhood definition; 2) selection of area-level SES measures; 3) age and social position (e.g. race and SES) of population studied; 4) metrics used for stress measurement; and 5) the inclusion of objective versus perceived measures of neighborhood SES. Given the universal use of neighborhood SES (e.g. household income, education, and occupation) as a key aspect of social environment[140], linkage of related demographic domains from the U.S. Census to health studies has become common practice. Greater consideration of the appropriate level of aggregation is being exercised to minimize the modifiable areal unit problem (MAUP), where differences in geographies with varying spatial extents can strongly affect the size and even direction of detected associations[44]. The census blockgroup is the smallest geographic area for which most census data can be obtained[96] and therefore is less likely to have large within-area differences in demographic characteristics compared to geographical units with larger spatial extent; investigators have moved towards using this level of aggregation for census data. Yet, there is still a lack of agreement as to what census variables to use to quantify SES given the large number of variables available including: median household income, % below federal poverty level, % female head of household, median household income, % with a bachelor's degree or higher, % holding white-collar jobs, to name a few, and the rationale behind variable selection is not always clear [140]. Attention to the age, gender, race/ethnicity, and social position of groups studied is also important as perceived stress varies by these groups with women, ethnic minorities, people of low SES, and people in middle-age experiencing higher levels of stress than their respective counterparts[116]. Inclusion of perceived measures of neighborhood in studies of neighborhood SES and stress is also important .Those within the same area can have varying perceptions and stress-appraisal of neighborhood characteristics that are influenced by individual differences such as gender, ethnicity, personality, and access to coping resources[170]. Furthermore, neighborhood perceptions measures may be more meaningful than objectively measured attributes of neighborhood since they are more proximally related to health compared to objectively measured attributes of neighborhood.[170]

The objective of this study was to investigate the degree to which perceived stress varies in relation to neighborhood SES and perceived neighborhood characteristics (i.e. neighborhood problems, neighborhood dissatisfaction, neighborhood walkability) at different levels of education. This analysis complements the evaluation of neighborhood SES, perceived neighborhood characteristics, and physiologic stress reactivity (i.e. cortisol non-response) in U.K. adults (see Chapter 4). We hypothesized that lower SES would correlate with higher stressors in the neighborhood and that both would be associated with higher perceived stress. Furthermore, we hypothesized that the neighborhood stressor-perceived stress association would be strongest for women of lower educational attainment. Our analyses within a large group of women aged 30-50 years (i.e. middle-aged) and of the same race address several limitations in the literature by reducing extraneous sources of variation while applying widely-used measures of perceived stress and neighborhood SES at the blockgroup level. Given our large sample size with a broad range of individual-level SES, we were also able to assess whether women with lower individual-level SES experienced more stress from their social neighborhood context compared to women with higher individual-level SES. Specifically, we hypothesized *a priori* that the relationship between neighborhood SES and stress would vary by individual-level SES.

METHODS

Study Design and Participants

The Socioeconomic Status and Obesity Study (SESO) was established to explain the association between SES and obesity among Hispanic and Non-Hispanic white women in South King County, Washington. The study was designed to test three specific mediating pathways including: 1) access to material resources; 2) psychosocial context; and 3) the stress process[171]. Women were recruited into the study using area-based sampling methods applied to a defined contiguous area of 454 block groups that had >4.4% Hispanic residents in the southern part of Seattle area. The first stage involved oversampling of blockgroups with a high representation of Hispanics, low education, and low income as determined by the 2000 census (N=143 blockgroups). Within block groups, clusters of houses were defined as "segments." A weighted random sample of segments was chosen within each blockgroup and houses within selected segments were approached by female study interviewers to determine residency of an eligible woman within selected households. Eligibility criteria included that participants were women aged 30-50 years who spoke English or Spanish and who were not planning to move out-of-state in the next 3 years (to facilitate longitudinal follow-up). Potential study participants were selected at screening stage to oversample women with low years of education among the non-Hispanic White group. Baseline data collection began in June of 2010 and finished in December 2011 and 1040 (530 Hispanic, 510 non-Hispanic white) women provided both screening and survey data. Analyses are limited to the cohort of white women to facilitate comparability with findings relating home neighborhood and stress in the U.K. (Chapter 4). Women were excluded if they had missing information on age (n=11), education (n=1), number of years lived in neighborhood (n=4), and perceived stress (n=5) resulting in a total sample size of 489 women within 112 blockgroups for this analysis.

Measures

Area-level SES. As SES includes the domains of income, education, and occupation, we selected commonly used census variables that mapped to these domains including: 1) percent of persons within a blockgroup living under 100% of federal poverty level (FPL); 2) median household income; 3) percent of persons with less than a high school education; 4) percent of persons with a bachelor's degree or higher; and 5) percent of persons within a blockgroup with a white-collar occupation. All measures were derived from the 2010 Census. The blockgroup is the smallest geographic area for which most census information is available, generally containing between 600 and 3000 persons[96]. We chose this level of aggregation to facilitate the interpretation and comparability of our findings.

Perceived Neighborhood Characteristics. There are many physical and social characteristics that correlate with neighborhood SES such as dirt and noise, vandalism, poor quality of housing and structures, lack of access to public services and amenities, threats to property and personal safety, as well as antisocial behavior of neighbors. Many of these characteristics are essentially tapping the constructs of neighborhood disorder and decay[124]. Detrimental neighborhood characteristics are measured neighborhood stressors or "problems" whereas beneficial characteristics are measured neighborhood resources. We used a 10-item scale developed by Steptoe and Feldman to quantify neighborhood problems which can be used to characterize any neighborhood [125]. Although developed in the U.K., neighborhood problems is a domain that has also been relevant to health outcomes in the U.S.[172,173].

Responses were on a 3-point scale and were summed to create a continuous score ranging from 10 to 30. Neighborhood dissatisfaction was quantified with a single-item (“Overall, how would you rate your community as a place to live?”) which could be answered with “excellent”, “good”, “only fair”, or “poor.” This measure of neighborhood is used to compare levels of social capital via the Social Capital Benchmark Survey in many communities across the U.S.[174,175] We also measured the perception of the walkability of the neighborhood, a generally accepted positive characteristic of the environment, which has been negatively associated with obesity and adverse health behaviors[172,173]. Walkability is defined as the degree to which an area supports walking or cycling for transport or recreation and is an indicator of access to services (e.g. shops, businesses, churches) as well as presence of supporting infrastructure (e.g. sidewalks, bus service, street connectivity, law enforcement)[77]. The perceived walkability of a neighborhood was assessed using 4 modified items from the Neighborhood Environment Walkability Scale (NEWS)[176]. Items included a single time domain (i.e. 20 minutes) versus 5 separate time-ranges per the original scale. Items included: 1) “There are many places to go (e.g. stores, businesses, churches, parks) within easy walking distance (i.e. within 20 minutes) of my home”; 2) “There are sidewalks on most of the streets in my neighborhood”; 3) There is a high crime rate in my neighborhood”; and 4) The sidewalks in my neighborhood are well maintained (paved, even, and not a lot of cracks).” Responses were on a 4-point Likert scale anchored at “strongly agree” and “strongly disagree.” Positive items were reverse-scored and all were summed to create a continuous score ranging from 4 to 16 with higher values indicative of higher walkability.

Perceived Stress. The degree of stress due to life situations encountered by the participant during the past 30 days was assessed via Cohen’s 10-item Perceived Stress Scale (PSS-10)[134]. Each item (e.g. “In the last month, how often have you been angered because of things that were outside of your control?”) was rated on a five-point Likert scale ranging from “Never” to “Very Often”. Possible total scores ranged from 0 to 40, with higher scores indicating greater perceived stress. Studies of human social stress and health outcomes extensively use the PSS which has good reliability [α: 0.84 to 0.86] [134].

Covariates. Individual-level age and SES (i.e. education) were obtained via screening interviews to establish participant eligibility. Level of education was assessed via single-item ("What is the highest degree or level of school you have completed?"). Responses were on a 16-point scale anchored at "no schooling completed" and moving to "nursery school or 4th grade", "5th grade or 6th grade", "7th grade or 8th grade", "9th grade", …, "12th grade, no diploma", "high school graduate", "some college, but less than 1 year", " 1 or more years of college, no degree", "associates degree (AA, AS)", "bachelor's degree (BA, AB, BS)", "master's degree (MA, MS, MSW, MBA)", "professional degree (MD, DDS, DVM, LLB, JD)", and "doctorate degree (PhD, EdD)". Educational level was divided into five categories for sampling purposes with 100% sampling in the lowest two categories (less than high school graduate, high chool graduate). For this analysis, low educational attainment was defined as having less than a Bachelor's degree as this was at the median of the variable distribution. Social capital, defined as the degree to which citizens within a community cooperate together to overcome shared dilemmas[177], may be a community resource that buffers the effect of neighborhood stressors on the stress process[125]. Social capital, measured via single-item (i.e. "How many times in the past 12 months have you volunteered (in your community, neighborhood, etc.?"), is one of 11 measures found on the Social Capital Community Benchmark Survey[174]. In general, these measures of social capital cohere as a core concept[174]. For example, those who volunteer in their neighborhood are also likely to be civically and politically involved, have greater social trust and informal social ties, as well as a diversity of friendships. Responses were measured on a 9-point discrete scale ranging from "never", "once", "a few times", "2-4 times",…, to "twice a month", "about once a week", "more than once a week". The number of years an individual lived in the neighborhood was also assessed via single-item from the Social Capital Community Benchmark Survey[174].

