Effect of neighborhood environment and individual social integration on mortality risk: An analysis of the Third National Health and Nutrition Examination Survey (NHANES III)

By Andrea Fleisch Marcus, MPH

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ABSTRACT OF THE DISSERTATION

EFFECT OF NEIGHBORHOOD ENVIRONMENT AND INDIVIDUAL SOCIAL INTEGRATION ON MORTALITY RISK: AN ANALYSIS OF THE THIRD NATIONAL HEALTH AND NUTRITION EXAMINATION SURVEY (NHANES III)

By ANDREA FLEISCH MARCUS, MPH

Dissertation Directors:

Dr. Marian R. Passannante and Dr. Sandra E. Echeverria

Background: Neighborhood socioeconomic condition and individual social integration are social constructs that have been independently linked to health. A decline in neighborhood condition has been linked to increased risks of poor health and mortality while social isolation has been shown to have similar risks. The goal of this study was to evaluate the association between these two known social determinants of health. This was achieved through three projects with the following objectives: 1) to evaluate the relationship between neighborhood socioeconomic context and distinct forms of social integration, 2) to examine whether neighborhood socioeconomic context influences time-to-death within this sample while controlling for confounders, and 3) to explore whether neighborhood socioeconomic context and social integration together have an impact on time-to-death.

METHODS: The present study used data from the Third National Health and Examination Survey (NHANES III) and the NHANES III Linked Mortality File geocoded according to participants' residential address and matched to Census data. A measure of neighborhood poverty that examined the proportion of residents in a census tract living

below the federal poverty line was used to account for neighborhood context and a modified-Social Network Index was used to measure social integration. Logistic regression and Cox proportional hazards were used to assess associations while controlling for confounding. Additive interaction between neighborhood poverty and social integration was also examined. All analyses accounted for the complex sample design and sample weights.

RESULTS: When controlling for individual-level factors, living in high poverty neighborhoods was associated with 47% (95% confidence interval: 1.15, 1.88) greater odds of having a low score on the SNI when compared with those living in more affluent neighborhoods. Living in a low poverty neighborhood was associated with a lower mortality risk when compared to living in a high poverty (≥20%) neighborhood. Those in high poverty neighborhoods with low social integration scores had a 63% (95% confidence interval: 1.34, 1.96) greater mortality risk when compared to those in low poverty neighborhoods with high social integration scores.

CONCLUSION: The results of this dissertation provide evidence of the associations between neighborhood context, social integration and mortality.

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TABLE OF CONTENTS

LIST OF TABLES

Manuscript 3:

LIST OF FIGURES

INTRODUCTION

Background

Behaviors and other health outcomes once thought to be solely a product of personal attributes and choices have now been shown to occur within broader social contexts, including the family/household unit, peer groups, occupational settings, schools, and neighborhoods (1, 2). These contexts can influence health in a myriad of ways ranging from health behaviors such as smoking, alcohol consumption, nutritional intake, and involvement in interpersonal violence, to mental health and ultimately death (3-6). These complex, interconnected relationships are the subject of study in social epidemiology, a field defined as the study of the distribution and determinants of the health of populations that seeks to identify "which societal conditions affect health [and] that can be altered by informed action (7)."

Over the past few decades, two broad but distinct bodies of literature have emerged in social epidemiology. One body of literature has focused on examining how social relationships relate to health. Studies have been conducted examining whether being married predicts a longer, healthier life and whether individuals with cancer have a better chance of recovering when they have stronger support from family and friends (8-10). Another thread of research has examined how the material or structural characteristics of neighborhoods, generally defined by neighborhood socioeconomic condition, increases risk of disease, above and beyond individual-level characteristics (2, 11-13).

What has received less attention in the literature, however, is how these areas of study intersect. The present doctoral dissertation seeks to address this gap and is motivated by two fundamental questions relating social relationships, neighborhoods and health. The first general question seeks to answer if neighborhood socioeconomic disadvantage shapes social relationships. While in recent years there has been a steady growth of studies examining how specific characteristics of the neighborhood such as neighborhood social cohesion or social capital are associated with health, less emphasis has been placed on empirically demonstrating the extent to which neighborhood socioeconomic disadvantage influences social relationships. Thus, the first general question to be examined in this proposal is, do individuals who reside in poor neighborhoods report fewer social relationships, than individuals living in more affluent neighborhood settings? Building on this question, the second general question examines the association between social relationships and health, specifically mortality, and whether this relation differs by neighborhood socioeconomic condition. That is, if social relationships are associated with mortality, does this relation vary depending on whether individuals live in poor or wealthy neighborhoods? The present study tests these associations using the Third National Health and Nutrition Examination Survey (NHANES III) Linked Mortality File, a dataset containing a representative sample of the United States (US) population with death ascertainment at up to 18 years of follow-up.

Social relationships: Definitions and empirical evidence

Definitions. Social relationships have an important impact on physical and mental health (8, 14). This association has been the subject of numerous research studies and has been broadly accepted in many disciplines (3, 8, 14, 15). Social relationships can be defined simply as interactions among individual people. Researchers in many scientific disciplines have been interested in various aspects of these interactions such as their quantity, quality, and the ways that people benefit from participating in them. The terminology used when discussing aspects of social relationships and the types of instruments used to measure them varies in the literature (1).

Berkman and Glass (16) discuss three categories of measurements used to assess social relationships. These categories are: " 1) those measures that primarily assess social ties or social integration, 2) measures that more formally assess aspects of social networks, and 3) measures assessing social support, both cognitively 'perceived' and behaviorally 'received.'" Those most typically used in population-based studies and that have been shown to have a relationship with all-cause mortality primarily fall into the first category, social ties or social integration (9, 15, 17-21). Hence, the present dissertation study focuses on measures of social integration.

The instruments used to measure social integration are brief, quantitative and "tap the size of networks, frequency of contact, membership in voluntary and religious organizations and social participation (16)." The Berkman-Syme Social Network Index (SNI) is an instrument that is frequently used in epidemiological studies. It examines four

sources of social contacts: marriage, contacts with friends and relatives, religious organization membership, and group associations (17, 18). One prevailing theory about why measures of social integration predict mortality so consistently is that they quantify a person's connectedness to his or her life. To be socially integrated is to participate in one's life fully, to be obligated and to feel attached to others. It requires engagement and participation in one's personal circle and society (16).

Empirical evidence. Studies have shown that there is an inverse association between social relationships and mortality (8, 9, 18, 20, 22). In 1979, analyses from the Alameda County cohort study (18) demonstrated that people with more social ties had lower mortality rates than those with fewer social ties. Four types of social ties were examined (marriage, contacts with friends and relatives, religious group membership, and other group memberships) and this relationship held across all four types, even after adjustment for baseline health status. The relationship continued when the four types were combined into one index; men in the group with the least number of ties had a mortality rate 2.3 (confidence intervals not provided in the article) times higher than those with the most ties and isolated women had a mortality rate 2.8 times that of women scoring higher on the index (18). Using data from the same cohort but with an extended follow-up time, Seeman et al (20) examined mortality rates for older individuals and found that for those over 70 years of age at baseline, lack of social connectedness was a strong predictor of mortality risk and, interestingly, at older age groups the types of relationships that were found to be most protective changed;

marital status became less strongly associated with mortality while lack of contact with close friends and relatives became more predictive of mortality in the older age groups.

Individuals who are more socially isolated have been shown to be at increased risk for cardiovascular disease and injuries that lead to death (9). According to a study by White et al (23), social isolation is greater among those who report having poor health. After conducting an experimental study, Cohen et al (24) reported that individuals in the study who were more socially isolated showed greater susceptibility to the common cold.

Studies have examined functional aspects of social relationships as well as their structure in an attempt to identify the pathways through which social relationships influence health. Functional aspects of relationships are the ways in which the relationships affect the individuals involved; examples are the provision or perception of emotional support from a relationship or the resources provided as part of the relationship. Structural aspects of relationships can be viewed as a skeleton or map, these are networks, marital status, who someone lives with and how many people they spend time with on a regular basis. A study of rural, partnered African-American women showed that the quality of these women's intimate relationships and their relationships with neighbors was positively associated with psychological and physical health (25). A recent meta-analysis combined 148 studies looking at social relationships and mortality producing a weighted average odds ratio of 1.5 (95% confidence interval: 1.42, 1.59); they found studies that reported risks as high as 6.5 (15). These findings of increased mortality risk associated with a decrease in social relationships held

regardless of the ways in which these relationships were defined or examined. Although researchers have used different terminologies and measures to examine social relationships and mortality, the association between them remains. House et al (8), in the paper that first reviewed epidemiological evidence of the association between social relationships and health, stated that the evidence of the impact of social relationships on health rivaled that of other more widely accepted health risks such as smoking, obesity and high blood pressure. At that time the main challenge presented was much the same as it is today, researchers do not understand exactly how social interactions affect health nor is it clear how to best use this information for health promotion (26).

Neighborhood contexts: Definitions and empirical evidence

Definitions. There is now a consistent body of evidence linking neighborhood contexts to health (6, 27-31). Neighborhoods are the geographic area within which individuals reside and are hypothesized to influence health by shaping access to resources, through environmental conditions, and via various types of social controls (32, 33). Many dynamic processes, such as peer group influence and collective socialization, and structural dimensions, such as geographic isolation of poor, concentrated affluence or disadvantage and concentration of institutional resources, may have a direct effect on the health of the people who live within communities (13). Neighborhoods have been defined as communities nested within broader communities and it may be the concentration of resources, both financial and social, within those nested communities that influence health in a myriad of ways (32). Studies have

examined how social processes within neighborhoods predict mortality, violence, infant birth weight, and cardiovascular health among other notable health outcomes (5, 28, 34-37).

One popular method used to assign neighborhood characteristics in population-based public health studies is through census tracts. There are limitations attributed to the use of census tracts (32, 33, 38). They are often considered to be a crude proxy for residents' experience of their neighborhood-both in terms of geographical boundaries and measures of effect (11), and census tracts are typically composed of roughly 4,000 residents which is often a heterogeneous grouping (33). However, there are also advantages to their use (39-42). The origins of census tracts dates to 1906 with the recognized need to divide large cities into smaller geographic areas allowing for better reporting of the growth and change in area populations and for better urban planning (39). These areas were designed for public health planning and they still have political relevance today as they are the best way to measure population change within consistently defined geographic areas (39, 42). Census tracts are used by a multitude of government agencies for planning and distribution of resources and therefore can be useful within a public health study not just for ease of use but for the future application of research data to develop programs targeted at geographic areas with particular socioeconomic characteristics.

Empirical Evidence. Health conditions that lead to morbidity and mortality from causes as disparate as arthrosclerosis and violence have been attributed to the quality of neighborhood resources, community social capital and neighborhood socioeconomic

status (4, 5, 34, 43). The body of work supporting the link between neighborhood socioeconomic status and mortality is similar to that described above for social relationships (36). Yen and Kaplan (6), using data from the Alameda County study, found that people living in neighborhoods with the lowest population socioeconomic status had 1.53 (95% confidence interval: 0.91, 2.57) times the risk of death when compared to those in the highest socio-economic status (SES) neighborhoods. Although the results from this study were not statistically significant, they are representative of the trend in the literature showing a consistent relationship between neighborhood socio-economic conditions and mortality (32). In a more recent longitudinal study of older adults it was found that men living within the highest level of deprivation had a 17% (hazard ratio: 1.17; 95% confidence interval: 1.10, 1.24) higher risk of all-cause mortality than those in areas that measured lower on the deprivation scale. Those living within greater deprivation also had an increased risk of cancer death (36).

Studies using multi-level statistical models to examine the effect of various community factors on health while controlling for individual-level confounders have been widely used over the last decade (2, 44-46). These models have allowed researchers to examine the effects of group-level constructs on the health of individuals while taking into account possible statistical issues due to clustering and allow the combination of multiple ecological levels into a single measure of risk. Further, these multilevel studies have produced results that support the idea that neighborhood conditions have an impact beyond that of the characteristics of the individuals who live there.

A multilevel analysis of all-cause mortality data in Massachusetts showed that between-neighborhood variation in mortality was six times greater for Blacks than Whites and that neighborhood poverty significantly contributed to the area variations in excess mortality among Blacks (42). Thus, a neighborhood-level characteristic known to have a relationship with mortality was shown to affect different individual-level groups differently, establishing the notion that context matters.

Social epidemiologists studying neighborhood effects have relied heavily on existing data from observational studies and thus have used imperfect approximations of their measurements of interest. However, evidence of neighborhood effects on health is consistent despite heterogeneity in definition and study design and despite the various limitations described (2, 46).

Theoretical framework

A theoretical model put forth by Berkman et al (3) posits that the ways in which social relationships affect health include factors that are both upstream and downstream on the causal pathway between social-structural conditions and the behavioral, psychological and physiological factors that directly affect health. These authors suggest that the context within which social interactions occur likely has an impact on how these interactions affect an individual's health. Important contexts include cultures, communities, governmental policies, work environments and neighborhoods. Thus, the characteristics of one's neighborhood influence the amount and types of social relationships one has which in turn may alter one's health behaviors

to the extent that one may be more likely to engage in behaviors that are acceptable to his/her peer group and these health behaviors will in turn alter future health. Another way to look at the model is through the lens of social support in that residing in a neighborhood that encourages supportive social interactions will have an effect on health behaviors, overall health status and ultimately, mortality risk. In their paper, these authors call for more multi-level studies that can help guide the development of interventions and policies to improve public health. After a thorough review of the literature it appears that the association between neighborhood socioeconomic context, individual social integration and mortality has yet to be tested.

Different social constructs or even the same construct experienced in different levels of social grouping have been shown to interact; the interaction creates a combined effect on the health of individuals that differs from each constructs' independent effect (47). For example, in one study women with low individual-level socioeconomic status (SES) living in high SES areas had about 1.7 (95% confidence interval: 1.2, 2.4) times the risk of death when compared to those with high individual-level SES living in high SES neighborhoods, while women with low SES living in low SES neighborhoods had 1.4 (95% confidence interval: 1.0, 2.0) times the risk when compared to high SES women living in high SES neighborhoods (48). Previous studies have found that neighborhood SES predicts mortality independent of an individual's SES (49). However, Winkleby et al (48) found that those with low individual-level SES living in high SES neighborhoods are at greater risk of mortality than their counterparts living in low SES areas. These distinctions are important because once they are known and

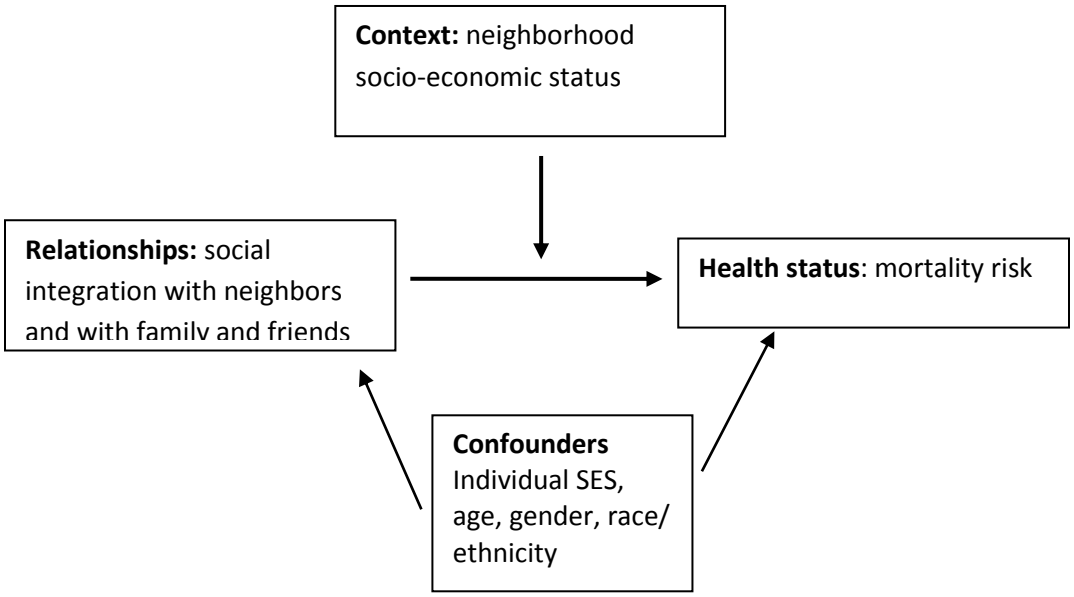
understood targeted interventions can be developed that can work to eliminate these types of health disparities.

Diez Roux (2) writes that the relationships between individuals and the group contexts within which they operate (e.g. live and work) are dynamic and that not only does the group-level context affect the individual but the individual, in turn, has an impact on his/her environment. The previously referenced study by Subramanian et al (42) directly supports this assertion and these authors state, "it is entirely reasonable (and perhaps more realistic) to anticipate that contextual differences as well as contextual effects inherently interact with individual characteristics."