<u>Statistical analysis</u>

We evaluated whether neighborhood SES, measured via multiple Census domains, was associated with perceived neighborhood characteristics. We also evaluated whether perceived stress levels were influenced by lower neighborhood SES over and above perceptions of neighborhood characteristics among women with lower and higher educational attainment. Employing generalized estimating equations (GEE) assuming an exchangeable correlation structure to account for clustering by blockgroup, we first calculated predicted mean values and corresponding 95% confidence intervals (CI) for the difference in PSS-10 per unit change in neighborhood perceptions by level of education. We did not find evidence of interaction on the multiplicative scale. After first checking for interaction between individual-level education or income and area-level measures of SES, we then calculated predicted mean values and corresponding 95% CIs for the difference in PSS-10 per units representing the interquartile range of area-level SES variables. This is the predicted difference in stress between those in the 75%ile and those in the 25%ile of area-level SES variables. All models were adjusted for: age, education, social support, and the number of years the individual reported living in the neighborhood (Model 1). Individual-level measures of neighborhood problems, neighborhood dissatisfaction, and perceived walkability were then added (Model 2). The rationale for adjusting for these additional measures was to ascertain whether stress was impacted by area SES above and beyond individual-level perceptions of the neighborhood. Essentially, we wanted to determine whether neighborhood contextual associations existed beyond the individual-level neighborhood perceptions. All analyses were conducted using Stata SE version 12 (College Station, TX, USA).

RESULTS

Demographic and neighborhood characteristics for women below and above the median of individual-level education are presented in Table 10. Both groups were similar in age (about 40 years), although women in the lower education category reported higher levels of perceived stress compared to women in the higher education category. Length of time lived in the neighborhood as well as neighborhood perceptions and neighborhood SES variables appeared similar between groups.

There was no evidence of interaction on the multiplicative scale by individual-level education in associations between perceived neighborhood characteristics and stress. There was evidence of interaction by individual-level education, however, in relations between area-level SES and perceived stress. Our three measures of perceived neighborhood characteristics were strongly and significantly associated with perceived stress among all women in our sample (Table 11). Analyses were repeated adjusted for area-SES (and therefore stratified by individual education) and results were virtually identical to Table 11. Among women of lower education, living in a neighborhood with a higher proportion of individuals with white-collar occupations was associated with lower perceived stress (Table 12). This association persisted, although somewhat attenuated, after adjustment for neighborhood perceptions. Other measures of neighborhood SES were not significantly associated with perceived stress levels for these women. Among higher income women, however, living in a neighborhood with a higher proportion of persons in poverty, lower median household income, and lower proportion of individuals with a college degree were associated with lower perceived stress. These associations also remained after adjustment for perceived neighborhood characteristics. Living in areas with higher proportions of less than high-school educated or white-collar workers was not significantly associated with stress for these women. Measures of neighborhood SES were not significantly associated with neighborhood perceptions among women in these data (Table 13).

DISCUSSION

Perceived neighborhood characteristics were associated with perceived stress levels independent of individual-level SES (parameterized as education) among middle-aged white women in Seattle. Higher perceived problems and dissatisfaction and lower perceived walkability of the neighborhood were strongly associated with higher stress levels among women. In post-hoc analyses, results were virtually identical when individual-level SES was parameterized via family household income (data not shown). The relationship between perceived neighborhood characteristics with perceived stress did not vary by level of individual SES. Our findings are consistent with previously published studies with higher neighborhood stressors being associated with higher stress[167].

The association of objective neighborhood SES with perceived stress, however, was dependent on individual-level education in these data. Specifically, within women with education levels above the median, we found that living in lower SES neighborhoods was associated with lower perceived stress for women with higher individual-level education. This association was consistent across all measures of neighborhood SES, although not all were statistically significantly associated with stress. Furthermore, this association, while somewhat attenuated, persisted after adding measured perceived neighborhood characteristics to the models. This finding is contrary to hypotheses linking lower SES neighborhoods to poorer health outcomes. In contrast, among women with below the median education, living in lower SES neighborhoods (as measured by % of persons with white-collar occupation) was statistically significantly associated with higher stress. Post-hoc analyses where individual-level SES was parameterized via family household income were consistent and statistically significant only for one measure of neighborhood SES (i.e. % persons with white-collar occupation) and the association was subsequently explained by the addition of perceived neighborhood characteristics (data not shown).

Stratification by individual-level SES may be important to consider given the quite different patterns of association for women with lower education versus women with higher education. There may be one or more unmeasured neighborhood variables associated with neighborhood SES that differentially affect stress levels for lower education versus higher education women. In South King County, density is highly correlated with area-level SES and proximity to downtown Seattle. As density also dictates the access to and quality of infrastructure and services[109], living in higher SES neighborhoods may be less stressful for women who utilize these services (e.g. bus service). Additional studies are needed, however, to untangle these associations.

Several limitations bear consideration. First and foremost, the definition of neighborhood as census blockgroup may not apply to individual women's definition of neighborhood. This not only would affect relationships between objective neighborhood SES measures and stress, but may also impact the relevance of neighborhood perceptions to objective neighborhood SES measures as well. Also, survey scale items may introduce measurement error if differentially understood by women of lower versus higher education. This appeared not to be an issue with the perceived stress scale as scores were higher in women with lower education as has been noted elsewhere[142]. Finally, this study was cross-sectional by nature, using baseline data from a large cohort of single-race middle-aged women. Reciprocal causation, therefore, is quite possible in that women who felt under stress may have had different perceptions (or different reporting styles) as a result. Additional analyses of stress biomarker and follow-up survey data, however, may provide needed information to evaluate causal hypotheses.

In summary, we found associations between neighborhood perceptions and stress independent of objective neighborhood SES measures. Contrary to hypothesis, we found no association between objective area-level SES and measures of perceived neighborhood disorder. Furthermore, neighborhood SES measures may be associated with the stress process, but differentially according to population sub-group. As other investigators have noted[172], perceived neighborhood characteristics are important factors associated with health that are distinct from objective measures of the neighborhood. Including perceived measures of neighborhood characteristics in models explaining health outcomes is important as those living in the same area may have different perceptions of that area. Additional analyses of stress biomarker and follow-up survey data may provide needed information to further elucidate the causal hypotheses arising from the cross-sectional results.

Table 10. Area- and individual-level demographic characteristics of SES and Obesity (SESO) participants

	Low Education (n=243)	High Education (n=246)
Individual-level	**mean ± sd**	**mean ± sd**
Age	40.9 ± 6.0	38.8± 5.9
Perceived stress	17.6 ± 7.7	14.4 ± 6.8
Duration of neighborhood residence	3.2 ± 1.5	2.7 ± 1.1
Neighborhood problems	16.4 ± 4.0	15.9 ± 3.8
Neighborhood dissatisfaction	2.1 ± 0.7	1.9 ± 0.7
Perceived Walkability	11.0 ±2.3	11.3 ±2.4
Neighborhood-level		
% Persons below 100% FPL	16.6 ± 13.8	15.0± 14.1
Median household income	53,099 ± 17,023	54,814 ± 17,696
% with less than HS education	19.5 ± 11.3	17.2 ± 10.5
% with college degree	22.7 ± 13.8	25.1 ± 14.6
% with white-collar occupation	26.1 ± 13.2	28.5 ± 13.7

[a] Number of persons in block group with white-collar occupation per block group population
[b] Number of persons in block group below 100% federal poverty level (FPL)per total block group population

Table 11. Predicted mean difference in perceived stress associated with neighborhood perceptions among middle-aged white women in SESO.

	Diff[a]	95% CI	P-value[b]
Neighborhood problems	0.42	(0.26, 0.58)	<0.0001
Neighborhood dissatisfaction	1.97	(1.05, 2.89)	<0.0001
Perceived walkability	-0.46	(-0.73, -0.18)	0.001

[a] Predicted mean difference in perceived stress per unit neighborhood perception adjusting for individual age, education, social capital, and number of years in neighborhood
[b] Wald test

Table 12. Predicted mean difference in perceived stress associated with area-level SES among participants with low and high education in SESO.

	Low Education			High Education			
	Diff[a]	95% CI	P-value[b]	Diff[a]	95% CI	P-value[b]	P-value for Interaction[c]
% Persons below 100% FPL							**0.04**
Model 1	0.69	(-0.47, 1.84)	0.25	**-1.67**	**(-2.62, -0.73)**	**0.001**	
Model 2[d]	0.75	(-0.45, 1.96)	0.22	**-1.55**	**(-2.54, -0.56)**	**0.002**	
Median household income							**0.02**
Model 1	-0.24	(-1.11, 0.62)	0.58	**0.93**	**(0.20, 1.66)**	**0.01**	
Model 2[d]	-0.22	(-1.10, 0.67)	0.63	**0.83**	**(0.06, 1.59)**	**0.03**	
% with less than HS education							**0.048**
Model 1	0.56	(-0.66, 1.79)	0.37	-1.17	(-2.39, 0.05)	0.06	
Model 2[d]	0.32	(-0.91, 1.54)	0.61	-1.03	(-2.24, 0.19)	0.10	
% with college degree							**0.005**
Model 1	-0.75	(-2.14, 0.65)	0.30	**1.36**	**(0.15, 2.56)**	**0.03**	
Model 2[d]	-0.16	(1.59, 1.28)	0.83	**1.25**	**(0.04, 2.46)**	**0.04**	
% Persons with white-collar occupation							**0.002**
Model 1	**-1.42**	**(-2.54, -0.31)**	**0.01**	0.88	(-0.17, 1.92)	0.10	
Model 2[d]	**-1.23**	**(-2.42, -0.03)**	**0.04**	0.70	(-0.36, 1.76)	0.20	

[a] Predicted mean difference in perceived stress per change in interquartile range (IQR) of block-group level neighborhood SES variables adjusting for individual age, education, social capital, and number of years in neighborhood
[b] Wald test
[c] P-value for interaction between neighborhood SES measures and individual SES (i.e. education)
[d] Also adjusted for neighborhood problems, neighborhood dissatisfaction, and perceived walkability
FPL=federal poverty level

Table 13. Predicted mean difference in neighborhood perceptions associated with area-level SES among participants in SESO.

	Neighborhood Problems			Neighborhood Dissatisfaction			Perceived Walkability		
	Diff[a]	95% CI	P-value[b]	Diff[a]	95% CI	P-value[b]	Diff	95% CI	P-value
% Persons below 100% FPL	-0.06	(-0.39, 0.26)	0.72	-0.02	(-0.08, 0.04)	0.52	0.08	(-0.13, 0.28)	0.46
Median household income	0.11	(-0.21, 0.44)	0.48	0.03	(-0.03, 0.08)	0.39	-0.09	(-0.29, 0.11)	0.38
% with less than HS education	0.03	(-0.29, 0.36)	0.85	0.03	(-0.03, 0.09)	0.38	-0.08	(-0.28, 0.12)	0.44
% with college degree	-0.03	(-0.36, 0.30)	0.85	-0.03	(-0.09, 0.04)	0.42	0.06	(-0.14, 0.26)	0.57
% with white-collar occupation	-0.05	(-0.38, 0.28)	0.77	-0.01	(-0.07, 0.05)	0.70	0.10	(-0.10, 0.30)	0.33

[a] Predicted mean difference in neighborhood perceptions per quartile of each census variable adjusting for individual age, education, and number of years in neighborhood
[b] Wald test
FPL=federal poverty level

Chapter 4:

Socioeconomic deprivation, perceived neighborhood disorder, and cortisol non-response to mental stress

ABSTRACT

Background: There is a growing literature relating neighborhood factors with health. One hypothesized mechanism involves the individual's response to chronic stress stemming from exposure to the social environment, but few studies have tested how objective or perceived aspects of the social neighborhood impact psychobiologic processes.

Objective: The purpose of this study was to verify that perceptions of neighborhood disorder (i.e. social control, neighborhood threat, fear of crime) were associated with objective measures of the social environment (i.e. income and employment deprivation) as well as determine whether these perceptions were associated with cortisol reactivity among older healthy British men and women.

Methods: Participants (N=526, age= 62.8 ±5.7 yrs) were drawn from the Heart Scan study, an ancillary study of the Whitehall II epidemiological cohort. Generalized estimating equations (GEE) were used to estimate differences in scores of social control, neighborhood threat, and fear of crime per percent increase in area income and employment deprivation adjusting for age, sex, duration of neighborhood residence, and individual-level measures of income and employment. A logit link function was used to evaluate the estimated odds of cortisol non-response (i.e. "blunted" cortisol response profile associated with chronic stress) associated with area measures of deprivation as well as social control, neighborhood threat, and fear of crime. Cortisol non-response was defined as a <5% increase in cortisol to two mental stressors, the Stroop task and mirror tracing. These analyses were adjusted for age, sex, average task stress rating, baseline cortisol level, duration of neighborhood residence, and individual-level income.

Results: Increase in quartile of area-level income deprivation was associated with lower social control (slope: -0.42; 95% CI: -0.75, -0.08; p=0.017) and higher neighborhood threat (slope: 0.13; 95% CI: 0.8, 0.19; p<0.0001). Fear of crime was not associated with income deprivation in these data. Similar results emerged for area employment deprivation. The highest levels of income and employment deprivation were also associated with risk of cortisol non-response (OR=1.94; 95% CI: 1.19, 3.17; p=0.008) and (OR=1.90; 95% CI: 1.17, 3.09; p=0.009), respectively. Social control (OR=0.94; 95% CI: 0.90, 0.97; p=0.001) and neighborhood threat (OR=1.43; 95% CI: 1.13, 1.81; p=0.003) were significantly associated with cortisol non-response. Fear of crime was essentially unrelated to cortisol in these data.

Conclusion: These findings support the hypothesis that social environment influences neighborhood perceptions which, in turn, are associated with physiologic differences associated with disease processes. Given that few studies have explored how cortisol is affected by neighborhood perceptions, more research is needed before firm conclusions can be drawn.

INTRODUCTION

Neighborhood and health

The literature evaluating place-based effects on health is voluminous and can be broadly categorized by type of environment (e.g. social vs. physical) as well as outcome (e.g. mental vs. physical health). Furthermore, these domains may also be sub-divided by type of exposure measurement (e.g. objective vs. subjective). Social environment has been operationalized objectively based on collected demographic census information such as education, median income, car ownership, employment status, occupation, racial composition, as well as created composite indices of these variables. In a critical review, the majority of these type of social environment variables were modestly associated with such outcomes as mortality, morbidity, chronic disease, and health behaviors after adjustment for individual-level socio-demographic factors[74,154]. While the effect of individual SES was much greater, these studies supported the notion that social context does play a role in people's health. Perceptions of the social environment are subjectively measured, highly associated with objective measures[178,179] , and include constructs such as collective efficacy, social control, social cohesion, social fragmentation, and neighborhood disorder. Overall, findings in the literature suggest that a positively perceived social environment is associated with better mental health and health behaviors[180] although reverse causation, with mental health influencing neighborhood perceptions, cannot be ruled out. Evidence for associations between perceived social environment and chronic disease outcomes is also emerging[156,181,182]. Similar to findings in the field of cardiovascular research, a large prospective study recently found lower stroke mortality to be significantly associated with greater social cohesion[181]. Studies of both social[72,124,183] and built environment characteristics[67,71,184] have suggested that although related, observed and perceived measures of neighborhood are not interchangeable and may even vary systematically with perception mediating the effects of neighborhood on health[72,124,170].

Perception and stress

The stress process may provide a means to operationalize the link between the individual and the various environmental contexts within which it is nested as suggested by the socio-ecologic model[46]. Research interest in stress's potential mechanistic role in health continues to grow for it is an individual-level response to area-level environmental factors as well as an integral component of individual-level chronic disease processes[116]. Stress is a condition of living and is described as involving the activation of neurobiological systems that preserve viability through change or allostasis[116]. When environmental demands challenge or overwhelm the adaptive capacity of an individual, cognitive, behavioral, as well as physiologic processes arise which increases risk for disease[185,186]. The extent of this response depends on the type, intensity, and duration of the stressor. Causes of stress may include neighborhood stressors, such as high crime rates or lack of infrastructure in addition to individual-level stressors such as illness or injury[187]. Any event, scenario, or object can conceivably be thought of as a potential source of stress (i.e. stressor) depending on how it is perceived and appraised in relation to the individual[188]. Perceived neighborhood disorder, a subjective measure of the social environment, is generally higher among areas of low SES and has been shown to be associated with depression, anxiety, and psychological distress[80]. Social position (of which level of income, education, and employment are indicators) is a salient and ubiquitous cause of stress as it impacts many group-level attributes via access to material and social resources necessary for successful living. In a U.S. probability sample, for example, perceived stress levels were shown to be higher among lower levels of socioeconomic status (SES)[142] while the Whitehall II cohort has demonstrated linkages between low SES and physiologic indicators of abnormal stress response among individuals in the United Kingdom (U.K.)[189,190].