Figure 1 displays the conceptual framework that was used to frame the examination of multi-leveled social determinants of health in the present dissertation study. Our conceptual framework was designed in the fashion of diagrams proposed by Diez Roux (50) to illustrate conceptual models. This framework theorizes that there is a dynamic relationship between social relationships and neighborhood context (not shown) and that in turn neighborhood socioeconomic condition modifies the relationship between social integration and mortality risk. It illustrates the direct relationship between social integration and mortality and the way that neighborhoods differentially influence health, through processes previously discussed, as well as indirectly via the relationships that one may build within specific contexts. This proposed framework integrates the many ways it has been theorized that social integration and neighborhood context relate to one another to influence mortality and will allow for analyses that examine group-level contexts and individual-level factors

together to narrow in on their joint effects on health. Determining whether these two types of characteristics interact and, if so, how they interact may be vital to improving current public health interventions focused on neighborhood contexts.

Figure 1: Conceptual Framework



Past studies and theoretical writings (3, 8, 33) suggest there are factors that may mediate the relationships between group context, social relationships, and health. Namely, social influence and health behaviors or health pathways are theorized to be on this causal pathway. However, the current study did not test this part of the theory. Neighborhood-level effects and the effects of social integration on mortality risk are quite distal and more proximate factors such as health behaviors and health status are likely both mediators and confounders of the relationships of primary interest in this study (11). Analyses that include mediation can be complex and discovering the

contribution of mediating factors is an interesting research question in and of itself. Further, including mediating factors as though they are solely confounders in a regression analysis can disguise the true main effects of interest (15, 51). Hence, once the dynamic relationship between group and individual-level social constructs has been established, future studies will be needed to determine the ways through which these factors impact health and mortality.

Rationale and study aims

As described above, individual and group characteristics may not always work in tandem in their effect on health. Specifically, while social integration has been shown to have a strong association with health and mortality, the question of whether this association is the same for those living in different types of neighborhood environments remains largely unexplored. Although both neighborhood socioeconomic status and social integration have been studied for their impact on health, the interaction between the two had yet to be examined. Given that social integration has been found to have an inverse effect on mortality risk and that lower neighborhood socioeconomic status also predicts higher mortality rates: Does neighborhood socioeconomic status interact with social integration to affect mortality risk?

Recent studies suggest that low socioeconomic status may predict lower levels of social support among individuals and within communities. Small (41) found that racial differences in distinct aspects of social support and the size of social networks did not hold in statistical models that accounted for neighborhood conditions. It was

neighborhood poverty, and not race, that best accounted for smaller social networks among minority groups. Additionally, Stringhini et al (21) found a positive linear relationship between SES and a social support profile among men in the Whitehall Cohort study showing that men with higher SES had a better social support profile as well as better health than those with lower SES. The present dissertation study contributes to this body of literature by examining whether neighborhood socioeconomic conditions and social integration interact and whether these two factors together have an effect on time to death within a national US sample.

Three projects were undertaken and are described in the present dissertation narrative. The specific aims of project 1 were to:

1a) Assess the relationship between neighborhood socioeconomic context and social integration with neighbors in the NHANES III/Linked Mortality file dataset.

1b) Assess the relationship between neighborhood socioeconomic context and social integration overall (i.e., with family, friends and neighbors) in the NHANES III/Linked Mortality file dataset.

The specific aim of project 2 was to assess whether the accepted relationship between neighborhood poverty and all-cause mortality risk holds within the updated NHANES III Linked Mortality File for those over age 17 while controlling for known confounders.

Finally, the specific aims of project three were to:

3a) Assess whether the accepted relationship between social integration and all-cause mortality risk holds within the updated NHANES III Linked Mortality File for those over age 17 while controlling for known confounders, and

3b) Determine if the relation between social integration and mortality risk differs by neighborhood socioeconomic context.

These aims are addressed herein in the form of the three independent manuscripts that follow.

REFERENCES

1. Berkman LF, Kawachi I. *Social Epidemiology*. New York, N.Y.: Oxford University Press; 2000.
2. Diez Roux AV. Next steps in understanding the multilevel determinants of health. *Journal of Epidemiology and Community Health* 2008;62(11):957-9.
3. Berkman LF, Glass T, Brissette I, et al. From social integration to health: Durkheim in the new millennium. *Social Science & Medicine* 2000;51(6):843-57.
4. Diez-Roux AV, Nieto FJ, Muntaner C, et al. Neighborhood environments and coronary heart disease: A multilevel analysis. *American Journal of Epidemiology* 1997;146(1):48-63.
5. Sampson RJ, Raudenbush SW, Earls F. Neighborhoods and violent crime: A multilevel study of collective efficacy. *Science* 1997;277(5328):918-24.
6. Yen IH, Kaplan GA. Neighborhood social environment and risk of death: Multilevel evidence from the Alameda County Study. *American Journal of Epidemiology* 1999;149(10):898-907.
7. Krieger N. A glossary for social epidemiology. *Journal of Epidemiology and Community Health* 2001;55(10):693-700.
8. House JS, Landis KR, Umberson D. Social relationships and health. *Science* 1988;241(4865):540-5.
9. Kawachi I, Colditz GA, Ascherio A, et al. A prospective study of social networks in relation to total mortality and cardiovascular disease in men in the USA. *Journal of Epidemiology and Community Health* 1996;50(3):245-51.
10. Reynolds P, Boyd PT, Blacklow RS, et al. The relationship between social ties and survival among black and white breast cancer patients. National Cancer Institute Black/White Cancer Survival Study Group. *Cancer Epidemiology, Biomarkers & Prevention : A Publication of the American Association for Cancer Research, cosponsored by the American Society of Preventive Oncology* 1994;3(3):253-9.
11. Diez Roux AV. The study of group-level factors in epidemiology: Rethinking variables, study designs, and analytical approaches. *Epidemiologic Reviews* 2004;26:104-11.
12. Merlo J, Chaix B, Yang M, et al. A brief conceptual tutorial on multilevel analysis in social epidemiology: Interpreting neighbourhood differences and the effect of neighbourhood characteristics on individual health. *Journal of Epidemiology and Community Health* 2005;59(12):1022-8.
13. Sampson RJ, Morenoff JD, Gannon-Rowley T. Assessing "neighborhood effects": Social processes and new directions in research. *Annu Rev Sociol* 2002;28:443-78.
14. Kawachi I, Berkman LF. Social ties and mental health. *Journal of Urban Health : Bulletin of the New York Academy of Medicine* 2001;78(3):458-67.
15. Holt-Lunstad J, Smith TB, Layton JB. Social relationships and mortality risk: A meta-analytic review. *PLoS Medicine* 2010;7(7):e1000316.
16. Berkman LF, Glass T. Social Integration, Social Networks, Social Support, and Health. In: Berkman LF, Kawachi I, eds. *Social Epidemiology*. New York, NY: Oxford University Press, 2000.
17. Berkman LF. *Social Networks. Host Resistance, and Mortality: A Follow-up Study of Alameda County Residents* [dissertation]. Berkley, CA: University of California-Berkley; 1977.

18. Berkman LF, Syme SL. Social networks, host resistance, and mortality: A nine-year follow-up study of Alameda County residents. *American Journal of Epidemiology* 1979;109(2):186-204.
19. Kaplan GA, Salonen JT, Cohen RD, et al. Social connections and mortality from all causes and from cardiovascular disease: Prospective evidence from Eastern Finland. *American Journal of Epidemiology* 1988;128(2):370-80.
20. Seeman TE, Kaplan GA, Knudsen L, et al. Social network ties and mortality among the elderly in the Alameda County Study. *American Journal of Epidemiology* 1987;126(4):714-23.
21. Stringhini S, Berkman L, Dugravot A, et al. Socioeconomic status, structural and functional measures of social support, and mortality: The British Whitehall II Cohort Study, 1985-2009. *American Journal of Epidemiology* 2012;175(12):1275-83.
22. Eng PM, Rimm EB, Fitzmaurice G, et al. Social ties and change in social ties in relation to subsequent total and cause-specific mortality and coronary heart disease incidence in men. *American Journal of Epidemiology* 2002;155(8):700-9.
23. White AM, Philogene GS, Fine L, et al. Social support and self-reported health status of older adults in the United States. *American Journal of Public Health* 2009;99(10):1872-8.
24. Cohen S, Doyle WJ, Skoner DP, et al. Social ties and susceptibility to the common cold. *JAMA : The Journal of the American Medical Association* 1997;277(24):1940-4.
25. Black AR, Cook JL, Murry VM, et al. Ties that bind: Implications of social support for rural, partnered African American women's health functioning. *Women's Health Issues : Official Publication of the Jacobs Institute of Women's Health* 2005;15(5):216-23.
26. Berkman LF. Social epidemiology: Social determinants of health in the United States: Are we losing ground? *Annual Review of Public Health* 2009;30:27-41.
27. Borrell LN, Diez Roux AV, Rose K, et al. Neighbourhood characteristics and mortality in the Atherosclerosis Risk in Communities Study. *International Journal of Epidemiology* 2004;33(2):398-407.
28. Diez Roux AV, Merkin SS, Arnett D, et al. Neighborhood of residence and incidence of coronary heart disease. *The New England Journal of Medicine* 2001;345(2):99-106.
29. Echeverria SE, Borrell LN, Brown D, et al. A local area analysis of racial, ethnic, and neighborhood disparities in breast cancer staging. *Cancer Epidemiology, Biomarkers & Prevention : A publication of the American Association for Cancer Research, cosponsored by the American Society of Preventive Oncology* 2009;18(11):3024-9.
30. Haan M, Kaplan GA, Camacho T. Poverty and health. Prospective evidence from the Alameda County Study. *American Journal of Epidemiology* 1987;125(6):989-98.
31. Krieger N, Chen JT, Waterman PD, et al. Geocoding and monitoring of US socioeconomic inequalities in mortality and cancer incidence: does the choice of area-based measure and geographic level matter?: The Public Health Disparities Geocoding Project. *American Journal of Epidemiology* 2002;156(5):471-82.
32. Bond Huie SA. The concept of neighborhood in health and mortality research. *Sociological Spectrum: Mid-South Sociological Association* 2001;21(3):341-58.
33. O'Campo P. Invited commentary: Advancing theory and methods for multilevel models of residential neighborhoods and health. *American Journal of Epidemiology* 2003;157(1):9-13.
34. Bell N, Schuurman N, Hameed SM. A multilevel analysis of the socio-spatial pattern of assault injuries in greater Vancouver, British Columbia. *Can J Public Health* 2009;100(1):73-7.

35. Buka SL, Brennan RT, Rich-Edwards JW, et al. Neighborhood support and the birth weight of urban infants. *American Journal of Epidemiology* 2003;157(1):1-8.
36. Major JM, Doubeni CA, Freedman ND, et al. Neighborhood socioeconomic deprivation and mortality: NIH-AARP Diet and Health Study. *PloS One* 2010;5(11):e15538.
37. O'Campo P, Burke JG, Culhane J, et al. Neighborhood deprivation and preterm birth among non-Hispanic Black and White women in eight geographic areas in the United States. *American Journal of Epidemiology* 2008;167(2):155-63.
38. Diez Roux AV, Borrell LN, Haan M, et al. Neighbourhood environments and mortality in an elderly cohort: results from the cardiovascular health study. *Journal of Epidemiology and Community Health* 2004;58(11):917-23.
39. Krieger N. A century of census tracts: Health & the body politic (1906-2006). *Journal of Urban Health : Bulletin of the New York Academy of Medicine* 2006;83(3):355-61.
40. Krieger N, Chen JT, Waterman PD, et al. Painting a truer picture of US socioeconomic and racial/ethnic health inequalities: The Public Health Disparities Geocoding Project. *American Journal of Public Health* 2005;95(2):312-23.
41. Small ML. Racial differences in networks: Do neighborhood conditions matter? *Soc Sci Q* 2007;88(2):320-43.
42. Subramanian SV, Chen JT, Rehkopf DH, et al. Racial disparities in context: A multilevel analysis of neighborhood variations in poverty and excess mortality among black populations in Massachusetts. *American Journal of Public Health* 2005;95(2):260-5.
43. Echeverria S, Diez-Roux AV, Shea S, et al. Associations of neighborhood problems and neighborhood social cohesion with mental health and health behaviors: The Multi-Ethnic Study of Atherosclerosis. *Health & Place* 2008;14(4):853-65.
44. Hubbard AE, Ahern J, Fleischer NL, et al. To GEE or not to GEE: Comparing population average and mixed models for estimating the associations between neighborhood risk factors and health. *Epidemiology* 2010;21(4):467-74.
45. Merkin SS, Basurto-Davila R, Karlamangla A, et al. Neighborhoods and cumulative biological risk profiles by race/ethnicity in a national sample of U.S. adults: NHANES III. *Annals of Epidemiology* 2009;19(3):194-201.
46. Pickett KE, Pearl M. Multilevel analyses of neighbourhood socioeconomic context and health outcomes: A critical review. *Journal of Epidemiology and Community Health* 2001;55(2):111-22.
47. Szklo M, Nieto FJ. *Epidemiology : Beyond the Basics*. 3rd ed. Burlington, Mass.: Jones & Bartlett Learning; 2014.
48. Winkleby M, Cubbin C, Ahn D. Effect of cross-level interaction between individual and neighborhood socioeconomic status on adult mortality rates. *American Journal of Public Health* 2006;96(12):2145-53.
49. Bird CE, Seeman T, Escarce JJ, et al. Neighbourhood socioeconomic status and biological 'wear and tear' in a nationally representative sample of US adults. *Journal of Epidemiology and Community Health* 2010;64(10):860-5.
50. Diez Roux AV. Conceptual approaches to the study of health disparities. *Annual Review of Public Health* 2012;33:41-58.
51. Rothman KJ, Greenland S, Lash TL. *Modern Epidemiology*. 3rd ed. Philadelphia: Wolters Kluwer Health/Lippincott Williams & Wilkins; 2008.

METHODS

Data sources

Third National Health and Nutrition Examination Survey (NHANES III). The data for this study comes from NHANES III. Various NHANES studies have been carried out over the last 50 years by the National Center for Health Statistics at the Centers for Disease Control and Prevention. The NHANES program was designed to monitor the health and nutritional status of people in the United States. In the last 50 years NHANES has contributed significantly to the field of public health; allowing for the creation of pediatric growth charts, the monitoring of obesity among children and adults, the assessment of diabetes and other important health conditions as well as contributing advances in population survey design and analytic methods (1).

This survey employs a complex, multi-stage, stratified sampling design intended to recruit a nationally representative sample of the non-institutionalized, civilian US population. NHANES III was conducted from October 1988-October 1994 and included individuals from age 2 months with no upper age limit. Data collection for the survey consisted of an in-home interview and a series of examinations both in-home and via mobile exam centers (2). The data for the present study were taken entirely from the household interview portion of the NHANES III from all interview years.

NHANES III data are available geocoded according to home address and can be matched to selected 1990 Census variables by census tract. These data are made available for restricted-use only by the National Center for Health Statistics (NCHS). The

restrictions assure confidentiality of the study participants. The proposal for the present study was reviewed by NCHS and we were granted access to these data.

NHANES III Linked Mortality File. The NHANES III Linked Mortality File contains follow-up data for NHANES III participants. The current NHANES III Linked Mortality File is the second mortality follow-up for NHANES III. The first followed participants through December 21, 2000 while the current file followed participants through December 31, 2006. The updated file became available in 2009. Mortality status for NHANES III participants was identified using the National Death Index (NDI) primarily through probabilistic record matching. NCHS used a matching algorithm for NHANES III records specific to this file but similar to that which is the standard used by NDI. It is considered to be a reliable source of mortality follow-up and is intended to be used to conduct an array of investigations of health, risk factors and mortality (3). Researchers have used the NHANES III to study the associations between all-cause and cause-specific mortality and health conditions including chronic obstructive pulmonary disease (4) and diabetes (5). It has also been utilized in the study of health factors such as the recommended cardiovascular health metrics (6) and low risk lifestyle behaviors (7). In all of these published studies, the linked mortality file proved to be a reliable source of mortality follow-up. The mortality measure was associated with the predictor variables in the anticipated directions and the studies were all cited as having advanced the understanding of these important health factors (4-7). In a sensitivity analysis, the current mortality file's probabilistic matching algorithm was compared with the NHANES I follow-up study where personal follow-up was combined with the NDI matching (4). In

this analysis, cases where follow-up status was considered unknown as of a defined end-date in the NHANES I were changed to not deceased as they would have been classified in the NHANES III linked mortality file. Using this methodology, the authors found a 1.5-4.5% reduction in NHANES I mortality rates. Although this demonstrates some discrepancy between the two methods, it results in a modest decrease in mortality rates which would attenuate any found association between risk factors and mortality.

The public-use NANES III Linked Mortality File was utilized for the proposed study to examine time from household interview to all-cause mortality.

1990 Census. The U.S. Census is mandated in the Constitution. It requires a count of every resident of the United States to occur every ten years. 1990 U.S. Census consisted of two questionnaires; the short form that was given to 100% of the population and consisted of 13 questions, and the long form that was given to 20% of the population and contained 45 questions (8). The decennial census strives to describe the US population and collects information on race, ethnicity, types and current value of housing, income and education among other characteristics. Summary File 3 (SF3), the dataset provided by the Census Bureau that was used to create the poverty measure for the present study, is made up primarily of weighted data from the long form of the 1990 Census. It provides aggregate information about household characteristics at various geographic levels. This study used data aggregated at the census tract level. A census tract is "a small, relatively permanent statistical subdivision of a county (9)." Census tracts were developed for densely populated states and metropolitan areas by local committees following guidelines provided by the Census Bureau. In 1990, less densely

populated areas were assigned to block numbering areas (BNAs) which were replaced by census tracts beginning in 2000. These were also used in this study in place of census tracts where needed.