Once something is identified as a stressor, psychobiological processes are activated, notably the sympathetic-adrenomedullary (SAM) system and the hypothalamic-pituitary-adrenocortical (HPA) system, that involve complex feedback between hormones in the body, autonomic processes, and specific areas of the brain[187]. These systems may affect emotional, cognitive, and behavioral reactions as well as the physiological functioning of the individual (e.g. cortisol response). While responses to shorter acute stressors are beneficial for survival, more frequent or prolonged exposure to stressors has been associated with increased disease risk as it is hypothesized that chronic activation damages feedback loops that return hormonal levels to normal[187]. Physiological 'wear and tear' (i.e. allostatic load) attributed to overexposure to stress processes is a phenomenon of disease-risk that is associated with socioeconomic status[78]. Specifically, allostatic load occurs when allostatic processes (e.g. HPA axis) are overworked or fail to "turn off" or, conversely, fail to "turn on" in response to stress[191]. Therefore, both heightened and prolonged cortisol response as well as cortisol non-response to initial challenge are indicative of abnormal physiologic functioning associated with chronic stress[192] and disease[193] and one likely consequence of such 'wear and tear'[191,194-196]. While a lack of cortisol response may result in low-levels of cortisol, or hypocortisolemia, this same lack of response (i.e. "blunted" profile) may also occur among those with already high levels of cortisol[192]. Specifically, cortisol non-response might reflect exhaustion of allostatic regulatory mechanisms, central corticotropin releasing factor (CRF) downregulation, or alterations in feedback sensitivity. For example, it has been posited that stress exacerbates conditions characterized by deficient cortisol signaling (i.e. posttraumatic stress disorder (PTSD), chronic fatigue syndrome, rheumatoid arthritis) while it has also been found that stressors that threaten physical well-being, involve trauma, or are uncontrollable elicit a high, flat diurnal cortisol secretion profile[192]. Clearly, detecting associations between HPA function and chronic stress is complex due to both over- and under-exposure to cortisol providing mechanisms leading to disease[192].

Despite the widely held view that physiologic stress in response to psychosocial factors provides a mechanism linking neighborhoods and health, there remains a scarcity of information relating neighborhood perceptions to stress biomarkers[122]. The objective of this study, therefore, was to first verify the relationship between neighborhood characteristics of the social environment (i.e. income and employment deprivation) and measures of neighborhood perception (i.e. social control, neighborhood threat, fear of crime) (Figure 1). Specifically, we expected that higher levels of area socioeconomic deprivation would be associated with lower perceptions of social control and higher perceptions of neighborhood threat and fear of crime. Furthermore, we sought to evaluate whether these perceptions of threat were associated with cortisol non-response as well as the extent to which they mediated associations with area socioeconomic deprivation among older British civil servants.

METHODS

Participants

These analyses were conducted within the Heart Scan Study, an investigation of the psychobiological processes associated with socioeconomic and psychosocial factors, physiological stress responsivity, and sub-clinical cardiovascular outcomes[197,198]. Heart Scan Study participants were healthy men and women aged 53-76 years who were drawn from Whitehall II, an epidemiological cohort of British civil servants established to evaluate socioeconomic disparities in health[199], for psychophysiological testing during 2006-2008[200] . Eligibility criteria included: no history or clinical signs of CHD, no previous diagnosis or treatment for hypertension, inflammatory diseases, or allergies and no medication which might affect cortisol levels, including hormone treatment and recruitment was restricted to only include participants within a 100 mile radius of London. Heart Scan participants tended to be of higher employment grade (i.e. middle-ranking executive grades and senior administrative grades vs. clerical and office support grades). This was due to a higher proportion of participants from lower work grades who declined to take part compared with higher grades, (38.6% vs. 20.3%, respectively). The study group comprised 543 individuals of white European ancestry, 541 of whom resided within England and 2 within Wales. These analyses are limited to residents of England. Our sample is also further limited to those without missing data on demographic covariates (i.e. age, gender, number of years residence in neighborhood, and household income) for a total of N=526.

Cortisol stress responses

Methodology for psychophysiological testing for the Heart Scan Study has been described elsewhere[197,201]. Briefly, a saliva sample was taken via Salivette (Sarsted, Leicester, U.K.) for baseline assessment of cortisol after the participant rested for 30 minutes. Mental stress was induced via two 5-minute behavioral tasks, a computerized version of the Stroop task and mirror-tracing, administered in random order [202]. The Stroop task presents the participant with target color words (e.g. blue, green, red, yellow) printed in another color[203]. Participants were asked to select the color that the target color word was printed in via keystroke using 1 of 4 letters that were assigned to a specific color. To ensure sustained demands, the rate of presentation of stimuli was adjusted to the performance of the participant. The mirror-tracing task involves moving a stylus along the outline of a printed start which is seen in mirror-image[204]. Each time the stylus veers from the outline, the error is counted and a loud beep is emitted by the apparatus (Lafayette Instruments Corp., Lafayette, IN, USA). Participants were told that the average person could complete five circuits of the star in the available time to increase levels of social-evaluative threat, a stressor highly associated with cortisol response in humans[205]. Study personnel collected another saliva sample immediately after administering both stress tasks. Participants then rested for 75 minutes and post-task measurements were taken at 20 minutes, 45 minutes, and 75 minutes. As the time course of cortisol response to mental stress varies between individuals, participants were defined as non-responders if they did not experience at least a 5% increase relative to baseline (where distribution median corresponded to 10% increase relative to baseline) either immediately or at 20 minutes post task. Using cortisol response distribution to characterize over-responders (approximately 75%ile of distribution) in relation to health outcomes has also been used in this cohort[197,201]. Levels of cortisol were assessed using a time resolved immuno-assay with fluorescence detection, at the University of Dresden, Germany. The intra and inter-assay coefficients of variation were <8%.

Neighborhood perceptions

Social control. A measure of informal social control that was developed for the Project on Human Development in Chicago Neighborhoods[153] was used to assess whether respondents perceived that their neighbors would take action to safeguard the welfare of the neighborhood. This measure is thought to tap the same latent construct as social cohesion and includes elements of willingness and intention to intervene on behalf of neighbors which is also likely enhanced under conditions of mutual trust and cohesion[153]. Participants were queried about the likelihood (response ranging from "very unlikely" to "very likely" on a 5 point Likert scale) that their neighbors could be counted on to intervene in various ways if: 1) children were truant and loitering; 2) children were doing graffiti on a local building; 3) children were showing disrespect to an adult; 4) fighting broke out in front of your home; and 5) the school closest to home was threatened with budget cuts. The last question was adapted from the original item, "The fire station closest to your house was threatened with budget cuts", to be appropriate in the U.K.[206]. The internal consistency of the scale (Cronbach's alpha) in this sample was 0.87.

Neighborhood threat. Neighborhood disorder refers to visible social and physical cues indicating a breakdown of order and social control in a community[124]. Visible signs of social disorder include fights, public drinking, begging or loitering, and creating a sense of danger or distrust whereas signs of physical disorder pertain to the overall physical appearance of the neighborhood[124]. Our measure of "neighborhood threat" includes 9 items related to perceived safety and inclusion in the neighborhood (e.g. feelings of belonging and loneliness, trust and friendliness of neighbors, fear of walking alone, neighbor's fair treatment and willingness to act) as well as its physical characteristics (e.g. presence of litter and graffiti). As neighborhood disorder is conceptualized on a continuum[124], responses ranged from 1 to 7 anchored with the positive and negative statement of each item (e.g. "I often feel lonely living in this area" versus "I have never felt lonely living in this area"). Items were adapted from those developed by Ross and Mirowsky[124]. The internal consistency of the scale (Cronbach's alpha) in this sample was 0.79.

Fear of crime. To assess the level of perceived danger due to violence in their neighborhood, participants were asked how worried they were regarding the following: a) having their home broken into; b) being mugged or robbed; c) having their car broken into or stolen; and d) being raped. Possible responses were "very worried" (score 3), "fairly worried" (2), "not very worried" (1), or "not worried at all" (0). This measure has been used within the total Whitehall II cohort and found to be associated with poorer mental health, reduced physical functioning, and lower quality of life [207]. The relationship between fear of crime and neighborhood context likely differs for men and women[208] , especially with respect to the fear of sexual assault [209]. We therefore chose to drop the last item and sum the remaining items to create a fear of crime score ranging from 0-9 (Cronbach's alpha =0.78).

Area-level socioeconomic deprivation

Participants provided their home address as well as the number of years of residence via self-report. Postcodes were then matched to a geographic administrative boundary called a lower super output area (LSOA), which is the smallest aggregation used to disseminate census information in the U.K. The area-level socioeconomic measures were obtained from the Index of Multiple Deprivation (IMD) 2007 which provides deprivation information based on 38 indicators grouped in seven domains including income and employment[210]. Data are aggregated at the level of LSOA and both the rate of deprivation and the rank of LSOAs from most to least deprived are provided for each domain. There are 32,482 LSOAs in England with a population range of 1000 to 3000 and an average of 1500 people[211] which is analogous to a U.S. Census blockgroup[96]. Income deprivation for England is defined as the proportion of individuals within a LSOA who are below 60% of the median income for England. Employment deprivation for England is defined as the proportion of those within an LSOA who receive Job Seeker's Allowance (JSA), both contribution- and income-based, derived from the Department of Work and Pensions (DWP) Work and Pensions Longitudinal Study (WPLS). The 2007 version of the IMD is formulated primarily from administrative data gathered in 2005 and data is available to academic institutions within the U.K.