The Census data file used for this dissertation was compiled by The Public Health Disparities Geocoding Project at the Harvard School of Public Health. This data file contains a variable measuring the percent of people in each census tract living below the poverty line. This variable was computed using 1990 Census data and is publically available at the Project's website (10).

Data from the 1990 US Census was chosen for the present dissertation research because it most closely matches the time period during which the interview data was collected for the NHANES III (October 1988-October 1994). The main effect of interest from the interview – social integration- was collected during this time period as were the residential addresses of the study participants. Although other methods might have been used to reflect the neighborhood status for specific years, such as interpolation using multiple Census years (11), these methods were not utilized in the present study. Consequences could be an under- or over-estimation of neighborhood poverty for some years, however, this study aimed to estimate the longer–term exposure to neighborhood context. An inclusion criterion in the study is residence in the reported area for at least one year and the majority of study subjects lived in their reported areas of residence for multiple years. Therefore, the use of the data from the 1990 Census likely accurately reflects the census tracts within which they resided.

Measures

Social Integration index. A modified social network index (SNI) was used to measure social integration (SI) for the present study. The items used to assess social support within the NHANES III primarily measure the quantity of social ties and therefore fall into the measurement category of social integration. These items tap into constructs similar to those measured in the commonly used Berkman-Syme SNI (12). This index was originally derived by Berkman in her dissertation work (13). In this writing, Berkman explains how data from the Human Population Laboratory –many pieces of which were validated and are described therein- were used to develop a social network measure that would predict mortality and other health outcomes in population-based studies. Although, she acknowledges that many pieces of the social questionnaire were unable to be validated, similar measures have since been used many times over to predict mortality (12, 14-16) as well as other health outcomes with remarkable consistency (14, 17-22).

Published research studies (17, 19) have used items from NHANES III to create a modified SNI that captures the four domains assessed by the Berkman-Syme index. The four domains are marriage or partnership, friends and relatives, religious activity, and voluntary associations. These studies have used the marital status item to split respondents into 2 categories – assigning a value of 1 to those married or living as married and 0 to all others (never married, widowed, divorced or separated). The frequency of contacts from two questions (# of times one talks on the phone with family or friends, how often per year do you get together with family or friends) were added

and then respondents split again into 2 groups with those above 156 contacts being assigned a 1 and less than 156 contacts assigned a 0. Frequency of church or religious service attendance was measured and respondents were assigned a 0 if they attended less than four services per year and a 1 if they attended four or more. Finally, those who responded that they were part of a voluntary organization were assigned a 1 with those that are not assigned a 0. The scores were added to give each individual a score from 0 to 4. This exact approach, used in previous studies, predicted health behaviors and outcomes as expected (17, 19). The present study followed this previously reported analytic approach in order to strengthen comparability across the studies.

Contact and connectedness with neighbors were also concepts explored in NHANES III but not included in the modified SNI as previously described. For this dissertation, the variable "How often per year do you visit with neighbors?" was used to measure an individual's social integration with neighbors. Preliminary analyses indicated that over half of the study sample provided a response of 0 defined as "never." Therefore a three-level variable was created where 0=never was one of the levels and the other 2 were low # of visits and high # of visits, based on the distribution of the data. Low number of visits was defined as less than 52 visits per year and high number of visits was defined as 52 or greater. This decision was made based on the distribution of the data. Fifty-two visits was a clear cut-point in the distribution. It also makes empirical sense in that 52 visits represent approximately one visit per week with neighbors.

Neighborhood socioeconomic status measurement. Neighborhood socioeconomic status (NSES) will be determined for each individual using the percent of people in their census tract living below the federally-defined poverty line. This variable has been shown to be a reliable measure of socioeconomic inequality in health studies (10). The variable was created and tested for use by The Public Health Disparities Geocoding Project at the Harvard School of Public Health. Specifically, this neighborhood poverty measure for the 1990 Census was compared to several other area-based socioeconomic measures and was found to have the most consistent results and to be the most sensitive to expected gradients in health (23). The poverty measurement variable was calculated for the 1990 Census for each census tract by adding together all of the variables measuring people living below the poverty line and dividing by the total number of people living in the census tract. Thus, the variable measures the proportion of people living in the census tract below the federally defined poverty line (10). These data were chosen for use in this study because they are well-tested and defined, as well as for their ease of use. Ordinal groupings of NSES values were created for use in the analysis.

Neighborhoods were defined using census tracts for the purpose of this study. As discussed earlier, census tract have been shown to adequately represent neighborhood in previous studies looking at neighborhood socioeconomic status. In addition, these geographic groupings are used for public program planning and will thus produce results that can be immediately utilized by practitioners (24). Geo-coded data

from NHANES III was merged to data from the 1990 Census via census tracts and BNAs and then used to measure NSES as described above.

All-cause mortality. The outcome of interest for the present study was time-to-death or more specifically, person-months of follow-up from the interview to December 31, 2006. There is between 12-18 years of follow-up for the sample depending on the year of NHANES interview. There is a mean of 167 months (95% confidence interval: 162, 172) of follow-up for the weighted study population which is roughly 14 years. The follow-up study was conducted by NCHS and linked NHANES participants over age 17 to the National Death Index. There were 20,024 participants eligible for the linkage and 5,360 deaths were identified. The linkage process has been used by NCHS for multiple studies over many years and is considered to be a reliable measure of death as described previously in this dissertation. This study focuses on all-cause mortality.

Covariates. A number of baseline characteristics will be included in the final statistical models. Due to their relationships with mortality and social integration, age, sex, and race/ethnicity was adjusted for in all regression models. In addition, individual SES at the time of the baseline interview was accounted for via the household poverty income ratio (PIR) and the individual's years of education completed.

Measures of baseline health and health behaviors were not considered as covariates for the regression models. Although past studies have included these factors as a way to account for characteristics other than the social factors of interest and therefore isolate their particular impact (12, 21, 22, 25), recent theory suggests that these may be the very mechanisms through which social integration impacts health (26).

In the interest of carefully testing the previously described conceptual framework these factors were not included in the present study. They will be examined through mediation analysis in future work.

Another potentially confounding variable that was included in the study is the length of time an individual has lived at his or her current residence. This may have an impact on how social integration and neighborhood conditions impact health (27). Length of time at residence may change the effect of NSES because if one has lived at the residence where he/she was interviewed for a short period of time, this address may have a different effect than if he/she had lived there for an extended period. This variable may also have an impact on social integration because the longer an individual lives in the same place, the more opportunity he or she may have to interact with his/her neighbors. We therefore limited the study to those who had lived in their area for at least one year.

Statistical methods

As mentioned previously, this study was approved by the Research Data Center at the National Center for Health Statistics. As a condition of this approval all study personnel completed a confidentiality orientation and submitted three confidentiality forms. Further, an application and study protocol was submitted to the UMDNJ New Brunswick Campus Institutional Review Board (IRB). The protocol was approved and deemed exempt. All decisions made by the legacy UMDNJ campus IRBs are accepted by the Rutgers IRB until their expiration dates. Thus insuring human subjects protection oversight for the present study.

This report section describes the various analytical procedures used in this dissertation overall. The specific ways in which the methods were applied to the individual specific aims previously mentioned, will be made clear in the manuscripts that follow.

NHANES III used a complex, multi-stage probability sample and the appropriate weights and statistical software that adjusts for the sample design were used to conduct these analyses. In the present dissertation, only data from the household and family interviews was utilized. Therefore, the final interview weight (WTPFQX6) was used in all analyses as well as the appropriate PSU and strata variables (SDPPSU6 and SDPSTRA6)(2).

The analyses described herein include another important analytical component to be considered. This component is the inclusion of neighborhood-level variables. The inclusion of these variables introduces additional concerns about the effects of two levels of variables (individual and neighborhood) and how correlation within these may influence estimates of variance in the models. Individuals within the same neighborhoods may be more similar to each other than to individuals in other neighborhoods introducing analytical concerns in addition to the theoretical interest. Analytical methods have been developed to address these issues such as hierarchical linear modeling or mixed modeling and generalized linear mixed modeling. These methods take into account the random effects of clustering within the models' levels. Unfortunately, the software packages that are available which can take into account both multilevel and complex design effects within the same statistical models were not

available for use via the RDC's secure remote access server at the time this analysis was conducted. Of the available statistical packages, SAS-callable SUDAAN (version 10)(28) was chosen as the most appropriate. This statistical package allows for a variety of analytical models that account for complex survey design but they do not explicitly account for the additional variable levels we were interested in for this dissertation study. SUDAAN can only account for one cluster variable for the purpose of variance estimation (G. Gordon Brown, Research Triangle Institute, personal communication, 2012). Given this limitation, the primary sampling units (PSUs) from the NHANES III was chosen as the cluster variable. The PSUs contain census tracts and are the higher level cluster variable, their use thus accounted for clustering at the neighborhood level as well as at the PSU-level and are therefore the most appropriate choice given the software constraints.

SUDAAN uses generalized estimating equations (GEE) and the Taylor Series Linearization variance estimation method to account for the complex survey design. These same methods have been used in multilevel studies of neighborhood effects on individual health (29, 30). They provide a population average estimate that takes into account the level clustering on the estimations of standard error. This has been shown to produce similar estimates to those of random effects models and these models are considered to be more robust because an exact covariance structure does not have to be identified (30). Further, GEE estimates the within-cluster similarity of the residuals in a regression model. It then takes the estimated within-cluster correlation to re-estimate the regression parameters and calculate standard errors that account for the

clustering. GEE estimates are found to be very reliable in situations when there are a large number of clusters but small numbers of individuals within clusters as was the case in this dissertation's analysis (31).

For descriptive analyses, SUDAAN's CROSSTAB procedure was used to summarize categorical variables and the DESCRIPT procedure was used for continuous variables. The procedures yielded frequencies, percentages, means, medians and ranges that were adjusted for the complex survey design and weight variables.

Chi-Square analyses were conducted using the CROSSTAB procedure as well to assess the bivariate relationship between our two main effects. Logistic regression analyses were carried out to adjust for confounding variables in manuscript 1. This was done using the RLOGIST procedure in SUDAAN. The models were built by first examining crude models of the main independent variable and outcome of interest and then potential confounders were manually entered. The log-likelihood ratio statistic was used to assess goodness-of-fit as was the Cox and Snell psuedo-R^2 (32).

Kaplan-Meier curves were created both to assess the bivariate association between time-to-death and our main effects as well as to assess the appropriateness of the proportional hazards assumption in preparation for Cox proportional hazards regression analyses (33). The Kaplan-Meier curves were created by first generating the Kaplan-Meier survival estimates using the KAPMEIER procedure in SUDAAN and exporting the results to PROC SGPLOT in SAS 9.2. (34). This created the graphical display of the Kaplan-Meier estimates that are included in the manuscripts.

Cox proportional hazards (PH) regression was used in the analysis where the outcome of interest was time-to-death. This was carried out using SUDAAN's SURVIVAL procedure which allows for regression of time-to-event data that includes variance estimates that account for complex survey design and in this case, the lower-level neighborhood clusters. In manuscript three we were especially interested in modeling the cross-level interaction between neighborhood poverty and individual social integration. Cox PH models were built that accounted for this interaction in several ways. As is appropriate to assess interaction in a Cox PH model (35), main effects models with individual social integration were built that were stratified by neighborhood poverty. This allowed for the estimation of the baseline hazard for social integration at each level of neighborhood poverty separately; when these baselines differ an interaction would be indicated.

A requirement in the use of survival analysis is that some meaning be placed on the start time of the study. In a study such as this one where the start time is only significant in that it happens to be the date that data was collected there may be concern about the meaningfulness of the outcome of interest. This may be especially true if the individuals being studied have some varied risk of experiencing the event of interest (death). In the case of the present study, there is an assumption of a "steady state (36)." That is, one can assume that death (the event of interest) occurs in the study sample at a steady rate equal to that in the target population and that being chosen for the study did not alter this risk in any way for any individual. NHANES uses randomly selected, national probability sample, and subjects were not chosen for any

reason connected to their risk of death. For this reason the assumption of a steady state should hold and survival analysis is an appropriate methodology for analyzing this time-to-event data.

Additive interaction was directly assessed by creating "dummy variables" that combined the effects of neighborhood poverty and social integration at defined levels as suggested by Knol and VanderWeele (37). A four-level variable was inserted into the regression model in place of social integration and neighborhood poverty. The referent category is the category of least risk, in this case high SNI and low neighborhood poverty (dR). The other three categories are high SNI/ high neighborhood poverty (d1), low SNI/low neighborhood poverty (d2), and low SNI/high neighborhood poverty (highest risk group=d3). While the referent group represents the absence of the main effects, the high risk group represents the joint effects of these risk factors and the other two variables represent the independent effect of each risk. The following measures of additive effect modification (37, 38) are reported in the current study: relative excess risk due to interaction (RERI), the synergy index (SI), and attributable proportion due to interaction (AP). These measures were calculated using the hazard ratios (HR) from the Cox regression as follows- RERI= HRd3-HRd2-HRd3+1; S=HRd3-1/(HRd2-1)+(HRd1-1); AP=RERI/HRd3. The RERI and AP are interpreted as being equal to 0 if there is no effect modification or exact additivity; greater than 0 for positive or less for negative, and the SI is interpreted with 1 being exact additivity. In order to test the significance of the interaction measures, covariance matrices were output from the SURVIVAL procedures and imported to an excel spreadsheet designed by Knol (39). This produced p-values

and confidence intervals via the delta method for each separate measure of additive interaction.

REFERENCES

1. Centers for Disease Control and Prevention. Celebrating the First 50 years of NHANES. Atlanta, GA: Centers for Disease Control and Prevention; 2010. (Accessed June 29, 2013).
2. National Center for Health Statistics. Third National Health and Nutrition Examination Survey, 1988-1994, NHANES III Household Adult Data File and Documentation. Hyattsville, MD: Centers for Disease Control and Prevention, 1996, (US Department of Health and Senior Services publication no. 77560)
3. National Center for Health Statistics. The Third National Health and Examination Survey (NHANES III) Linked Mortality File, Mortality Follow-up through 2006: Matching Methodology. Hyattsville, MD, 2009.
4. Ford ES, Mannino DM, Zhao G, et al. Changes in mortality among US adults with COPD in two national cohorts recruited from 1971-1975 and 1988-1994. *Chest* 2012;141(1):101-10.
5. Goldfarb-Rumyantzev AS, Rout P, Sandhu GS, et al. Social adaptability index predicts overall mortality in patients with diabetes. *Journal of Diabetes and its Complications* 2012;26(1):44-9.
6. Yang Q, Cogswell ME, Flanders WD, et al. Trends in cardiovascular health metrics and associations with all-cause and CVD mortality among US adults. *JAMA : The Journal of the American Medical Association* 2012;307(12):1273-83.
7. Ford ES, Zhao G, Tsai J, et al. Low-risk lifestyle behaviors and all-cause mortality: Findings from the National Health and Nutrition Examination Survey III Mortality Study. *American Journal of Public Health* 2011;101(10):1922-9.
8. US Census Bureau. History: 1990 Overview. Washington, DC: US Department of Commerce; 2013. (http://www.census.gov/history/www/through_the_decades/overview/1990.html). (Accessed June 29, 2013).
9. US Census Bureau. Census Tracts and Block Numbering Areas. Washington, DC: US Department of Commerce; 2000. (http://www.census.gov/geo/www/cen_tract.html). (Accessed June 29, 2013).
10. The Public Health Disparities Geocoding Project. U.S. Census Tract Poverty Data. Boston, MA: Harvard School of Public Health; 2004. (http://www.hsph.harvard.edu/thegeocodingproject/webpage/monograph/povdata.htm). (Accessed June 29, 2013).
11. Merkin SS, Basurto-Davila R, Karlamangla A, et al. Neighborhoods and cumulative biological risk profiles by race/ethnicity in a national sample of U.S. adults: NHANES III. *Annals of Epidemiology* 2009;19(3):194-201.
12. Berkman LF, Syme SL. Social networks, host resistance, and mortality: A nine-year follow-up study of Alameda County residents. *American Journal of Epidemiology* 1979;109(2):186-204.
13. Berkman LF. *Social Networks. Host Resistance, and Mortality: A Follow-up Study of Alameda County Residents* [dissertation]. Berkley, CA: University of California-Berkley; 1977.
14. Berkman LF, Glass T. Social Integration, Social Networks, Social Support, and Health. In: Berkman LF, Kawachi I, eds. *Social Epidemiology*. New York, NY: Oxford University Press, 2000.

15. Seeman TE, Kaplan GA, Knudsen L, et al. Social network ties and mortality among the elderly in the Alameda County Study. *American Journal of Epidemiology* 1987;126(4):714-23.
16. Stringhini S, Berkman L, Dugravot A, et al. Socioeconomic status, structural and functional measures of social support, and mortality: The British Whitehall II Cohort Study, 1985-2009. *American Journal of Epidemiology* 2012;175(12):1275-83.
17. Ford ES, Loucks EB, Berkman LF. Social integration and concentrations of C-reactive protein among US adults. *Annals of Epidemiology* 2006;16(2):78-84.
18. Kawachi I, Berkman LF. Social ties and mental health. *Journal of Urban Health : Bulletin of the New York Academy of Medicine* 2001;78(3):458-67.
19. Obisesan TO, Gillum RF. Cognitive function, social integration and mortality in a U.S. national cohort study of older adults. *BMC Geriatrics* 2009;9:33.
20. White AM, Philogene GS, Fine L, et al. Social support and self-reported health status of older adults in the United States. *American Journal of Public Health* 2009;99(10):1872-8.
21. House JS, Landis KR, Umberson D. Social relationships and health. *Science* 1988;241(4865):540-5.
22. Cohen S, Doyle WJ, Skoner DP, et al. Social ties and susceptibility to the common cold. *JAMA : The Journal of the American Medical Association* 1997;277(24):1940-4.
23. Krieger N, Chen JT, Waterman PD, et al. Race/ethnicity, gender, and monitoring socioeconomic gradients in health: A comparison of area-based socioeconomic measures--the public health disparities geocoding project. *American Journal of Public Health* 2003;93(10):1655-71.
24. Krieger N. A century of census tracts: health & the body politic (1906-2006). *Journal of Urban Health : Bulletin of the New York Academy of Medicine* 2006;83(3):355-61.
25. Kaplan GA, Salonen JT, Cohen RD, et al. Social connections and mortality from all causes and from cardiovascular disease: Prospective evidence from Eastern Finland. *American Journal of Epidemiology* 1988;128(2):370-80.
26. Berkman LF, Glass T, Brissette I, et al. From social integration to health: Durkheim in the new millennium. *Social Science & Medicine* 2000;51(6):843-57.
27. O'Campo P. Invited commentary: Advancing theory and methods for multilevel models of residential neighborhoods and health. *American Journal of Epidemiology* 2003;157(1):9-13.
28. Shah VBBB, Bieler GS. *SUDAAN User's Manual*. Research Triangle Park, NC: Research Triangle Institute; 2005.
29. Echeverria SE, Borrell LN, Brown D, et al. A local area analysis of racial, ethnic, and neighborhood disparities in breast cancer staging. *Cancer Epidemiology, Biomarkers & Prevention : A publication of the American Association for Cancer Research, cosponsored by the American Society of Preventive Oncology* 2009;18(11):3024-9.
30. Hubbard AE, Ahern J, Fleischer NL, et al. To GEE or not to GEE: Comparing population average and mixed models for estimating the associations between neighborhood risk factors and health. *Epidemiology* 2010;21(4):467-74.
31. Hanley JA, Negassa A, Edwardes MD, et al. Statistical analysis of correlated data using generalized estimating equations: An orientation. *American Journal of Epidemiology* 2003;157(4):364-75.
32. Hosmer DW, Lemeshow S. *Applied Logistic Regression*. 2nd ed. New York: Wiley; 2000.
33. Persson I. *Essays on the Assumption of Proportional Hazards in Cox Regression* [Dissertation]. Uppsala, Sweden: Uppsala University; 2002.

34. SAS Institute. *SAS 9.2 Language Reference Dictionary*. 3rd ed. Cary, NC: SAS Institute; 2010.
35. Kleinbaum DG, Klein M. *Survival Analysis : A Self-Learning Text*. 2nd ed. New York, NY: Springer; 2005.
36. Szklo M, Nieto FJ. *Epidemiology : Beyond the Basics*. 3rd ed. Burlington, Mass.: Jones & Bartlett Learning; 2014.
37. Knol MJ, VanderWeele TJ, Groenwold RHH, et al. Recoding preventive exposures to get valid measures of interaction on an additive scale. *European Journal of Epidemiology* 2011;26(10):825-6; author reply 6.
38. Knol MJ, VanderWeele TJ. Recommendations for presenting analyses of effect modification and interaction. *International Journal of Epidemiology* 2012;41(2):514-20.
39. Knol MJ. Spreadsheet for measures of additive interaction with confidence intervals and p-values using the delta method. Utrecht, The Netherlands: Julius Center, 2011.

Examining the relationship between social integration and neighborhood poverty: An analysis of NHANES III

ABSTRACT *(the abstract herein was accepted for an oral presentation at the American Public Health Association's 141st Annual Meeting and Exposition in Boston, MA on November 4, 2013. It is abstract #286730)*

Background: Social integration, defined as number and frequency of social ties, is associated with various health outcomes. There is also growing evidence of the importance of neighborhood contexts, such as level of poverty, on health. We examined how neighborhood poverty structures two dimensions of social integration: integration with neighbors and more general integration with family/ friends.

Methods: We examined data from the Third National Health and Nutrition Examination Survey (NHANES III) geocoded and matched to census tracts, serving as neighborhood proxies. We assessed social integration using a modified version of the social network index (SNI) and neighborhood integration based on the number of visits with neighbors. We operationalized neighborhood poverty as the proportion of residents in a census tract living below the poverty level. We analyzed data using bivariate methods as well as logistic regression models that accounted for the complex survey design.

Results: When controlling for individual-level factors, living in high poverty neighborhoods was associated with 47% (95% confidence interval: 1.15, 1.88) greater odds of having a low score on the SNI when compared with those living in more affluent neighborhoods. In contrast, living in a high poverty neighborhood significantly

decreased odds (odds ratio=0.72, 95% confidence interval: 0.55, 0.93) of having fewer visits with neighbors.

Discussion: Compared with affluent neighborhoods, living in high poverty neighborhoods is associated with having fewer social ties generally but also with more visits with neighbors. These results merit further exploration as they suggest that neighborhood poverty may influence social integration in different ways and may lead to varying effects on health.

INTRODUCTION

There is now a consistent body of evidence linking neighborhood contexts and social integration to health. For example, several studies have shown that neighborhoods are associated with mortality, cardiovascular disease, cardiovascular risk factors, depression, and perinatal outcomes among other health outcomes (1-12). Neighborhoods are the geographic area within which individuals reside, and are hypothesized to influence health by shaping access to resources, environmental exposures, and various types of social relationships and controls (13, 14). Specifically, dynamic processes, such as peer group influence and collective socialization, and structural dimensions, such as geographic isolation of the poor, concentrated affluence or disadvantage and differences in institutional resources, may have a direct effect on the health of the people who live in particular neighborhood settings (4, 15).

In a separate body of literature, researchers have examined the role of social relationships on health (16-19). Social relationships can be defined simply as interactions among individuals. Researchers in many scientific disciplines have been interested in various aspects of social relationships such as their quantity, quality, and the ways that people benefit from participating in them (20). House et al (19), in the paper that first reviewed epidemiologic evidence of this association suggested that the impact of social relationships on health rivaled that of other more widely accepted health risks such as smoking, obesity and high blood pressure.

Despite the relatively consistent body of literature indicating that neighborhoods and social relationships influence health, less is known about the role that neighborhoods play in actually patterning social relationships. Berkman et al (16) theorize that the context within which social relationships occur likely has an impact on how they affect an individual's health. Stringhini et al (21) found a positive association between individual socioeconomic status (SES) and dimensions of social relationships among men in the Whitehall Cohort study. The authors showed that men with higher SES had higher quality social relationships as well as better health than those with lower SES. However, this study did not assess the contribution of neighborhood-level socioeconomic condition. Small (22) found that racial differences in the quality and quantity of social relationships did not remain significant in statistical models that accounted for neighborhood conditions. Thus in that study, it was neighborhood poverty, and not race, that best accounted for the smaller number and reduced quality of social relationships among minority groups. Improved understanding of the role of

neighborhoods in patterning social relationships may inform future health research and interventions focused on strengthening neighborhood cohesion or other related efforts.

In the present study, we investigate how neighborhood socioeconomic status relates to social integration, a quantitative measure of social relationships. The study begins by examining if neighborhood poverty is associated with the amount of general social integration individuals report. Then, we specifically investigate if neighborhood poverty is associated with the intensity of relationships with neighbors. Although previous studies have asked similar questions, this is one of the first studies to examine social integration across neighborhoods of varying socioeconomic conditions on a national scale.

METHODS

Data Sources

Data for this study comes from the Third National Health and Nutrition Examination Survey (NHANES III). The survey, conducted by the Centers for Disease Control and Prevention, employed a complex, multi-stage, stratified sampling design intended to recruit a nationally representative sample of the non-institutionalized, civilian US population. NHANES III was conducted from October 1988-October 1994 and included individuals from age 2 months with no upper age limit. Data collection for the survey consisted of an in-home interview and a series of examinations both in-home and via mobile exam centers (23). The data for the present study are taken entirely from the household interview portion of the NHANES III from all interview years. The

NHANES III data were geocoded according to participants' home address and matched to 1990 Census tracts. These data are made available for restricted-use only by the National Center for Health Statistics (NCHS). The restrictions assure confidentiality of the study participants.

The Census data file used for this study was compiled by The Public Health Disparities Geocoding Project at the Harvard School of Public Health. This data file contains a variable measuring the percent of people in each census tract living below the poverty line which was computed using 1990 Census data. It is publically available at the Project's website (24).

Measures

Social Integration (dependent variable). Previously published studies (25, 26) have used items from NHANES III to create a modified Social Network Index (SNI) that captures the four domains first assessed by Berkman and Syme (27, 28). This index is used in the present study. The four domains are marriage or partnership, friends and relatives, religious activity, and voluntary associations. These studies used the marital status item to split respondents into 2 categories – assigning a value of 1 to those married or living as married and 0 to all others (never married, widowed, divorced or separated). The frequency of contacts from two questions (# of times one talks on the phone with family or friends, how often per year do you get together with family or friends) were added together and then respondents split into 2 groups with those above 156 contacts being assigned a 1 and less than 156 contacts assigned a 0. Frequency of church or religious service attendance was measured and respondents were assigned a

0 if they attended less than four services per year and a 1 if they attended four or more. Finally, those who responded that they were part of a voluntary organization were assigned a 1 and those that were not assigned a 0. The scores were added to give each individual a score from 0 to 4. This approach has been shown to have good predictive validity (25, 26) and similar measures have had consistent associations with health outcomes (17, 20, 21, 28-32). For descriptive purposes, the Social Network Index was transformed into a three-level variable; high (score of 3-4), moderate (score of 2) or low (score of 0-1) social integration. In logistic regression models, the dichotomous variable was formed by combining the high and moderate groups to contrast with the low social integration group.

Social contacts with neighbors are also explored in NHANES III. We created a separate measure of social integration with neighbors based on the question "How often per year do you visit with neighbors?" Preliminary analyses indicated that over half of the study sample provided a response of 0 defined as "never." Therefore a three-level variable was created where 0=never is one of the levels and the other two are low # of visits and high # of visits, based on the distribution of the data. Low number of visits is defined as 1-52 visits per year and high number of visits is defined as 52 or greater. For logistic regression models, participants were classified into those with less than 52 visits compared to those with 52 visits or greater. This decision was made based on the distribution which showed that the group with at least 52 visits per year was different from the two lower frequency groups. It also made empirical sense as 52

visits per year is approximately equal to one visit per week with more than 52 visits indicating contact that was more frequent than once a week.

Neighborhood socioeconomic status measurement (main independent variable). Neighborhoods were defined using census tracts for the purpose of this study. Census tracts have been extensively used in prior neighborhood research (11, 22, 33-35). It is a geographic boundary used for public program planning purposes, thus producing results that can be immediately utilized by practitioners (34). To represent neighborhood socioeconomic context, a variable measuring the percent of residents within a census tract living below the federally-defined poverty line was used. This variable has been shown to be a reliable measure of socioeconomic inequality in several health studies (24). Specifically, the neighborhood poverty measure for the 1990 Census tracts was compared to several other area-based socioeconomic measures and was found to have the most consistent results and to be the most sensitive to expected gradients in health (36). A four-level categorical measure of neighborhood poverty was created. The categories were based on the federal definition of "poverty areas" as areas where greater than 20% of the population are living below the federal poverty line (11, 37). Based on calculations of the distribution of the variable in this dataset, the four-level variable in the current study is like that used by Subramanian et al (11): 0%–4.9%, 5%–9.9%, 10%–19.9%, and 20%–100%. These categories were divided into a two-level measure for modeling purposes, where individuals were classified as those living in neighborhoods where less than 20% of residents live below poverty compared to neighborhoods with 20% or more living below the poverty line.

Covariates. A number of baseline characteristics will be included in the final statistical models. Due to their demonstrated associations with social integration, age, sex, and race/ethnicity were adjusted for in the regression models. In addition, individual SES at the time of the baseline interview is accounted for via the household poverty income ratio (PIR) and the individual's years of education completed. Age has been discussed as having a curvilinear relationship with social integration in past studies (38) and is therefore included here as a categorical variable. Individual SES has also been shown to be a strong predictor and therefore 5 levels of the PIR variable is used to account for the fine gradations in its effects (8, 22, 38). Although other studies have examined gender-specific associations (21, 28, 39), this was not the focus of our study since we were interested in exploring the overall association between neighborhood poverty and social integration. Therefore, all analyses were adjusted for gender.

The amount of time that one is exposed to their neighborhood is an important consideration in this study. While the data are cross-sectional in nature and therefore we cannot test the importance of life-course exposure to neighborhood condition, we did take steps to insure that the study participants had a substantial exposure to their neighborhood of residence. To insure adequate time for exposure to the main independent variable, the sample was limited to those who responded they had lived in their city/town/ area of residence for at least one year.

Statistical Analysis

All analyses were conducted using SUDAAN, version 10 (40). Descriptive statistics were used to present the distribution of key covariates by neighborhood

poverty, using weighted estimates that accounted for the complex study design of NHANES III. Bivariate associations between neighborhood poverty and visits with neighbors and the modified Social Network Index were calculated using chi-square statistics. Logistic regression models were built to assess the relationship between neighborhood poverty (independent variable) and social integration (dependent variable) while controlling for theorized confounders. When building the regression models, the bivariate relationships were examined using both the two and three level variables of social network score and neighbor visits and compared to the two and four level variables of neighborhood poverty. These were exploratory analyses used to assess how fine a gradation of these variables was most efficient and highlight the potential associations. Next, a crude logistic regression model was fit followed by models with various combinations of the confounding variables. The final models were chosen based on how well they explained the association of the main effects with the outcome. Fit of the models was examined using the log likelihood, the likelihood ratio and the Cox and Snell's pseudo R-square statistic (41). The final models do the best job of parsimoniously explaining the outcome and include clinically as well as statistically significant covariates.

In planning the regression analyses, we strongly considered the multilevel nature of the individual-level outcome and the neighborhood-level exposure and how this could be accounted for within the complex sample design of NHANES III. It is likely that individuals living within the same census tract were more similar to each other than to those within other census tracts. This can have an effect on the calculation of variance

in the models and there are analytic methods available to account for this effect. When analyzing complex survey data, SUDAAN takes these same issues into consideration using similar analytic methods. People within the same primary sampling units (PSUs) of the NHANES are projected to be more similar to each other than to those sampled from other PSUs. In order to properly account for this, SUDAAN uses generalized estimating equations (population average models) and variances are estimated using the Taylor-series method. As of this writing, SUDAAN is unable to take more than one set of stratification variables into account (G. Gordon Brown, Research Triangle Institute, personal communication, 2012) which forced us to decide which level of stratification would be accounted for in the present study. We decided to use the sample design variables instead of the census tracts in order to analyze the data in the way it was intended. We consider this to be an accurate analysis because the PSUs in NHANES are mainly individual counties which contain several census tracts and the PSUs are, therefore, the higher level grouping in this multilevel regression analysis. In essence, therefore, the census tract clustering is also accounted for in the logistic regression models.

Human subjects review was conducted by the University of Medicine and Dentistry of New Jersey- New Brunswick campus Institutional Review Board (the present study was conducted under the legacy UMDNJ IRB which as if July 1, 2013 is, part of the newly integrated Rutgers University IRB). The study was also reviewed by the Research Data Center (RDC) at the National Center for Health Statistics in Hyattsville, Maryland.

The study was approved and all analyses were conducted either in the RDC offices or remotely via ANDRE, their secure remote data analysis system.

The final analytic sample consisted of 16,044 survey respondents. The full sample included 20,024 adults age 17 or older who were interviewed as part of NHANES III and eligible for subsequent follow-up. Respondents were excluded from the present analysis if their addresses at the time of the interview were not able to be geocoded and matched to a 1990 Census tract (n=2,778). In order to insure that individuals had an opportunity to have their social experiences shaped by the neighborhood where they live, those who responded that they lived in their city/town/area for less than one year were also excluded (n=1,202). The sample size may be less than 16,044 for some analyses when values for included variables are missing. There are 1,699 individuals (about 10% of the sample) for whom PIR is missing and in those analyses that include PIR these responses are excluded as well. The group with missing PIR is more likely to be from the extremes in the age spectrum, in racial/ethnic minorities, be less educated and have lived in their areas for shorter periods of time when compared to those where PIR is provided.