Statistical analysis

Due to heteroskedasticity of the error variances that was not remedied by log transformation of variables, we employed generalized estimating equations (GEE) to evaluate associations. As we wanted to account for the variance at multiple levels and not necessarily estimate those variances specifically, GEE was chosen as it performs well when there are numerous groups (here, N=516) with few observations within each group (n=1-3 individuals per group). We assumed an exchangeable working correlation matrix as it is plausible that the same correlation in error variances exist for each pair of persons within an area.

We calculated predicted mean values and corresponding 95% confidence intervals (CI) for the difference in each neighborhood perception variable per one unit change in rate of area-level deprivation for both the income and employment domains. Three models for each neighborhood perception variable (i.e. social cohesion, neighborhood threat, and fear of crime) are presented with the first model adjusting for age and gender only. Model 2 adds the number of years in the neighborhood as a covariate to minimize possible differences in neighborhood perceptions due to a recent move, for example, where social ties to a new area would likely be underdeveloped. Model 3 then adds individual level income for the models assessing the association with area-level income deprivation and individual level employment grade as a covariate for the model assessing the association with area-level rate of employment deprivation. In essence, we attempted to ascertain if an area-level effect exists above and beyond the corresponding individual-level effect.

We then calculated odds ratios and corresponding 95% CIs using a logit link function to approximate the odds of cortisol non-response due to area-level measures of deprivation as well as all three measures of neighborhood perceptions. For area deprivation, estimated odds of non-response are presented for quartiles of both deprivation variables due to heteroskedasticity and to facilitate interpretation.

To test for mediation, we employed currently recommended product-of-coefficients methods involving biased-corrected bootstrapped 95% confidence intervals[212,213], applicable to dichotomous outcomes[214]. Essentially, the equation for the indirect effect takes the form of:

$$\mathbf{OR \approx exp[}\boldsymbol{a*b}\mathbf{]}$$

where *a* is the coefficient resulting from GEE relating the predictor and mediator (e.g. the association of income deprivation with social control) and *b* is the coefficient resulting from GEE with a logit link function relating the mediator to the outcome while adjusting for the predictor (e.g. the association of social control with cortisol non-response independent of income deprivation). The indirect, or mediating, effect is considered statistically significant if the bootstrapped bias-corrected 95% confidence intervals do not include one. All analyses were conducted using Stata SE version 11 (College Station, TX, USA).

RESULTS

Descriptive information concerning area-level neighborhood and individual demographic and outcome measures is presented in Table 14. The mean age of the total group was 62.9 years (SD= 5.7 years), slightly more than half of individuals were male and about 20% were of lower employment grades. Cortisol non-responders reported slightly lower scores for social control compared to responders while other measures of neighborhood perceptions appear comparable between the two groups. By region, approximately 45.5% reporting living in London while about 35.5% reporting living in South East England. As one would expect, very few reported primary residences in the more rural regions of the country. Area-level measures of socioeconomic deprivation also appear slightly higher in cortisol non-responders. The correlation between income and employment deprivation measures was 0.89.

Crude analyses showed that the rate of area-level income deprivation in the neighborhood was significantly associated with two of the three measures of neighborhood perceptions used in this study (Table 15). Despite evidence of confounding, especially due to level of individual household income, the area-level associations remained significant in Model 3. Specifically, a 1-quartile difference in neighborhood income deprivation was associated with a 0.42 (95% CI: -0.75, -0.08; p=0.017) lower social control score and a 0.13 (95% CI: 0.8, 0.19; p<0.0001) greater neighborhood threat score. Area income deprivation was not significantly associated with fear of crime in these data. Significant associations between area-level employment were exhibited for all neighborhood perceptions (Table 16) after adjustment. Specifically, a 1-quartile higher rate of employment deprivation was associated with 0.36 (95% CI: -0.70, -0.03; p=0.033) lower social control score, a 0.14 (95% CI: 0.08, 0.20; p<0.0001) higher neighborhood threat score, and a 0.13 (95% CI: 0.01, 0.25; p=0.034) higher fear of crime score. The corresponding associations in Tables 15 and 16 all had similar signs.

Area-level deprivation measures of the neighborhood were also associated with estimated odds of cortisol non-response. A significant trend in the relationship between income deprivation and cortisol non-response was evident (p-value for trend= 0.024), although the pattern of increase in cortisol non-response in relation to income deprivation was somewhat irregular. The highest quartile of deprivation, however, exhibited a significant association even after adjustment for individual level demographic factors including household income (OR=1.94; 95%CI: 1.19, 3.17; p=0.008) (Table 17). A significant trend in the relationship between employment deprivation and cortisol non-response (p-value for trend= 0.008) with the highest quartile of deprivation also showing the highest association (OR=1.90; 95% CI: 1.17, 3.09; p=0.009) (Table 18).

Relationships between neighborhood perceptions and odds of cortisol non-response were significantly demonstrated for two of the three measures. After adjustment for age, gender, baseline cortisol level, perceived stress of mental stress task, number of years in the neighborhood, and individual household income, there was an estimated 6% reduction in odds of cortisol non-response associated with one unit higher social control (OR=0.94; 95% CI: 0.90, 0.97; p=0.001) (Table 19). In addition, higher neighborhood threat also appeared to be associated with greater odds of cortisol non-response (OR=1.43; 95% CI: 1.13, 1.81; p=0.003). Fear of crime, however, was not significantly associated with cortisol non-response in these data.

Mediation analyses indicated that both social control and neighborhood threat significantly contributed to the relationship between income deprivation and cortisol non-response (Table 20). A quartile higher rate of income deprivation was associated with about a 3% increased odds of cortisol non-response (OR=1.028; 95% bias-corrected CI: 1.021, 1.032) via lower social control. About a 4% increased odds of cortisol non-response was associated with a quartile higher rate of income deprivation through higher neighborhood threat.

DISCUSSION

Previous literature suggests an overall effect of neighborhood on health[180,215] and neighborhood analyses within the Whitehall II study cohort supported this[75]. Specifically, area-level deprivation as measured by the Townsend deprivation index was found to have a dose-response relationship to self-rated poor health which incorporates both physical and mental health domains. Further, a neighborhood perception (i.e. fear of crime) was also found to be associated with both mental health and physical functioning in this same cohort[207]. Tasked with exploring the psychobiologic mechanisms linking social position and health in Whitehall II, the Heart Scan Study provided a unique opportunity to test more specific variables in this pathway (e.g. separate domains of income and employment deprivation, multiple neighborhood perceptions, and cortisol response). To our knowledge, this is the first analysis relating objectively measured social context, neighborhood perceptions, and psychobiologic elements of the stress response.

High correlation between income and employment deprivation (r=0.89) introduces the potential for collinearity, thereby rendering these area-level effects to be indistinguishable. In this study, patterns of association between these two measures of socioeconomic disadvantage and perceptions of neighborhood threat were very similar. As these measures are likely tapping the same underlying construct, it may be more appropriate to interpret them together as indicators of broader socioeconomic deprivation. Participants who lived in areas with greater socioeconomic deprivation tended to report less social control, greater neighborhood threat, and greater fear of crime even after adjusting for individual-level household income. That is, there appeared to be a contextual effect whereby living in a poorer area engendered negative neighborhood perceptions regardless of the socioeconomic status of the individual. These findings are consistent with the literature on objective measures of neighborhood socioeconomic status being moderately related to perceived measures of the neighborhood[183].

Socioeconomic deprivation was salient to the individual manifestation of the stress process as well as the appraisal of the neighborhood. The highest quartiles of both income and employment deprivation were associated with increased risk of cortisol non-response. These findings are consistent with a breadth of literature evaluating the effects of SES on psychobiological processes (specifically, blunted cortisol response profiles) associated with chronic stress exposure[195,216] as well as similar analyses in the parent cohort[190]. Yet, few studies have then attempted to further operationalize this association. Given that perception and appraisal is key to activating the stress process, it follows that neighborhood perceptions explain at least part of the relationship between area SES and stress[89]. Mediation analyses supported this line of thinking. In other words, individuals who lived in more socioeconomically deprived areas appeared to exhibit higher risk for abnormal laboratory-induced cortisol non-response associated with chronic stress exposure due to both lower social control and higher neighborhood threat.

Interestingly, Do and colleagues found that perceptions of violence were more strongly related to waking cortisol levels while other measures of neighborhood perceptions such as social cohesion and disorder were less consistently associated with cortisol[122]. Although our studies share an overlapping construct of crime/violence, the measures used to operationalize this construct are different and any bias in either measure could lead to differences in the magnitude of effect. Furthermore, this study was conducted in the U.K. versus the U.S. where social norms, fears, and perceptions likely differ. Finally, this study measured the cortisol response to a laboratory-induced challenge versus measured diurnal cortisol profile. However, Do and colleagues did report that those in the highest tertile of violence exhibited a blunted diurnal cortisol profile[122] which, similar to lack of cortisol response to a stressor, might reflect exhaustion of allostatic regulatory mechanisms, central CRF downregulation, or alterations in feedback sensitivity associated with chronic stress exposure[191,217]. Our findings are also consistent with studies involving neighborhood perceptions and subjective stress[125,218-221], a precursor to biologically manifested stress responses[188]. For example, a study among London-area residents found that neighborhood problems were associated with higher levels of psychological distress independent of area-level SES, age, gender, individual deprivation, and social capital[125]. Also, among low-income African-American patients with diagnosed post-traumatic stress disorder (PTSD), neighborhood perceptions of disorder were associated with symptoms independent of traumatic event[222].

Some limitations of our study should be borne in mind. First, measurement of individual perceptions was completed via self-report and at a single-point in time. It is also possible that our measure did not adequately capture neighborhood perceptions. This would be an issue for more rapidly changing neighborhoods and could differ for newer residents who are less familiar with the area (which we attempted to account for by considering length of neighborhood residence).

Additionally, Heart Scan participants, drawn from the Whitehall II epidemiological cohort, tended to be older, mostly white British civil servants of higher employment grade and who were free of disease at study enrollment[197]. These study restrictions may, in essence, control for causally downstream effects of physiologic stress (e.g. CHD and hypertension) thereby possibly attenuating associations of interest. For example, participants likely lived in more affluent areas as well and sufficient range of exposure to neighborhoods of high and low deprivation could be an issue. In comparing the top 20% of income deprived LSOAs reported by Heart Scan participants, the mean rate of income deprivation was 21.4% compared with 35.4% for all of England[223]. This could be due to the large proportion of participants who resided in South East England (which has a low rate of income deprivation) and relatively few participants residing in the more rural regions (which report higher rates of income deprivation)[223]. Despite a lower average rate of income deprivation compared to all of England, the range within this study was still quite broad (i.e. 1% to 46%). The range of area-level rate of employment deprivation, however, was more limited (i.e. 1% to 24%) and could be one explanation for the weaker findings for this variable. Also, the exclusion of participants with chronic disease at baseline may have dropped individuals from the analysis whose disease was associated with their neighborhood context, thereby biasing associations towards the null.

In our attempt to make the 'fear of crime' variable more gender-neutral, we could also have diminished our capacity for detecting an association by limiting the range of this scale (original range 0-12 vs. modified range 0-9). However, post-hoc analyses with the variable including all 4 items remained unchanged. What is more likely is that respondents simply did not report high levels of fear from crime regardless of variable used as 75% reported a score of 3 or less for the 3- item and 75% reported a score of 4 or less for the 4-item. There simply was likely not a sufficient range in this exposure to detect an association and we therefore cannot rule out the possibility that fear of crime may be related to cortisol as previously demonstrated[122].

In conclusion, these findings provide some needed information of possible mechanisms involving area measures of deprivation, neighborhood perceptions, and psychobiological processes. These findings suggest the existence of mechanisms beyond health behaviors that underpin linkages between area and health. Given the cross-sectional nature of these analyses, more research is needed before firm conclusions can be made. Additionally, more testing of area-level effects on components of the stress process, especially involving avenues for embodiment such as perception, is needed.

Table 14. Area- and individual-level demographic characteristics of Heart Scan Study participants according to cortisol stress response

	Non-responder (n=223)	Responder (n=291)
Age (years)	62.3 ± 5.8	63.3 ± 5.8
Men (%)	53.4	56.0
Work grade (% lower grades)	21.5	18.6
Social control	10.9 ± 4.9	12.3 ± 4.5
Neighborhood threat	2.7 ± 0.8	2.5 ± 0.8
Fear of crime	2.9 ± 1.6	2.6 ± 1.6
Rate of income deprivation [a]	10.3 ± 7.7	8.8 ± 7.2
Rate of employment deprivation [a]	6.8 ± 4.0	5.8 ± 3.4

Values are means ± SD

[a] Rate per 100 persons

Table 15. Association between area-level income deprivation[a] and perceptions of the neighborhood in Heart Scan Study participants.

	Model 1[b]			Model 2[c]			Model 3[d]		
	Diff	95% CI	P-value	Diff	95% CI	P-value	Diff	95% CI	P-value
Social control	-0.56	(-0.89, -0.22)	0.001	-0.52	(-0.85, -0.19)	0.002	-0.42	(-0.75, -0.08)	0.017
Neighborhood threat	0.14	(0.08, 0.20)	<0.0001	0.13	(0.07, 0.19)	<0.0001	0.13	(0.08, 0.19)	<0.0001
Fear of crime	0.08	(-0.03, 0.20)	0.169	0.07	(-0.04, 0.19)	0.222	0.09	(-0.03, 0.21)	0.124

[a] Rate of income deprivation based on the IMD 2007 income score (i.e. proportion of residents within a lower super output area (lsoa) that fall at or below 60% of median income for England); variable split into quartiles from lowest to highest

[b] Generalized estimating equation (GEE) assuming exchangeable correlation adjusting for age and gender

[c] Model 1 + number of years in neighborhood

[d] Model 2 + individual household income

Table 16. Association between area-level employment deprivation[a] and perceptions of the neighborhood in Heart Scan Study participants.

	Model 1[b]			Model 2[c]			Model 3[d]		
	Diff	95% CI	P-value	Diff	95% CI	P-value	Diff	95% CI	P-value
Social control	-0.49	(-0.82, -0.15)	0.004	-0.46	(-0.80, -0.13)	0.006	-0.36	(-0.70, -0.03)	0.033
Neighborhood threat	0.15	(0.09, 0.20)	<0.0001	0.14	(0.08, 0.20)	<0.0001	0.14	(0.08, 0.20)	<0.0001
Fear of crime	0.13	(0.01, 0.24)	0.035	0.12	(0.03, 0.24)	0.045	0.13	(0.01, 0.25)	0.034

[a] Employment score: rate of residents who are employment deprived based on the following indicators: unemployment claimant count for women (18-59) and men (18-64); Incapacity Benefit claimants; Severe Disablement Allowance claimants; participation in New Deal for 18-24 year olds (not captured in the claimant count); participants in New Deal for 25+ who are not included in the claimant count; participation in New Deal for lone parents aged 18 and over. The scores for England are provided by the Department for Communities and Local Government with higher scores indicating higher level of deprivation within a lower super output area (lsoa); variable split into quartiles from lowest to highest

[b] Adjusting for age and gender

[c] Model 1 + number of years in neighborhood

[d] Model 2 + individual grade of employment

Table 17. Association between area-level rate of income deprivation[a] and odds of cortisol non-response to laboratory acute stress task in Heart Scan Study participants[b]

	Model 1[c]			Model 2[d]			Model 3[e]		
	OR	95% CI	P-value	OR	95% CI	P-value	OR	95% CI	P-value
% Income Deprived[f]									
1 to 4.9 (referent)	1.00			1.00			1.00		
5 to 6.9	1.75	(1.01, 3.03)	0.045	1.75	(1.01, 3.03)	0.046	1.80	(1.03, 3.14)	0.038
7 to 11.9	1.22	(0.75, 1.98)	0.414	1.22	(0.75, 1.98)	0.418	1.21	(0.74, 1.98)	0.453
12 to 46	1.83	(1.14, 2.95)	0.013	1.84	(1.14, 2.97)	0.013	1.94	(1.19, 3.17)	0.008

[a] Rate of income deprivation based on the IMD 2007 income score (i.e. proportion of residents within a lower super output area (lsoa) that fall at or below 60% of median income for England); variable split into quartiles from lowest to highest

[b] Where non-response was defined as <5% increase in detected cortisol immediately or 20 min post-task, relative to baseline

[c] Generalized estimating equation (GEE) assuming exchangeable correlation adjusting for age, gender, perceived stress of task, and baseline cortisol

[d] Model 1 + number of years in neighborhood

[e] Model 2 + individual household income

[f] P-value for trend=0.024

Table 18. Association between area-level rate of employment deprivation[a] and odds of cortisol non-response to laboratory acute stress task in Heart Scan Study participants.