RESULTS

Table 1 presents the weighted descriptive statistics for the full sample by categories of neighborhood poverty. Results indicate that a little over half the sample are women (53%), the majority (74%) are identified as Non-Hispanic white, and over half (61%) are between 20 and 49 years of age. Most (74%) have completed at least a high

school education and 82% live above the poverty line. Over half (53%) of the study participants have lived in their area of residence for twenty or more years.

Demographic differences by degree of neighborhood poverty in the sample can be seen in Table 1 as well. Those living in the highest poverty areas (at least 20%) are more likely to be female, of a racial or ethnic minority, live below the poverty line and are less educated than those in the neighborhoods with less poverty. Further, as neighborhood poverty increases, the proportion of non-Hispanic whites decreases, with the most dramatic change between the higher two categories (from 10-19.9% to 20% and over, from 73% to 42%).

Table 2 shows significant bivariate associations between social integration and categories of neighborhood poverty. The score on the social network index is higher among those living in neighborhoods with 0-4.9% of residents living below poverty ($P < 0.0001$). Conversely, a higher percentage of individuals with low scores on the social network index are in neighborhoods with the highest percentage of poverty (48%). The relationship between the amount of yearly visits with neighbors and neighborhood poverty level reveals a different (although also statistically significant) pattern. Within the highest poverty area, a greater percentage of the study participants (42%) reported a higher number of visits than individuals living in neighborhoods with a lower percentage of poverty.

Table 3 displays the results of logistic regression models examining the association between neighborhood poverty on social integration generally as well as with neighbors after controlling for potential confounders. The unadjusted model

shows that those living in the neighborhoods with at least 20% of residents living in poverty are 2.05 (95% confidence interval: 1.68, 2.52) times more likely to have a low social network index score than those in the lowest poverty (less than 5%) neighborhoods. Those in neighborhoods with 10-19.9% poverty are also more likely to have low scores on the social network index with an odds ratio of 1.67 (95% confidence interval: 1.36, 2.06). After adjusting for sex, age and individual SES, the significant relationships between neighborhood poverty and social network score remain although the odds ratio is attenuated. Individuals in the highest poverty area are 1.43 (95% confidence interval: 1.10, 1.86) times as likely to have a low score on the social network index when compared to those in the most affluent neighborhoods. Neighborhoods with 10-19.9% poverty are 1.29 (95% confidence interval: 1.01, 1.64) times as likely to have a low score.

Table 4 displays the results of logistic regression models examining the relationship between neighborhood poverty and number of yearly visits with neighbors. The unadjusted model shows that individuals living in neighborhoods with high poverty are less likely (odds ratio: 0.70; 95% confidence interval: 0.57, 0.86) to have low numbers of visits with their neighbors when compared to those in neighborhoods with the lowest amount of poverty. That is, they were more likely to visit with neighbors than their counterparts living in more affluent neighborhoods. This relationship remained when controlling for individual-level factors (odds ratio: 0.75; 95% confidence interval: 0.58, 0.98).

DISCUSSION

The results of the present study indicate a significant association between living in high poverty neighborhoods and the extent of social integration among individuals in these neighborhoods. Specifically, individuals living in affluent neighborhoods were more likely to have high general social integration. However, living in poor neighborhoods was associated with more visits with neighbors when compared to those living in the least impoverished neighborhoods. These associations were found in a large nationally representative sample of the US population living in varying neighborhood settings, and after adjusting for demographic characteristics and individual-level socioeconomic condition.

The findings reported herein contribute to the literature in at least two ways. First, our study directly examined the role of neighborhood poverty in shaping general social integration. Previous studies have linked low neighborhood SES to low social integration within urban settings (22, 42). One study demonstrated that the social characteristics of poor neighborhoods such as low collective efficacy, the ability of neighbors to look out for each other, and physical neighborhood deterioration lead to a decrease in social integration and health of those who live there (42). Another study looking at different dimensions of social relationships suggested that larger networks with individuals who have the ability to encourage upward mobility through job and education connections are what differentiate the successful social relationships of those in affluent neighborhoods and why those in poor neighborhoods continue to be more socially isolated (22). Several other studies have examined the associations between

individuals' personal SES and social integration and these too have found that those with low SES are less socially integrated generally (21, 43). Our study found the relationship between social integration and neighborhood poverty remains even after adjusting for individual SES.

Second, in the present study, we distinguished between general social integration and social integration with neighbors, as measured through numbers of visits with neighbors. This distinction in important since neighborhood poverty is likely to exert a more direct impact on relationships developed in the immediate geographic area in which individuals live, than with relationships that may exist outside of the neighborhood. In line with the few studies that have investigated this topic (38), we found that living in neighborhoods characterized by poverty was associated with more visits with neighbors. In their study of Nashville neighborhoods, Campbell and Lee (38) found that although those with low SES did have a tendency toward lower general social integration and smaller networks, the frequency and intensity of contact with their neighbors was much greater than that of those with high SES. These authors hypothesized that because of their smaller networks and reduced resources generally, those with low SES needed to rely more heavily on their neighbors for support. Our findings support this theory although we did not have data that directly asked about the reasons for the frequency of neighbor visits or the quality of those interactions.

Psychological theories of stress, including the conservation of resources theory and the reserve capacity model (44, 45), posit that individuals respond to stressful situations by protecting the resources that they already possess. These resources can

include emotional, social and physical benefits. Under these theories it has been discussed that those living in more stressful situations, like concentrated poverty, may hold onto their resources and be unable to expend those resources to help others (45, 46). This scenario could explain this finding where people in affluent areas are able to provide benefit to and derive benefit from their neighbors through limited contacts. These theories also support the notion that those in high poverty areas do not benefit from their contacts in the same way as those in affluent areas nor are they able to maintain the more resource costly non-neighbor social relationships.

Our study results also corroborate classical writings by Sampson, Raudenbush and Wilson (15, 47, 48) that suggested that the poor had strong bonds with neighbors but lacked the economic, cultural and political resources to simultaneously transform these connections into tangible opportunities for individual or neighborhood benefits, so often the case in more affluent neighborhoods. However, this earlier work and other more recent studies have largely been based on local, mostly urban communities (22, 38). Our use of a variety of neighborhoods from across the United States adds new supporting evidence regarding how neighborhood socioeconomic condition structures social relationships and why frequent contact with neighbors may not be enough to offset the disadvantages faced by those living in poor neighborhoods.

The present study has several potential limitations that should be considered when interpreting results. One limitation of this study is the use of census tracts as proxies for neighborhood life. Census tracts capture reasonable geographic boundaries, but these boundaries may not directly map onto the same geographic space that a

person considers as his/her neighborhood. This personal experience of the neighborhood may be part of how the neighborhood influences social interactions and this lack of specificity may limit the results of the study. Further, self-reported assessments on the number of visits with neighbors on a yearly basis likely introduced measurement error that influenced the precision of our regression estimates (49, 50). Both social integration and neighborhood socioeconomic condition were measured using data at one point in time during adulthood. A growing body of evidence suggests that a life-course perspective that considers exposures over the course of a person's life may better elucidate the complexity of living in poverty and its many social and health consequences (51). In a recent review, Diez Roux (52) points out that the relationships between individuals and the group contexts within which they operate are dynamic and reciprocal, with the group-level context affecting the individual and the individual in turn having an impact on his/her environment. Future studies should examine how exposure to neighborhood poverty influences the development of social ties and whether this varies over time and based on age, race/ethnicity or gender.

A third limitation is in the measure of social integration in the study. Although other similar measures have had good predictive validity, the items included in the NHANES III are not the ideal and do not lend themselves to weighting based on the relative importance of some social interactions over others.

Finally, a concern with cross-sectional surveys like NHANES that include the collection of biological data is that those individuals with particular health concerns or social integration deficits may choose not to take part in the study, therefore possibly

inducing a selection bias. The NHANES III does have a high general response rate of 86% (53), although this is not perfect and could indicate a non-response bias, such a bias is not a strong concern.

The strengths of our study include the large sample size and the fact that the NHANES III is a probability sample representative of the US population. This ensures ample power for a variety of analyses, including those being conducted here. While these data are not nationally representative of race and ethnicity when compared to the US Census, the weighting procedure allows us to make inferences for all of the major racial/ethnic groups in the United States. A final strength of the study is the use of social integration and neighborhood poverty variables that have been used in previous studies, thus helping to build a cohesive body of research in this area.

Our results highlight the differential role of neighborhood poverty on distinct forms of social integration. Having meaningful connections to others is an essential human need. The implication of our findings is that fostering stronger ties and bonds with neighbors also requires addressing the resource deficits that exist in the neighborhoods where social integration is most urgently needed.

Table 1: Weighted descriptive summary statistics for the total sample (N=16,044) and by neighborhood poverty category. *This table displays column percentages.*

Variable	*Total Sample* % (SE)	*0-4.9% neighborhood Poverty* % (SE)	*5-9.9% neighborhood poverty* % (SE)	*10-19.9% neighborhood poverty* % (SE)	*≥20% neighborhood poverty* % (SE)
Neighborhood Poverty					
0-4.9%	30.9 (1.87)				
5-9.9%	25.4 (1.29)				
10-19.9%	25.1 (1.59)				
≥20%	18.7 (1.22)				
Individual level predictors:					
Age groups					
17-19 years	4.8 (0.35)	4.1 (0.66)	4.7 (0.53)	4.7 (0.53)	6.0 (0.51)
20-29 years	19.8 (0.81)	14.7 (1.07)	20.2 (1.54)	21.9 (1.27)	24.8 (1.55)
30-39 years	23.7 (0.75)	22.5 (1.48)	26.0 (1.45)	23.7 (1.47)	22.6 (1.33)
40-49 years	17.9 (0.62)	22.1 (1.47)	17.3 (1.03)	14.9 (0.93)	15.5 (1.06)
50-59 years	11.9 (0.41)	13.8 (0.96)	11.8 (0.93)	11.3 (0.81)	9.7 (0.63)
60-69 years	10.9 (0.49)	11.7 (1.19)	10.2 (0.83)	11.2 (0.80)	10.2 (0.74)
70-79 years	7.6 (0.41)	7.8 (0.93)	6.6 (0.62)	8.6 (0.56)	7.4 (0.62)
80+ years	3.4 (0.29)	3.2 (0.49)	3.1 (0.49)	3.7 (0.37)	3.7 (0.39)
Sex					
Male	47.1 (0.47)	48.0 (0.98)	48.2 (1.09)	47.6 (0.75)	43.6 (0.92)
Female	52.9 (0.47)	52.0 (0.98)	51.8 (1.09)	52.4 (0.75)	56.4 (0.92)
Race/Ethnicity					
Non-Hispanic White	73.6 (1.35)	89.5 (1.32)	77.8 (2.66)	72.9 (2.38)	42.4 (2.30)
Non-Hispanic Black	12.3 (0.74)	3.6 (0.53)	8.5 (1.16)	11.0 (1.02)	33.5 (2.07)
Mexican-American	5.6 (0.48)	1.8 (0.31)	4.4 (0.81)	6.3 (0.76)	12.6 (1.06)
Other	8.5 (0.93)	5.1 (1.14)	9.2 (1.82)	9.8 (1.52)	11.5 (1.72)
Living below poverty (PIR<1)	12.7 (0.90)	3.3 (0.64)	8.4 (1.48)	16.1 (1.49)	30.6 (1.86)
Highest year of school completed					
0-8 years	11.1 (0.61)	4.5 (0.42)	7.7 (1.06)	13.9 (0.97)	22.7 (1.11)
9-11years	14.8 (0.60)	8.8 (0.86)	13.1 (1.14)	18.7 (1.10)	21.7 (0.90)
12 years	32.8 (0.83)	29.9 (1.59)	36.2 (1.75)	33.7 (1.25)	31.9 (1.48)
13+ years	41.3 (1.27)	56.8 (2.08)	43.0 (2.14)	33.6 (1.61)	23.8 (1.29)
How long lived in city/town/area					
Whole life	26.8 (1.14)	24.7 (2.04)	25.1 (2.08)	27.2 (1.69)	31.9 (1.35)
>20 years	26.6 (0.89)	27.3 (2.00)	26.2 (1.26)	26.1 (1.56)	26.8 (1.45)
11-20 years	15.6 (0.72)	17.5 (1.51)	15.7 (1.31)	14.9 (1.15)	13.3 (1.03)
5-10 years	14.6 (0.76)	15.9 (1.41)	15.3 (1.20)	14.3 (1.28)	11.9 (0.97)
3-4 years	7.6 (0.48)	6.4 (0.86)	8.4 (0.87)	8.2 (0.81)	7.6 (1.00)
1-2 years	8.7 (0.59)	8.1 (1.00)	9.2 (1.14)	9.2 (0.82)	8.4 (1.45)

Table 2: Bivariate analysis examining neighborhood poverty and the 3-level social integration variables. *This table displays row percentages and p-values from Chi-Square tests.*

	Social Network Index (p<0.0001)			**Visits with neighbors (p<0.0001)**		
neighborhood poverty	Low (score 0,1)	Moderate (score = 2)	High (score 3,4)	No visits	Low (<52 /yr)	High (52+/yr)
0-4.9%	31%	35%	34%	45%	22%	34%
5-9.9%	35%	36%	29%	51%	15%	33%
10-19.9%	42%	35%	23%	51%	14%	35%
≥20%	48%	34%	18%	47%	11%	42%

Table 3: Logistic regression analysis of neighborhood poverty as a predictor of low social integration.

	Model 1		Model 2	
	Odds Ratio	**95%CI**	**Odds Ratio**	**95%CI**
Neighborhood Poverty				
<5%	1.00	Ref	1.00	Ref
5% - 9.9%	1.21	0.95, 1.55	1.00	0.77, 1.30
10% - 19.9%	1.67	1.36, 2.06	1.29	1.01, 1.64
≥20%	2.05	1.68, 2.52	1.43	1.10, 1.86
Sex				
Male			1.19	1.08, 1.32
Female			1.00	Ref
Race-Ethnicity				
Non-Hisp. white			1.00	Ref
Non-Hisp. black			0.95	0.80, 1.12
Mexican-Amercian			0.67	0.55, 0.81
Other			1.35	0.99, 1.86
Age				
17-19 years			1.00	Ref
20-29 years			1.56	1.22, 2.01
30-39 years			0.94	0.71, 1.27
40-49 years			0.80	0.60, 1.08
50-59 years			0.76	0.55, 1.06
60-69 years			0.62	0.44, 0.88
70-79 years			0.76	0.55, 1.06
80+ years			1.12	0.87, 1.45
Poverty Income Ratio				
>1			1.52	1.14, 2.01
1-1.99			1.21	0.97, 1.51
2-2.99			0.88	0.74, 1.04
3-3.99			0.88	0.72, 1.07
4+			1.00	Ref
Education				
0-8 years			2.12	1.66, 2.71
9-11 years			1.83	1.50, 2.23
12 years			1.60	1.35, 1.91
13+years			1.00	Ref

The outcome modeled is low social integration (SNI score of 0-1) as compared to high social integration (2-4)

Table 4: Logistic regression analysis of neighborhood poverty as a predictor of low social integration with neighbors.

	Model 1		Model 2	
	Odds Ratio	**95%CI**	**Odds Ratio**	**95%CI**
Neighborhood Poverty				
<5%	1.00	Ref	1.00	Ref
5% - 9.9%	1.01	0.83, 1.22	1.01	0.83, 1.24
10% - 19.9%	0.95	0.76, 1.17	1.05	0.82, 1.33
≥20%	0.70	0.57, 0.86	0.75	0.58, 0.98
Sex				
Male			1.00	0.91, 1.10
Female			1.00	Ref
Race-Ethnicity				
Non-Hisp. white			1.00	Ref
Non-Hisp. black			1.32	1.10, 1.58
Mexican-Amercian			1.68	1.32, 2.14
Other			1.08	0.77, 1.51
Age				
17-19 years			1.00	Ref
20-29 years			0.89	0.70, 1.12
30-39 years			0.90	0.71, 1.15
40-49 years			1.16	0.87, 1.54
50-59 years			1.07	0.83, 1.37
60-69 years			0.78	0.60, 1.01
70-79 years			0.79	0.59, 1.04
80+ years			0.74	0.55, 0.99
Poverty Income Ratio				
>1			0.55	0.43, 0.71
1-1.99			0.79	0.65, 0.96
2-2.99			0.88	0.70, 1.12
3-3.99			0.87	0.65, 1.17
4+			1.00	Ref
Education				
0-8 years			0.90	0.71, 1.15
9-11 years			0.93	0.76, 1.14
12 years			0.97	0.87, 1.09
13+years			1.00	Ref

The outcome modeled is low social integration with neighbors (<52 contacts/year) as compared to high social integration with neighbors (at least 52 contacts/year)

REFERENCES

1. Bird CE, Seeman T, Escarce JJ, et al. Neighbourhood socioeconomic status and biological 'wear and tear' in a nationally representative sample of US adults. *Journal of Epidemiology and Community Health* 2010;64(10):860-5.
2. Chaix B, Rosvall M, Merlo J. Assessment of the magnitude of geographical variations and socioeconomic contextual effects on ischaemic heart disease mortality: A multilevel survival analysis of a large Swedish cohort. *Journal of Epidemiology and Community Health* 2007;61(4):349-55.
3. Curry A, Latkin C, Davey-Rothwell M. Pathways to depression: The impact of neighborhood violent crime on inner-city residents in Baltimore, Maryland, USA. *Social Science & Medicine* 2008;67(1):23-30.
4. Diez-Roux AV, Nieto FJ, Muntaner C, et al. Neighborhood environments and coronary heart disease: a multilevel analysis. *American Journal of Epidemiology* 1997;146(1):48-63.
5. Diez Roux AV, Merkin SS, Arnett D, et al. Neighborhood of residence and incidence of coronary heart disease. *The New England Journal of Medicine* 2001;345(2):99-106.
6. Echeverria S, Diez-Roux AV, Shea S, et al. Associations of neighborhood problems and neighborhood social cohesion with mental health and health behaviors: The Multi-Ethnic Study of Atherosclerosis. *Health & Place* 2008;14(4):853-65.
7. Major JM, Doubeni CA, Freedman ND, et al. Neighborhood socioeconomic deprivation and mortality: NIH-AARP Diet and Health Study. *PloS One* 2010;5(11):e15538.
8. Merkin SS, Basurto-Davila R, Karlamangla A, et al. Neighborhoods and cumulative biological risk profiles by race/ethnicity in a national sample of U.S. adults: NHANES III. *Annals of Epidemiology* 2009;19(3):194-201.
9. Pickett KE, Pearl M. Multilevel analyses of neighbourhood socioeconomic context and health outcomes: A critical review. *Journal of Epidemiology and Community Health* 2001;55(2):111-22.
10. Pickett KE, Ahern JE, Selvin S, et al. Neighborhood socioeconomic status, maternal race and preterm delivery: A case-control study. *Annals of Epidemiology* 2002;12(6):410-8.
11. Subramanian SV, Chen JT, Rehkopf DH, et al. Racial disparities in context: A multilevel analysis of neighborhood variations in poverty and excess mortality among black populations in Massachusetts. *American Journal of Public Health* 2005;95(2):260-5.
12. Yen IH, Kaplan GA. Neighborhood social environment and risk of death: Multilevel evidence from the Alameda County Study. *American Journal of Epidemiology* 1999;149(10):898-907.
13. Diez Roux AV. Conceptual approaches to the study of health disparities. *Annual Review of Public Health* 2012;33:41-58.
14. Kawachi I, Berkman LF. Social Cohesion, Social Capital, and Health. In: Berkman LF, Kawachi I, eds. *Social Epidemiology*. New York, NY: Oxford University Press, 2000.
15. Sampson RJ, Morenoff JD, Gannon-Rowley T. Assessing "neighborhood effects": Social processes and new directions in research. *Annu Rev Sociol* 2002;28:443-78.
16. Berkman LF, Glass T, Brissette I, et al. From social integration to health: Durkheim in the new millennium. *Social Science & Medicine* 2000;51(6):843-57.
17. Kawachi I, Berkman LF. Social ties and mental health. *Journal of Urban Health : Bulletin of the New York Academy of Medicine* 2001;78(3):458-67.
18. Holt-Lunstad J, Smith TB, Layton JB. Social relationships and mortality risk: A meta-analytic review. *PLoS Medicine* 2010;7(7):e1000316.

19. House JS, Landis KR, Umberson D. Social relationships and health. *Science* 1988;241(4865):540-5.
20. Berkman LF, Glass T. Social Integration, Social Networks, Social Support, and Health. In: Berkman LF, Kawachi I, eds. *Social Epidemiology*. New York, NY: Oxford University Press, 2000.
21. Stringhini S, Berkman L, Dugravot A, et al. Socioeconomic status, structural and functional measures of social support, and mortality: The British Whitehall II Cohort Study, 1985-2009. *American Journal of Epidemiology* 2012;175(12):1275-83.
22. Small ML. Racial differences in networks: Do neighborhood conditions matter? *Soc Sci Q* 2007;88(2):320-43.
23. National Center for Health Statistics. Third National Health and Nutrition Examination Survey, 1988-1994, NHANES III Household Adult Data File and Documentation. Hyattsville, MD: Centers for Disease Control and Prevention, 1996, (US Department of Health and Senior Services publication no. 77560)
24. The Public Health Disparities Geocoding Project. U.S. Census Tract Poverty Data. Boston, MA: Harvard School of Public Health; 2004. (http://www.hsph.harvard.edu/thegeocodingproject/webpage/monograph/povdata.htm). (Accessed June 29, 2013).
25. Ford ES, Loucks EB, Berkman LF. Social integration and concentrations of C-reactive protein among US adults. *Annals of Epidemiology* 2006;16(2):78-84.
26. Obisesan TO, Gillum RF. Cognitive function, social integration and mortality in a U.S. national cohort study of older adults. *BMC Geriatrics* 2009;9:33.
27. Berkman LF. *Social Networks. Host Resistance, and Mortality: A Follow-up Study of Alameda County Residents* [dissertation]. Berkley, CA: University of California-Berkley; 1977.
28. Berkman LF, Syme SL. Social networks, host resistance, and mortality: a nine-year follow-up study of Alameda County residents. *American Journal of Epidemiology* 1979;109(2):186-204.
29. Seeman TE, Kaplan GA, Knudsen L, et al. Social network ties and mortality among the elderly in the Alameda County Study. *American Journal of Epidemiology* 1987;126(4):714-23.
30. Cohen S, Doyle WJ, Skoner DP, et al. Social ties and susceptibility to the common cold. *JAMA : The Journal of the American Medical Association* 1997;277(24):1940-4.
31. Kaplan GA, Salonen JT, Cohen RD, et al. Social connections and mortality from all causes and from cardiovascular disease: prospective evidence from Eastern Finland. *American Journal of Epidemiology* 1988;128(2):370-80.
32. White AM, Philogene GS, Fine L, et al. Social support and self-reported health status of older adults in the United States. *American Journal of Public Health* 2009;99(10):1872-8.
33. Echeverria SE, Borrell LN, Brown D, et al. A local area analysis of racial, ethnic, and neighborhood disparities in breast cancer staging. *Cancer Epidemiology, Biomarkers & Prevention : A publication of the American Association for Cancer Research, cosponsored by the American Society of Preventive Oncology* 2009;18(11):3024-9.
34. Krieger N. A century of census tracts: health & the body politic (1906-2006). *Journal of Urban Health : Bulletin of the New York Academy of Medicine* 2006;83(3):355-61.
35. Krieger N, Chen JT, Waterman PD, et al. Painting a truer picture of US socioeconomic and racial/ethnic health inequalities: The Public Health Disparities Geocoding Project. *American Journal of Public Health* 2005;95(2):312-23.

36. Krieger N, Chen JT, Waterman PD, et al. Race/ethnicity, gender, and monitoring socioeconomic gradients in health: A comparison of area-based socioeconomic measures--The Public Health Disparities Geocoding Project. *American Journal of Public Health* 2003;93(10):1655-71.
37. Bishaw A. Areas with Concentrated Poverty: 2006-2010. Washington, DC: US Census Bureau, 2011, (American Community Survey Briefs)(US Department of Commerce publication no. ACSBR/10-17)
38. Campbell KE, Lee BA. Sources of personal neighbor networks: Social integration, need, or time? *Social Forces* 1992;70(4):1077-100.
39. Winkleby M, Cubbin C, Ahn D. Effect of cross-level interaction between individual and neighborhood socioeconomic status on adult mortality rates. *American Journal of Public Health* 2006;96(12):2145-53.
40. Shah VBBB, Bieler GS. *SUDAAN User's Manual*. Research Triangle Park, NC: Research Triangle Institute; 2005.
41. Hosmer DW, Lemeshow S. *Applied Logistic Regression*. 2nd ed. New York: Wiley; 2000.
42. Cohen DA, Farley TA, Mason K. Why is poverty unhealthy? Social and physical mediators. *Social Science & Medicine* 2003;57(9):1631-41.
43. Antonucci TC, Ajrouch KJ, Janevic M. Socioeconomic status, social support, age, and health. *Annals of the New York Academy of Sciences* 1999;896:390-2.
44. Hobfoll SE, Jackson AP. Conservation of resources in community intervention. *American Journal of Community Psychology* 1991;19(1):111-21.
45. Gallo LC, Bogart LM, Vranceanu AM, et al. Socioeconomic status, resources, psychological experiences, and emotional responses: a test of the reserve capacity model. *Journal of Personality and Social Psychology* 2005;88(2):386-99.
46. Hobfoll SE, Johnson RJ, Ennis N, et al. Resource loss, resource gain, and emotional outcomes among inner city women. *Journal of Personality and Social Psychology* 2003;84(3):632-43.
47. Sampson RJ, Raudenbush SW, Earls F. Neighborhoods and violent crime: A multilevel study of collective efficacy. *Science* 1997;277(5328):918-24.
48. Wilson WJ. *The truly disadvantaged : The inner city, the underclass, and public policy*. Chicago: University of Chicago Press; 1987.
49. Armstrong BG. Effect of measurement error on epidemiological studies of environmental and occupational exposures. *Occupational and Environmental Medicine* 1998;55(10):651-6.
50. Delgado-Rodriguez M, Llorca J. Bias. *Journal of Epidemiology and Community Health* 2004;58(8):635-41.
51. Berkman LF. Social Epidemiology: Social determinants of health in the United States: Are we losing ground? *Annual Review of Public Health* 2009;30:27-41.
52. Diez Roux AV. Next steps in understanding the multilevel determinants of health. *Journal of Epidemiology and Community Health* 2008;62(11):957-9.
53. National Center for Health Statistics. NHANES Response Rates and CPS Totals. 2011. (http://www.cdc.gov/nchs/nhanes/response_rates_cps.htm). (Accessed August 27, 2013).

Neighborhood Socioeconomic Context and Mortality Risk among US adults in NHANES III

ABSTRACT

Background: There is a growing body of literature linking neighborhood contexts to health. Studies examining neighborhood socioeconomic status (SES) and mortality have shown a consistent, though not always significant, association between low neighborhood SES and increased mortality risk. The present study aimed to assess the relationship between neighborhood poverty and mortality risk among adults in the Third National Health and Nutrition Examination Survey (NHANES III), a national probability sample.

METHODS: We examined data from the NHANES III geocoded and matched to census tracts, serving as neighborhood proxies. We operationalized neighborhood poverty as the proportion of residents in a census tract living below the federal poverty level. We analyzed data using Kaplan-Meier survival curves as well as Cox proportional hazards regression models that accounted for the complex survey design.

RESULTS: Living in a low poverty neighborhood was consistently associated with a lower mortality risk when compared to living in a high poverty (≥20%) neighborhood in this sample. Men living in high poverty neighborhoods had 1.29 (95% confidence interval: 1.01, 1.64) times the risk of death of men living in low (<5%) poverty neighborhoods.

DISCUSSION: A positive association between neighborhood poverty and mortality risk was seen in this national probability sample, particularly among men. This finding

confirms previous writings of such an association and strengthens the case for health interventions and additional research aimed at neighborhoods with high rates of poverty.

INTRODUCTION

Health conditions and mortality from causes as disparate as arthrosclerosis and violence have been attributed to the quality of neighborhood resources, community social capital and neighborhood socioeconomic condition (1-4). The body of work supporting the link between neighborhood socioeconomic condition and mortality has shown modest but significant associations (5). Study after study, looking at various populations, age groups, and using different measures of neighborhood condition, has supported the assertion that neighborhoods are linked to mortality risk (6-11). The magnitude of the association and the way in which it should be measured and evaluated are still open questions. Researchers do not yet agree on how neighborhood context should best be measured (12), what factors must be adjusted for in assessing this relationship and which are considered to be on the causal pathway (2, 9, 13), nor within which population groups the association between neighborhood and mortality are most important (8).

Another debate in the existing literature is over the proper measurement of the neighborhood itself. Many make the argument that neighborhoods should be measured by the bounds of people's experience (4, 14, 15) and this makes logical sense. However, an argument for the use of replicable, stable boundaries such as census tracts can also be made. These areas were designed to be used for public health planning and they still

have political relevance today as the best way to measure population change within consistently defined geographic areas (7, 16-18).

The many unresolved questions outlined above encourage the continued study of neighborhoods and health. Each new examination of established associations allows for the issue to be looked at from a fresh perspective and has the potential to reinforce what may already be known. The present study contributes to the literature in that it examines the association between neighborhood context and all-cause mortality in a national probability sample. It uses a simple measure of neighborhood socioeconomic condition, area poverty level, and it adjusts for known confounders that are not on the causal pathway between neighborhood condition and mortality. Our study takes into account a complex survey design and considers the multilevel-nature of the main effect variable (neighborhood socioeconomic condition) and outcome of interest (mortality). Further, through the use of survival analysis we are able to maximize the use of information for every eligible individual in the study. The study aims to assess the relationship between neighborhood poverty and all-cause mortality within the updated NHANES III Linked Mortality File.

METHODS

Data Sources

Data for this study comes from the Third National Health and Nutrition Examination Survey (NHANES III). The survey, conducted by the Centers for Disease Control and Prevention, employed a complex, multi-stage, stratified sampling design

intended to recruit a nationally representative sample of the non-institutionalized, civilian US population. NHANES III was conducted from October 1988-October 1994 and included individuals from age 2 months with no upper age limit. Data collection for the survey consists of an in-home interview and a series of examinations both in-home and via mobile exam centers (19). The data for the present study were taken entirely from the household interview portion of the NHANES III from all interview years. The NHANES III data were geocoded according to participants' home address and matched to 1990 Census tracts. These data are made available for restricted-use only by the National Center for Health Statistics (NCHS). The restrictions assure confidentiality of the study participants.

The NHANES III Linked Mortality File contains follow-up data for NHANES III participants. The current NHANES III Linked Mortality File is the second mortality follow-up for NHANES III. The first followed participants through December 21, 2000 while the current file follows participants through December 31, 2006. The updated file became available in 2009. Mortality status for NHANES III participants was identified using the National Death Index (NDI) primarily through probabilistic record matching. NCHS used a matching algorithm for NHANES III records specific to this file but similar to that which is the standard used by NDI. It is considered to be a reliable source of mortality follow-up and is intended to be used to conduct an array of investigations of health, risk factors and mortality (20). The public-use Linked Mortality File was used to examine time from household interview to all-cause mortality.

The Census data file used for this study was compiled by The Public Health Disparities Geocoding Project at the Harvard School of Public Health. This data file contains a variable measuring the percent of people in each census tract living below the poverty line and was computed using 1990 Census data. It is publically available at the Project's website (21).

Measures

Neighborhood socioeconomic status measurement. Neighborhoods will be defined as census tracts in the present analysis. Census tract have been shown to adequately represent neighborhoods in previous studies examining neighborhood socioeconomic status (7, 17, 22). To represent neighborhood socioeconomic status, a variable measuring the percent of residents within a census tract living below the federally-defined poverty line was used. This variable has been shown to be a reliable measure of socioeconomic inequality in health studies (21). Specifically, the neighborhood poverty measure for 1990 Census tracts was compared to several other area-based socioeconomic measures and was found to have the most consistent results and to be the most sensitive to expected gradients in health (18). A four-level categorical grouping of neighborhood poverty was created. The categories are based on the federal definition of "poverty areas" as areas where greater than 20% of the population live below the federal poverty line (7, 23). Based on calculations of the distribution of the variable in this dataset, the four-level variable is like that used by Subramanian et al (7): 0%–4.9%, 5%–9.9%, 10%–19.9%, and 20%–100%. The

dichotomous variable used in some analyses is either less than 20% of residents living below poverty and greater than or equal to 20% of residents living below poverty.

Mortality. The outcome of interest for the present study is time-to-death or more specifically, person-months of follow-up from the interview to December 31, 2006. There are between 12-18 years of follow-up for the sample depending on the year of NHANES interview. There is a mean of 167 months (95% confidence interval: 162, 172) of follow-up for the weighted study population which is roughly 14 years. There were 20,024 participants eligible for the linkage and 5,360 deaths were identified. The present study focused on all-cause mortality.

Covariates. A number of baseline characteristics were included in the multivariable regression models. Age, sex, and race/ethnicity were adjusted for in the regression models due to their known associations with mortality. In addition, individual SES at the time of the baseline interview was accounted for via the household poverty income ratio (PIR) and the individual's years of education completed. Age, years of education and PIR were included as categorical variables because their relationships with the outcome are not strictly linear. Individual SES has been shown to be a strong predictor and therefore 5 levels of the PIR variable are used to account for the fine gradations in its effects (22, 24, 25).

Statistical analysis

NHANES III has a complex, multi-stage probability sample. In the present study, the appropriate weighting, strata and PSU variables were used to adjust for the sample design in all analyses. We used SUDAAN software, version 10 (26) which is designed to

address these specialized analysis considerations. Descriptive statistics were carried out to learn about the sample characteristics. Frequencies were calculated along with their standard errors that account for the sample design. Statistics were calculated for the whole sample and by neighborhood poverty group.