	Model 1[b]			Model 2[c]			Model 3[d]		
	OR	95% CI	P-value	OR	95% CI	P-value	OR	95% CI	P-value
% Employment Deprived[e]									
1 to 3.9 (referent)	1.00			1.00			1.00		
4 to 4.9	1.06	(0.63, 1.80)	0.810	1.07	(0.63, 1.80)	0.812	1.07	(0.64, 1.84)	0.777
5 to 7.9	1.36	(0.83, 2.22)	0.939	1.36	(0.83, 2.23)	0.227	1.37	(0.83, 2.25)	0.217
8 to 24	1.88	(1.16, 3.03	0.01	1.36	(1.16, 3.03)	0.010	1.90	(1.17, 3.09)	0.009

[a] Employment score: rate of residents who are employment deprived based on the following indicators: unemployment claimant count for women (18-59) and men (18-64); Incapacity Benefit claimants; Severe Disablement Allowance claimants; participation in New Deal for 18-24 year olds (not captured in the claimant count); participants in New Deal for 25+ who are not included in the claimant count; participation in New Deal for lone parents aged 18 and over. The scores for England are provided by the Department for Communities and Local Government with higher scores indicating higher level of deprivation within a lower super output area (lsoa); variable split into quartiles from lowest to highest

[b] Adjusting for age, gender, and baseline cortisol

[c] Model 1 + number of years in neighborhood

[d] Model 2 + individual employment grade

[e] P-value for trend=0.008

Table 19. Association between neighborhood perceptions and odds of cortisol non-response to laboratory acute stress task among Heart Scan Study participants [a].

	Model 1[b]			Model 2[c]			Model 3[d]		
	OR	95% CI	P-value	OR	95% CI	P-value	OR	95% CI	P-value
Social control	0.94	(0.90, 0.97)	0.001	0.94	(0.90, 0.97)	0.001	0.94	(0.90, 0.97)	0.001
Neighborhood threat	1.34	(1.08, 1.67)	0.009	1.35	(1.08, 1.69)	0.009	1.43	(1.13, 1.81)	0.003
Fear of crime	1.09	(0.97, 1.22)	0.128	1.09	(0.98, 1.23)	0.127	1.10	(0.98, 1.23)	0.104

[a] Where non-response was defined as <5% increase in detected cortisol immediately or 20 min post-task, relative to baseline

[b] Generalized estimating equation (GEE) assuming exchangeable correlation adjusting for age, gender, perceived stress of task, and baseline cortisol

[c] Model 1 + number of years in neighborhood

[d] Model 2 + individual household income

Table 20. Mediation analysis: bootstrap estimates of indirect effect (product of coefficients) of income deprivation through select neighborhood perceptions on cortisol non-response among Heart Scan Study participants.

	exp(*ab*)[a]	exp(95%CI)[b]
Social control	1.028	(1.021, 1.032)
Neighborhood threat	1.049	(1.042, 1.083)

[a]Estimates of indirect effect obtained via antilogarithm of mean product of coefficients *ab* presented for 1 quartile increase in income deprivation (path *a*) and 1 unit increase in mediator (path *b*))
[b]95% bias-corrected confidence intervals; effect is considered statistically significant if the BC confidence intervals do not overlap with 1.

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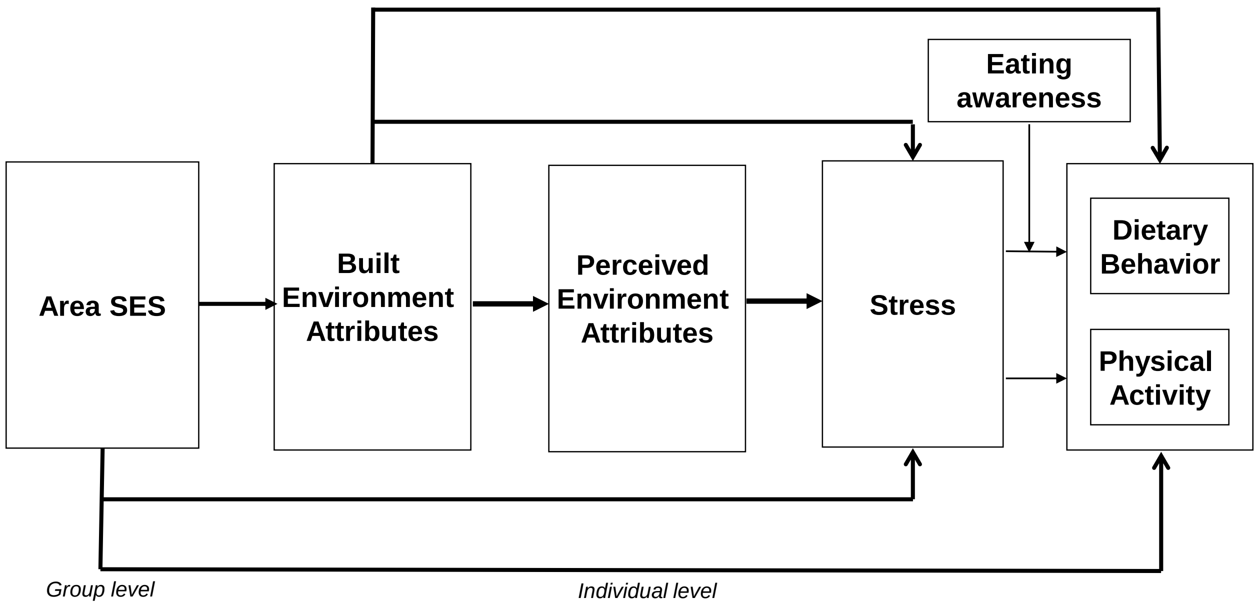
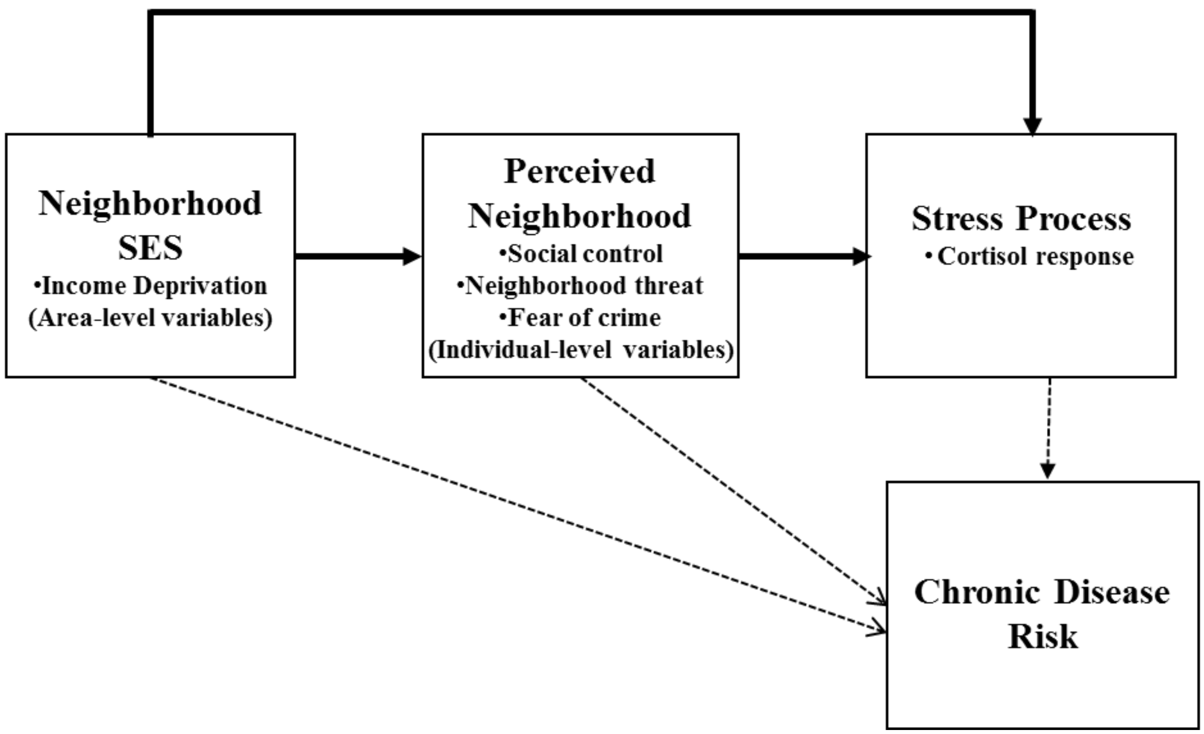
Appendix A. Conceptual model linking neighborhood context to obesogenic behaviors through built environment and perceived stress used to guide analyses for Chapters 1-3 where bolded arrows indicated associations evaluated with respect to home and the workplace among mostly white adults in King County, WA.



Appendix B. Conceptual model linking neighborhood SES to cortisol non-response through neighborhood perceptions used to guide analyses for Chapter 4 where bolded arrows indicate associations evaluated with respect to the home neighborhood among mostly white adults in London, England, U.K.