The relationship between neighborhood poverty and time-to-death was investigated using survival analysis techniques. The outcome of interest was time from NHANES household interview to death. If no death was recorded, those subjects were censored at time to December 31, 2006, which is the end of the follow-up period in the linked mortality database. In survival analysis, censoring allows the use of survival data for study subjects even if the exact survival time is unknown (27). In this study the data is considered right-censored because the time from the interview to follow-up was known for all subjects even if their exact survival time was not known. Cox Proportional Hazards regression was used to model the relationship between neighborhood poverty and time-to-death, while adjusting for age and the other known confounders. It is a semi-parametric model that is usually written in terms of the hazard model formula (27). In this formula, the baseline hazard is a function of time but does not involve the explanatory variables which are considered time-independent. This is an important feature of the model that assumes the risks are proportional between groups. The proportional hazards assumption was examined graphically using Kaplan-Meier curves of the binary neighborhood poverty groupings (low poverty < 20% and high poverty ≥ 20%).

An additional requirement in the use of survival analysis is that some meaning be placed on the start time of the study. In a study, such as the present study, where the start time is only significant in that it happened to be the date that data were collected, there may be concern about the meaningfulness of the outcome of interest. This may be especially true if the individuals being studied have some varied risk of experiencing the event of interest (death). In the case of the present study, there is an assumption of a "steady state (28)." That is, one can assume that death (the event of interest) occurs in the study sample at a steady rate equal to that in the target population and that being chosen for the study did not alter this risk in any way for any individual. NHANES III used a randomly selected, national probability sample, and subjects were not chosen for any reason connected to their risk of death. For this reason the assumption of a steady state should hold and survival analysis is an appropriate methodology for analyzing this time-to-event data.

In planning the regression analyses the multilevel nature of the exposure (i.e., neighborhood poverty), the study design, and the outcome of interest were considered. Individuals living within the same census tract are more likely to share similar characteristics and exposures than individuals living in other census tracts. These shared neighborhood-level characteristics are the focus of the present study and of neighborhood-health research more generally. Not accounting for this shared correlation can have an effect on the calculation of variance in statistical models. When analyzing complex survey data, SUDAAN takes these same issues into consideration. People within the same primary sampling units (PSUs) are expected to be more similar

to each other than to those sampled from other PSUs. In order to properly account for this, SUDAAN uses generalized estimating equations (population average models) and variances are estimated using the Taylor-series method. However, as of this writing, SUDAAN is unable to take more than one set of stratification variables into account (G. Gordon Brown, Research Triangle Institute, personal communication, 2012) when fitting statistical models that account for group-level characteristics. Thus, we could only specify the sampling design variable (i.e., PSU's) or the neighborhood-level variable (i.e. census tracts) as the higher order group-level variable. This could cause some error in the variance estimations but based on other studies (25), we expect this error to be small and it should not impact the statistical significance of our estimates. We, therefore, decided to preserve and incorporate the sampling design in all of the analyses. This was appropriate because we were not necessarily interested in partitioning the between and within neighborhood variance as in random effects models (29), rather we modeled the population average effects for the NHANES primary sampling units, which are groupings of census tracts.

Human subjects review was conducted by the University of Medicine and Dentistry of New Jersey- New Brunswick campus Institutional Review Board (as of July 1, 2013 this is now part of the Rutgers University IRB, however at the time of the analyses it was legacy the UMDNJ IRB). The study was deemed exempt from continued oversight. The study was also reviewed by the Research Data Center (RDC) at the National Center for Health Statistics in Hyattsville, Maryland. The study was approved

and all analyses were conducted either in the RDC offices or remotely via their secure system.

The full sample of adults over age 17 interviewed as part of NHANES III and eligible for subsequent follow-up was 20,024. Respondents were excluded from the present analysis if their addresses at the time of the interview were not able to be geocoded and matched to a 1990 Census tract (n=2,778). In order to insure that individuals had an opportunity to have their health shaped by the neighborhood where they live, those who responded that they lived in their city/town/area for less than one year were also excluded (n=1,202). The final analytic sample consisted of 16,044 survey respondents. The sample size may be less than 16,044 for some analyses when values for included variables are missing. There are 1,699 individuals (about 10% of the sample) for whom PIR is missing and in those analyses that include PIR these respondents are excluded as well. The group with missing PIR is more likely to be from the extremes in the age spectrum, in racial/ethnic minorities, be less educated and have lived in their areas for shorter periods of time when compared to those where PIR is provided. This should be taken into consideration when the results are evaluated.

RESULTS

In Table 1, we present the weighted summary statistics for the full analytic sample and by neighborhood poverty category. It can be seen that a little over half the sample members are women (53%), the majority (74%) are Non-Hispanic white, and over half (61%) are between 20 and 49 years of age. Most of the respondents (74%) have completed at least a high school education, have incomes above the poverty line

(82%) and over half (53%) have lived in their area of residence for a substantial amount of time (over 20 years or their whole life).

Demographic differences by degree of neighborhood poverty in the sample can be seen in Table 1 as well. Those living in the highest poverty areas (at least 20%) are more likely to be female, of a racial or ethnic minority, live below the poverty line themselves and be less educated than those in the areas with less poverty. Mean person-months of follow-up remains steady across categories of neighborhood poverty (166-167 months). However, the percent assumed deceased is higher within the category with the highest amount of neighborhood poverty (21%) than in the categories with less poverty (15-18%).

The Kaplan-Meier curves depicting person-months to death within each of two categories of neighborhood poverty can be found in Figure 1. These curves show an approximately proportional risk between the groups. The high poverty group has a consistently shorter survival time than the low poverty group.

The Cox proportional hazards regression models show an association between increased neighborhood poverty and risk of death. In the crude model that includes only the two-level poverty variable, those in the high poverty neighborhoods have 1.31 (95% confidence interval: 1.14, 1.51) times the hazard as those in the low poverty neighborhoods group. When the confounders are included in the model the hazard ratio decreases to 1.14 (95% confidence interval: 1.01, 1.28) but it is still statistically significant (Table 2). In the models of the 4-level neighborhood poverty variable (Table 3), there is some gradient of effect when comparing the category with the lowest

amount of neighborhood poverty to the higher levels with the areas of at least 20% poverty having the highest risk. In the unadjusted model that risk is 1.40 (95% confidence interval: 1.15, 1.70) and in the adjusted model the risk is 1.21 (95% confidence interval: 1.02, 1.43) . These results are statistically significant although the middle-categories do not have statistically significant hazard ratios when compared to the lowest poverty areas once the confounding factors are included in the models.

Although not a primary objective of this analysis, an interesting finding of the regression analysis is the decreased risk of death (hazard ratio: 0.70; 95% confidence interval: 0.60, 0.82) among Mexican-Americans in the sample when compared to Whites. Finally, in Table 4 we present the Cox regression models stratified by gender. The statistically significant increased risk associated with at least 20% neighborhood poverty remains for men (hazard ratio: 1.29; 95% confidence interval: 1.01, 1.64) only. Although the increased risk of living in a neighborhood with high poverty is still seen (hazard ratio: 1.13; 95% confidence interval: 0.90, 1.43), it is not statistically significant among women.

DISCUSSION

The results of the present study demonstrate a significant relationship between high poverty neighborhoods and increased risk of death even after controlling for individual-level risk factors. Most notable, these controlled risks include individual socioeconomic status; indicating that neighborhood socioeconomic condition does shape the health and risk of death of residents above and beyond the risks associated with their individual socioeconomic status. The results of the present study are

consistent with previous studies in the association that was found both for the main effect and as expected for the confounding covariates (9-11), most notable is the increased risk of death for men in the study.

In the present study, we were careful not to adjust for factors that may be on the causal pathway between neighborhood context and mortality (13). Health behaviors, such as exercise or nutritional intake, can arguably be linked to the environments within which people live. Perceived health status at the time of the interview, another variable that is commonly controlled for in studies of these types (9), could also be linked to the way that individuals interact with their surrounding neighborhood. The results of the current study are not affected by these potential mediators. This should impact the way one interprets the study results in two ways. One is that the results are not made artificially stronger or weaker by adjusting for causal factors and the other is that these factors likely are important components and they should be considered in future research on this topic.

A notable result of the study is that the association of neighborhood poverty with mortality has the greatest impact when area poverty is 20% or more. When age, race, gender and individual socioeconomic status are controlled, the middle categories of poverty (5-9.9% and 10-19.9%) do not have a significant association with mortality risk when compared to the lowest area poverty group. Thus, future research and interventions can be targeted at those neighborhoods already considered high in poverty by the federal government (23). Reviews of the social epidemiology literature discuss the importance of considering contextual-level influence on health to enhance

the planning of interventions (15, 30) and results such as these, aid in this endeavor.

The results of this study are interesting in that we see two other epidemiological phenomena operating as well. The first is the Latino paradox. Mexican-Americans were found to have a lower risk of death when compared to Whites in the study even after controlling for age, gender, individual socioeconomic status, and neighborhood poverty. This is an epidemiological paradox that has been noted in previous studies of population mortality but has not yet been fully explained (31). The second is the gender difference in the socioeconomic gradient in mortality (32, 33). When the analysis was stratified by gender, men living in high poverty areas were found to have a greater risk of death than women. Previous studies of the impact of neighborhood condition on mortality have found similar effects (9-11). Both of these findings warrant further study.

This study adds to the body of literature asserting an association between neighborhood conditions and health. The results are unique in that they highlight this association within a large US national probability sample over an extended period of mortality follow-up. While the study does have its limitations, it is generalizable to a larger population than shown previously. One limitation is that the NHANES III, while designed to capture the US non-institutionalized, civilian population, misses key population groups. In addition, the NHANES III was designed to oversample older adults, African-Americans, and Mexican-Americans. The use of weighting to match the US census attempts to address this issue but members of some minority race and ethnic groups are under-represented while others may be over-represented. This compounded the already challenging issue of accounting for the possible interaction of neighborhood

poverty with race and ethnicity. Residential segregation, and especially hypersegregation (34), as it impacts the disparities in mortality risk among Blacks in the US is of critical importance in epidemiological studies of neighborhood contexts. While this was not something we were able to account for here, it is important to acknowledge. Future studies of the association between neighborhood context and mortality should be designed specifically to collect information from individuals of all racial and ethnic groups in all types of neighborhood contexts.

Another limitation is the cross-sectional nature of the risk factor variables in the survival models. Neighborhood poverty is based on the census tract of residence at the time of the household interview. It does not account for mobility among the respondents nor does it account for residential history and we are therefore unable to make any statements about the importance of the neighborhood context over time. We attempted to address this somewhat by only analyzing data from those in the sample who lived in their area for at least one year but we acknowledge the limits of even this choice. Further, neighborhood poverty level may be only one aspect of the neighborhood context that influences health. However, it is one that has been consistently linked to health (17) as well as to other factors that influence health (9).

Future studies should incorporate the examination of mediating factors and additional layers of social influences on health. Further, similar studies can be carried out to examine the mortality risk of various populations over time. This information can be useful to track the relative health of different sub-populations in particular areas or types of areas. It could even be used to assess the success of area-specific

interventions. This study is an example of how the use of replicable neighborhood measures and limited information on individual-level factors can be used to compare the mortality risk of different types of population groups.

Table 1: Weighted descriptive summary statistics for the total sample (N=16,044) and by neighborhood poverty category. *This table displays column percentages, except in person-months of follow-up which shows the average number of months.*

Variable	*Total Sample % (SE)*	*0-4.9% neighborhood poverty*	*5-9.9% neighborhood poverty*	*10-19.9% neighborhood poverty*	*≥20% neighborhood poverty*
Neighborhood Poverty					
0-4.9%	30.9 (1.87)				
5-9.9%	25.4 (1.29)				
10-19.9%	25.1 (1.59)				
≥20%	18.7 (1.22)				
Individual level predictors:					
Age groups					
17-19 years	4.8 (0.35)	4.1 (0.66)	4.7 (0.53)	4.7 (0.53)	6.0 (0.51)
20-29 years	19.8 (0.81)	14.7 (1.07)	20.2 (1.54)	21.9 (1.27)	24.8 (1.55)
30-39 years	23.7 (0.75)	22.5 (1.48)	26.0 (1.45)	23.7 (1.47)	22.6 (1.33)
40-49 years	17.9 (0.62)	22.1 (1.47)	17.3 (1.03)	14.9 (0.93)	15.5 (1.06)
50-59 years	11.9 (0.41)	13.8 (0.96)	11.8 (0.93)	11.3 (0.81)	9.7 (0.63)
60-69 years	10.9 (0.49)	11.7 (1.19)	10.2 (0.83)	11.2 (0.80)	10.2 (0.74)
70-79 years	7.6 (0.41)	7.8 (0.93)	6.6 (0.62)	8.6 (0.56)	7.4 (0.62)
80+ years	3.4 (0.29)	3.2 (0.49)	3.1 (0.49)	3.7 (0.37)	3.7 (0.39)
Sex					
Male	47.1 (0.47)	48.0 (0.98)	48.2 (1.09)	47.6 (0.75)	43.6 (0.92)
Female	52.9 (0.47)	52.0 (0.98)	51.8 (1.09)	52.4 (0.75)	56.4 (0.92)
Race/Ethnicity					
Non-Hispanic White	73.6 (1.35)	89.5 (1.32)	77.8 (2.66)	72.9 (2.38)	42.4 (2.30)
Non-Hispanic Black	12.3 (0.74)	3.6 (0.53)	8.5 (1.16)	11.0 (1.02)	33.5 (2.07)
Mexican-American	5.6 (0.48)	1.8 (0.31)	4.4 (0.81)	6.3 (0.76)	12.6 (1.06)
Other	8.5 (0.93)	5.1 (1.14)	9.2 (1.82)	9.8 (1.52)	11.5 (1.72)
Living below poverty (PIR<1)	12.7 (0.90)	3.3 (0.64)	8.4 (1.48)	16.1 (1.49)	30.6 (1.86)
Highest year of school completed					
0-8 years	11.1 (0.61)	4.5 (0.42)	7.7 (1.06)	13.9 (0.97)	22.7 (1.11)
9-11years	14.8 (0.60)	8.8 (0.86)	13.1 (1.14)	18.7 (1.10)	21.7 (0.90)
12 years	32.8 (0.83)	29.9 (1.59)	36.2 (1.75)	33.7 (1.25)	31.9 (1.48)
13+ years	41.3 (1.27)	56.8 (2.08)	43.0 (2.14)	33.6 (1.61)	23.8 (1.29)
How long lived in city/town/area					
Whole life	26.8 (1.14)	24.7 (2.04)	25.1 (2.08)	27.2 (1.69)	31.9 (1.35)
>20 years	26.6 (0.89)	27.3 (2.00)	26.2 (1.26)	26.1 (1.56)	26.8 (1.45)
11-20 years	15.6 (0.72)	17.5 (1.51)	15.7 (1.31)	14.9 (1.15)	13.3 (1.03)
5-10 years	14.6 (0.76)	15.9 (1.41)	15.3 (1.20)	14.3 (1.28)	11.9 (0.97)
3-4 years	7.6 (0.48)	6.4 (0.86)	8.4 (0.87)	8.2 (0.81)	7.6 (1.00)
1-2 years	8.7 (0.59)	8.1 (1.00)	9.2 (1.14)	9.2 (0.82)	8.4 (1.45)
Outcome:					
Assumed deceased	17.2 (0.70)	15.4 (1.20)	15.1 (1.14)	18.6 (1.01)	21.2 (1.05)
Person-months of follow-up*	166.7 (2.43)	167.5 (3.03)	166.7 (2.86)	166.1 (2.90)	166.0 (2.32)

Figure 1: Kaplan-Meier curves for the person-months of survival for the two categories of neighborhood poverty. *Low poverty areas are those with less than 20% poverty and high poverty areas have 20% poverty or greater.*

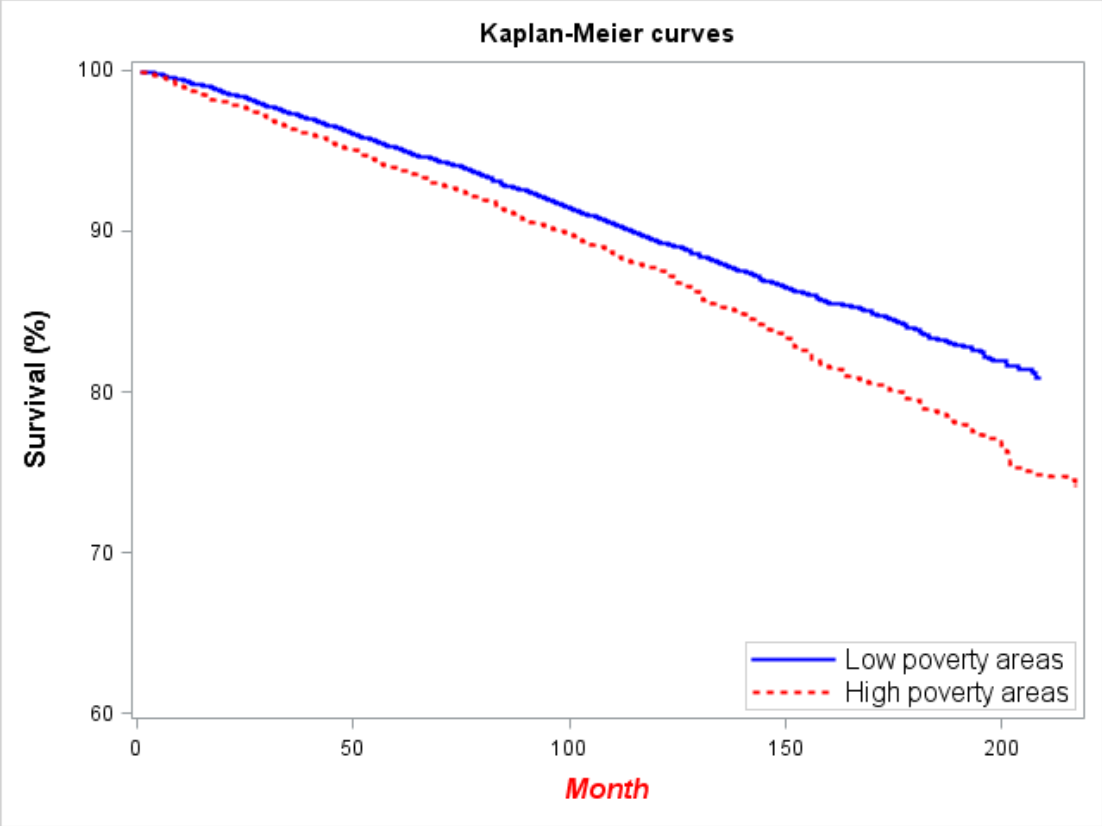


Table 2: Cox proportional hazards regression models examining the association of the 2-level neighborhood poverty variable with mortality risk.