CURRICULUM VITAE

Wendy E. Barrington

EDUCATION

Doctor of Philosophy, Epidemiology, June 2012
University of Washington, Seattle, WA

- Thesis: Neighborhood environment, stress, and obesogenic behavior among adults
- Committee Members: Shirley Beresford (Chair), Tom Koepsell, David Yanez, Bonnie McGregor, Anne Vernez Moudon
- Areas of interest: diet and physical activity, stress, obesity, cancer, cardiovascular disease, contextual effects, health disparities, social epidemiological methods

Master of Public Health, Epidemiology *with distinction,* May 2005
University of New Mexico, Albuquerque, NM

Bachelor of Science, Earth Systems, June 1997
Stanford University, Palo Alto, CA

ACADEMIC AND FUNDING AWARDS

Meritorious Student Abstract Award, Society of Behavioral Medicine
Title: Worksite neighborhood context and obesogenic behaviors among Seattle adults
Paper Session 29 - Translating Obesity Research to Policy
33rd Annual Meeting and Scientific Sessions, New Orleans, LA
April 2012

Minority Initiative Award, American Psychosomatic Society
70th Annual Scientific Meeting, Athens, Greece
March 2012

Research Supplement to Promote Diversity in Health-related Research, University of Washington
Explaining the SES/Overweight and Obesity Relationship (Co-PIs: S. Beresford & D. Bowen R01 DK079042)
School of Public Health, Seattle, WA
Fall 2010-Summer 2012

Research Supplement, Fred Hutchinson Cancer Research Center
Transdisciplinary Research in Energetics and Cancer (PI: A. McTiernan U54 CA116847)
Division of Public Health Sciences, Seattle, WA
Summer 2010

Pre-doctoral Fellowship, University of Washington

Bio-behavioral Cancer Prevention and Control Training Grant (PI: D. Patrick R25 CA92408)
School of Public Health, Seattle, WA
Fall 2007-Spring 2010

TEACHING EXPERIENCE

Teaching Assistant, University of Washington
Department of Epidemiology, School of Public Health, Seattle, WA
Fall 2010 (Epi 511)

- Substituted as lecturer and co-led discussion sections for introductory epidemiological methods course targeting pharmacy, global health, health services, nursing, and medical students
- Tutored students and taught review sessions
- Graded and provided comments for submitted homework sets and research papers
- Proctored and answered questions during examinations

Instructor, University of New Mexico
Master of Public Health Program, Albuquerque, NM
February 2006-July 2007

- Modified curriculum for Principles of Public Health, a core requirement in the MPH program, for clinical residents and faculty within the Department of Family and Community Medicine utilizing WebCT and other electronic media
- Co-instructed the course via WebCT and in-class meetings with MPH Program faculty

Teaching Assistant, University of New Mexico
Master of Public Health Program, Albuquerque, NM
Fall 2003 (Epi I), Fall 2004 (Epi I), Spring 2005 (Epi II)

- Tutored students and taught review sessions for Epidemiological Methods I and II
- Graded and provided comments for submitted homework sets

PROFESSIONAL EXPERIENCE

Associate Scientist I, University of New Mexico
Center for Development and Disability, Albuquerque, NM
July 2005-July 2006

- Performed program evaluation activities including survey development and data analysis for several health promotion interventions focusing on increased physical activity among people with disabilities
- Conducted qualitative and quantitative research for the development of quality-of-life measures for people with disabilities as well as performing evaluation analyses for the online Paralysis Resource Center (PRC) funded through the Christopher Reeve Foundation
- Assisted in conducting qualitative and quantitative research to explore access to care for people with disabilities, specifically concerning communication and cultural barriers

Consultant, New Mexico Department of Health
District I Public Health Offices, Albuquerque, NM
September 2003-April 2005

- Provided data compilation, analysis, and interpretation using major public health databases for the Health Promotion team at the North Valley Public Health Office. Data used: NM Youth Risk & Resiliency Survey (YRRS), NM Immunization Performance Measure data, Women, Infants and Children (WIC) Performance Measure data, NMDOH INPHORM data output, Medicaid enrollment data, District 1 School Health data, NM HIV/AIDS Surveillance data.
- Developed and presented initial evaluation of services provided by Bernalillo County Public Health Offices

Research Specialist, University of New Mexico
Department of Internal Medicine, Albuquerque, NM
August 2002-June 2004

- Performed basic science research on the effects of heavy metal inhalation on neuropathology resulting in the possible development of neurodegenerative diseases.
- Performed basic animal surgery, tissue harvesting and preparation, cryosectioning, running of immunohistochemical experiments, and histology
- Performed initial measurements for uptake, deposition, and clearance of inhaled toxicants via immunofluorescence
- Aided in writing papers and grants related to this research

Senior Research Tech, University of New Mexico
Department of Pathology, Albuquerque, NM
September 2001-July 2002

- Managed research and teaching laboratory
- Prepared and ran immunohistochemical experiments using various primary antibodies and secondary reagents
- Stained histological specimens
- Archived and maintained research tissue bank

Clinical Research Associate, InLight Solutions,Inc.
Albuquerque, NM
September 1999-September 2001

- Prepared and ran studies for glucose and cervical cancer research projects utilizing spectroscopy to quantify glucose levels in the skin as well as classify cervical cell morphology
- Recruited and provided informed consent for patients within a hospital setting
- Drafted study protocols and forms for submission to University of New Mexico Human Research Review Committee (UNM HRRC)
- Performed sample collection, archiving, and maintenance of reference database for use during data analysis
- Performed initial statistical data analysis and presentation of results to co-workers and outside collaborators and investors

Post-baccalaureate Research Assistant, Los Alamos National Laboratory
ESA-WMM, Los Alamos, NM
July 1997-October 1998

- Prepared and executed scientific experiments exploring the rate of de-mixing of suspended particles in a neutrally-buoyant fluid.
- Ran experiments in which nuclear magnetic resonance (NMR) images were taken of particles in a shear-induced flow field over time
- Aided in reducing the subsequent data using graphical software
- Presented data to team leaders and colleagues via presentations and reports
- Obtained "L" government security clearance

Summer Intern, Environmental Protection Agency, Region 9
Water Management Division, San Francisco, CA
Summer 1995

- Prepared background information regarding tribal cultures of Section 106 grantees for Regional Administrator
- Participated in meetings with tribal sovereign nations centered on implementation and enforcement of water standards

PUBLICATIONS

1. Barrington WE, Ceballos RM, Bishop SK, Brunner NL, McGregor BA, Beresford SAA. Perceived stress and behaviors associated with obesity in working adults. Preventing Chronic Disease. 2012. In Press.
2. Lewis J, Bench G, Myers O, Tinner B, Staines W, Barr E, Divine KK, Barrington W, Karlsson J. Trigeminal uptake and clearance of inhaled manganese chloride in rats and mice. Neurotoxicology. 2005 Jan;26(1):113-23.

PRESENTATIONS

1. Barrington WE, Beresford SAA, Yanez ND, Duncan G, McGregor BA, Koepsell TD, Bishop SK, Moudon AV. Worksite context and individual obesogenic behaviors among adults. Society of Behavioral Medicine's 33rd Annual Meeting and Scientific Sessions, Oral presentation at Paper Session 29 - Translating Obesity Research to Policy. New Orleans, LA . April 11-14, 2012.
2. Barrington WE, Stafford M, Hamer M, Beresford SAA, Steptoe A. Socioeconomic deprivation, neighborhood perceptions, and cortisol non-response to mental stress. Poster presentation at American Psychosomatic Society’s 70th Annual Scientific Meeting. Athens, Greece. March 14-17, 2012.
3. Barrington WE, Ceballos RM, Bishop SK, Brunner NL, McGregor BA, Beresford SAA. Perceived stress and behaviors associated with obesity in working adults. Poster presentation at Society of Behavioral Medicine’s 31st Annual Meeting and Scientific Sessions, Cancer Special Interest Group. Seattle, WA. April 7-10, 2010.
4. Barrington WE, Ceballos RM, Bishop SK, Brunner NL, McGregor B, Beresford SAA. Perceived stress and obesogenic behaviors in working adults. Oral presentation at the Annual Symposium for Progress in Biobehavioral Cancer Prevention, Seattle, WA. April 2009.
5. Barrington WE, Ceballos RM, Bishop SK, Brunner NL, Beresford SAA. Are dietary and physical activity behaviors associated with perceived stress? Poster presentation at TREC Scientific Meeting, Bethesda, MD. October, 2008.

6. Barrington WE, Ceballos RM, Beresford SAA, Thompson B. Perceived Stress and Dietary and Physical Activity-Related Behaviors. Poster presentation at TREC Quarterly Investigators Meeting, Seattle, WA. May 2008.
7. Barrington WE. Disability as a social determinant of health. Oral presentation at Annual Meeting of New Mexico Public Health Association, Albuquerque, NM, April 5-7, 2006.
8. Barrington WE, Scharmen T. An initial evaluation of public health services in Bernalillo County. Poster presentation at Annual Meeting of New Mexico Public Health Association, Albuquerque, NM, April6-8, 2005.

AFFILIATIONS

2012-	Student Member, American Psychosomatic Society
2010-	Student Member, Society of Behavioral Medicine
Summer 2010	Visiting Student, Psychobiology Group, Department of Epidemiology and Public Health, University College London, UK
2005-2007	Member, American Public Health Association
2003-2007	Member, New Mexico Public Health Association