	Model 1		Model 2	
	Hazard Ratio	**95%CI**	**Hazard Ratio**	**95%CI**
Neighborhood Poverty				
<20%	1.00	ref	1.00	Ref
≥20%	1.31	1.14, 1.51	1.14	1.01, 1.28
Sex				
Male			1.53	1.39, 1.70
Female			1.00	ref
Race-Ethnicity				
Non-Hisp. white			1.00	ref
Non-Hisp. black			1.15	1.03, 1.28
Mexican-American			0.70	0.60, 0.82
Other			0.66	0.50, 0.87
Age				
17-19 years			1.00	ref
20-29 years			2.10	0.86, 5.14
30-39 years			2.49	0.96, 6.42
40-49 years			7.08	2.81, 17.88
50-59 years			18.87	8.22, 43.32
60-69 years			44.87	19.11, 105.35
70-79 years			105.64	45.00, 248.00
80+ years			243.17	103.55, 571.05
Poverty Income Ratio				
>1			1.93	1.57, 2.36
1-1.99			1.59	1.28, 1.99
2-2.99			1.35	1.10, 1.65
3-3.99			1.06	0.87, 1.30
4+			1.00	ref
Education				
0-8 years			1.22	1.03, 1.44
9-11 years			1.19	0.99, 1.43
12 years			1.20	1.05, 1.36
13+years			1.00	ref

Table 3: Cox proportional hazards regression models examining the association of the 4-level neighborhood poverty variable with mortality risk.

	Model 1		Model 2	
	Hazard Ratio	**95%CI**	**Hazard Ratio**	**95%CI**
Neighborhood Poverty				
<5%	1.00	Ref	1.00	Ref
5% - 9.9%	0.99	0.81, 1.19	1.08	0.92, 1.27
10% - 19.9%	1.22	1.00, 1.48	1.08	0.94, 1.24
≥20%	1.40	1.15, 1.70	1.21	1.02, 1.43
Sex				
Male			1.53	1.39, 1.70
Female			1.00	ref
Race-Ethnicity				
Non-Hisp. white			1.00	ref
Non-Hisp. black			1.14	1.02, 1.27
Mexican-Amercian			0.70	0.60, 0.81
Other			0.66	0.49, 0.87
Age				
17-19 years			1.00	ref
20-29 years			2.08	0.85, 5.10
30-39 years			2.47	0.96, 6.36
40-49 years			7.07	2.80, 17.83
50-59 years			18.78	8.18, 43.11
60-69 years			44.72	19.05, 104.96
70-79 years			105.37	44.85, 247.53
80+ years			242.98	103.46, 570.65
Poverty Income Ratio				
>1			1.88	1.51, 2.34
1-1.99			1.56	1.24, 1.97
2-2.99			1.33	1.07, 1.65
3-3.99			1.05	0.85, 1.29
4+			1.00	ref
Education				
0-8 years			1.21	1.02, 1.43
9-11 years			1.18	0.99, 1.42
12 years			1.19	1.05, 1.35
13+years			1.00	ref

Table 4: Cox proportional hazards regression models examining the association of the 4-level neighborhood poverty variable with mortality risk stratified by gender and adjusted for confounding covariates

	Men		Women	
	Hazard Ratio	**95%CI**	**Hazard Ratio**	**95%CI**
Neighborhood Poverty				
<5%	1.00	Ref	1.00	Ref
5% - 9.9%	1.14	0.96, 1.36	1.02	0.82, 1.28
10% - 19.9%	1.13	0.93, 1.36	1.03	0.85, 1.26
≥20%	1.29	1.01, 1.64	1.13	0.90, 1.43
Race-Ethnicity				
Non-Hisp. white	1.00	ref	1.00	ref
Non-Hisp. black	1.17	0.95, 1.44	1.11	0.95, 1.30
Mexican-Amercian	0.70	0.55, 0.88	0.68	0.56, 0.83
Other	0.64	0.43, 0.96	0.69	0.43, 1.10
Age				
17-19 years	1.00	ref	1.00	ref
20-29 years	1.41	0.45, 4.47	4.78	1.16, 19.78
30-39 years	1.71	0.52, 5.65	5.54	1.35, 22.72
40-49 years	5.77	1.88, 17.73	12.51	3.28, 47.74
50-59 years	12.29	4.32, 34.99	45.24	12.55, 163.11
60-69 years	31.83	10.71, 94.57	97.74	27.80, 343.64
70-79 years	74.22	25.61, 215.08	235.27	66.27, 835.24
80+ years	151.18	51.40, 444.60	585.36	167.63, 2044.10
Poverty Income Ratio				
>1	2.14	1.61, 2.84	1.66	1.26, 2.20
1-1.99	1.75	1.42, 2.14	1.36	0.98, 1.88
2-2.99	1.51	1.18, 1.93	1.13	0.85, 1.50
3-3.99	1.11	0.86, 1.42	0.97	0.73, 1.29
4+	1.00	ref	1.00	ref
Education				
0-8 years	1.25	1.03, 1.52	1.14	0.87, 1.50
9-11 years	1.10	0.85, 1.42	1.24	0.95, 1.62
12 years	1.25	1.07, 1.45	1.13	0.91, 1.39
13+years	1.00	ref	1.00	ref

REFERENCES

1. Bell N, Schuurman N, Hameed SM. A multilevel analysis of the socio-spatial pattern of assault injuries in greater Vancouver, British Columbia. *Can J Public Health* 2009;100(1):73-7.
2. Diez-Roux AV, Nieto FJ, Muntaner C, et al. Neighborhood environments and coronary heart disease: a multilevel analysis. *American Journal of Epidemiology* 1997;146(1):48-63.
3. Echeverria S, Diez-Roux AV, Shea S, et al. Associations of neighborhood problems and neighborhood social cohesion with mental health and health behaviors: The Multi-Ethnic Study of Atherosclerosis. *Health & Place* 2008;14(4):853-65.
4. Sampson RJ, Raudenbush SW, Earls F. Neighborhoods and violent crime: A multilevel study of collective efficacy. *Science* 1997;277(5328):918-24.
5. Pickett KE, Pearl M. Multilevel analyses of neighbourhood socioeconomic context and health outcomes: a critical review. *Journal of Epidemiology and Community Health* 2001;55(2):111-22.
6. Major JM, Doubeni CA, Freedman ND, et al. Neighborhood socioeconomic deprivation and mortality: NIH-AARP Diet and Health Study. *PloS One* 2010;5(11):e15538.
7. Subramanian SV, Chen JT, Rehkopf DH, et al. Racial disparities in context: A multilevel analysis of neighborhood variations in poverty and excess mortality among black populations in Massachusetts. *American Journal of Public Health* 2005;95(2):260-5.
8. Yao L, Robert SA. Examining the racial crossover in mortality between African American and White older adults: A multilevel survival analysis of race, individual socioeconomic status, and neighborhood socioeconomic context. *Journal of Aging Research* 2011;2011:132073.
9. Yen IH, Kaplan GA. Neighborhood social environment and risk of death: Multilevel evidence from the Alameda County Study. *American Journal of Epidemiology* 1999;149(10):898-907.
10. Winkleby M, Cubbin C, Ahn D. Effect of cross-level interaction between individual and neighborhood socioeconomic status on adult mortality rates. *American Journal of Public Health* 2006;96(12):2145-53.
11. Haan M, Kaplan GA, Camacho T. Poverty and health. Prospective evidence from the Alameda County Study. *American Journal of Epidemiology* 1987;125(6):989-98.
12. Diez Roux AV. The study of group-level factors in epidemiology: Rethinking variables, study designs, and analytical approaches. *Epidemiologic Reviews* 2004;26:104-11.
13. Berkman LF, Glass T, Brissette I, et al. From social integration to health: Durkheim in the new millennium. *Social Science & Medicine* 2000;51(6):843-57.
14. Echeverria SE, Diez-Roux AV, Link BG. Reliability of self-reported neighborhood characteristics. *Journal of Urban Health : Bulletin of the New York Academy of Medicine* 2004;81(4):682-701.
15. Diez Roux AV. Next steps in understanding the multilevel determinants of health. *Journal of Epidemiology and Community Health* 2008;62(11):957-9.
16. Krieger N. A century of census tracts: Health & the body politic (1906-2006). *Journal of Urban Health : Bulletin of the New York Academy of Medicine* 2006;83(3):355-61.
17. Krieger N, Chen JT, Waterman PD, et al. Painting a truer picture of US socioeconomic and racial/ethnic health inequalities: The Public Health Disparities Geocoding Project. *American Journal of Public Health* 2005;95(2):312-23.

18. Krieger N, Chen JT, Waterman PD, et al. Race/ethnicity, gender, and monitoring socioeconomic gradients in health: a comparison of area-based socioeconomic measures--The Public Health Disparities Geocoding Project. *American Journal of Public Health* 2003;93(10):1655-71.
19. National Center for Health Statistics. Third National Health and Nutrition Examination Survey, 1988-1994, NHANES III Household Adult Data File and Documentation. Hyattsville, MD: Centers for Disease Control and Prevention, 1996, (US Department of Health and Senior Services publication no. 77560)
20. National Center for Health Statistics. The Third National Health and Examination Survey (NHANES III) Linked Mortality File, Mortality Follow-up through 2006: Matching Methodology. Hyattsville, MD, 2009.
21. Project TPHDG. U.S. Census Tract Poverty Data. Boston, MA: Harvard School of Public Health; 2004. (http://www.hsph.harvard.edu/thegeocodingproject/webpage/monograph/povdata.htm). (Accessed June 29, 2013).
22. Small ML. Racial differences in networks: Do neighborhood conditions matter? *Soc Sci Q* 2007;88(2):320-43.
23. Bishaw A. Areas with Concentrated Poverty: 2006-2010. Washington, DC: US Census Bureau, 2011, (American Community Survey Briefs)(US Department of Commerce publication no. ACSBR/10-17)
24. Campbell KE, Lee BA. Sources of personal neighbor networks: Social integration, need, or time? *Social Forces* 1992;70(4):1077-100.
25. Merkin SS, Basurto-Davila R, Karlamangla A, et al. Neighborhoods and cumulative biological risk profiles by race/ethnicity in a national sample of U.S. adults: NHANES III. *Annals of Epidemiology* 2009;19(3):194-201.
26. Shah VBBB, Bieler GS. *SUDAAN User's Manual*. Research Triangle Park, NC: Research Triangle Institute; 2005.
27. Kleinbaum DG, Klein M. *Survival Analysis : A Self-Learning Text*. 2nd ed. New York, NY: Springer; 2005.
28. Szklo M, Nieto FJ. *Epidemiology : Beyond the Basics*. 3rd ed. Burlington, Mass.: Jones & Bartlett Learning; 2014.
29. Hubbard AE, Ahern J, Fleischer NL, et al. To GEE or not to GEE: Comparing population average and mixed models for estimating the associations between neighborhood risk factors and health. *Epidemiology* 2010;21(4):467-74.
30. Berkman LF. Social Epidemiology: Social determinants of health in the United States: Are we losing ground? *Annual Review of Public Health* 2009;30:27-41.
31. Abraido-Lanza AF, Dohrenwend BP, Ng-Mak DS, et al. The Latino mortality paradox: A test of the "salmon bias" and healthy migrant hypotheses. *American Journal of Public Health* 1999; 89(10):1543-8.
32. Mustard CA, Etches J. Gender differences in socioeconomic inequality in mortality. *Journal of Epidemiology and Community Health* 2003;57(12):974-80.
33. McDonough P, Williams DR, House JS, et al. Gender and the socioeconomic gradient in mortality. *Journal of Health and Social Behavior* 1999;40(1):17-31.
34. Acevedo-Garcia D, Lochner KA, Osypuk TL, et al. Future directions in residential segregation and health research: a multilevel approach. *American Journal of Public Health* 2003;93(2):215-21.

Joint Effects of Neighborhood Context and Individual Social Integration on Mortality Risk: An analysis of NHANES III

ABSTRACT

BACKGROUND: Social relationships and the contexts within which they occur- such as neighborhood conditions – have been shown to impact health. The present study examines the joint effects of neighborhood socioeconomic condition and individual social integration on mortality risk.

METHOD: We examined data from the NHANES III geocoded and matched to census tracts, serving as neighborhood proxies. We operationalized neighborhood poverty as the proportion of residents in a census tract living below the federal poverty level. Social integration was measured via a modified Social Network Index. We analyzed data using Kaplan-Meier survival curves as well as Cox proportional hazards regression models that accounted for the complex survey design. Further, measures of additive interaction were calculated.

RESULTS: The association between social integration and mortality risk was significant in this sample (hazard ratio: 1.30; 95% CI: 1.17, 1.49), remained so after controlling for confounders (hazard ratio: 1.44; 95% confidence interval: 1.31, 1.58) and stratifying by level of neighborhood poverty (low poverty: hazard ratio: 1.41; 95% confidence interval: 1.27, 1.58/ high poverty: hazard ratio: 1.45; 95% confidence interval: 1.18, 1.78). Additive interaction measures were not statistically significant, however, the highest risk strata assessing the joint effects of low social integration and high neighborhood poverty had 63% (95% confidence interval: 1.35, 1.96) greater mortality risk than those who were more socially integrated and living in low poverty neighborhoods.

DISCUSSION: The joint effects of neighborhood poverty and social integration are striking. The magnitude of this association is practically relevant and warrants further research.

INTRODUCTION

Social relationships have been shown to have a profound effect on health (1-7). Social relationships and the various types of support linked to social relationships have been associated with a decrease in mortality from a variety of causes (3). Social relationships can be defined simply as interactions among individuals and many different terms have been used in the literature that explores social relationships and health (7, 8). Much of the public health literature focuses on the associations between social integration and health. Social integration can be loosely defined as the opposite of social isolation- that is engagement with others through social ties and institutional connections (7). While these associations have been observed across many disciplines, little is known about the causal pathways associated with social integration and how they may be impacted by other factors also known to be related to health outcomes.

There have been many calls in the health literature for a more advanced understanding of social contexts and how macro-level factors shape the way that social relationships are associated with health (9, 10). Social relationships among people not necessarily bound by membership in particular groups operate within larger social contexts, such as the neighborhoods where people reside (8). Berkman and colleagues (8) describe a cascading effect of social contexts on the properties of individual social

relationships on health behaviors and ultimately on the health of the population. Diez Roux (10) suggests a dynamic relationship between neighborhoods, work environments, and individual level factors, and Subramanian et al (11) state that "it is entirely reasonable (and perhaps more realistic) to anticipate that contextual differences as well as contextual effects inherently interact with individual characteristics."

Recent studies suggest that low neighborhood socioeconomic status may decrease the quality and/or quantity of social relationships among individuals living in those neighborhoods. Small (12) found that racial differences in distinct measurements of the quality and quantity of social relationships did not remain in statistical models that accounted for neighborhood conditions. This study counted both the number of social contacts individuals had as well as the type of support and social leverage they may have received as a result of their social relationships. The study found that neighborhood poverty, and not race, best accounted for the smaller quantity and poorer quality of social relationships among minority groups.

Stringhini et al (13) found a positive relationship between SES and a measure of the quality of social relationships among men in the Whitehall Cohort study showing that men with higher SES had better quality social relationships as well as better health than those with lower SES. The results of the study also demonstrated that the association between SES and mortality was partly explained by measures of social integration. Measures of social integration try to capture the amount of connectedness one has to people in his/her social life. These measures have long been shown to be associated with health and typically include counts of several types of social contacts

such as whether one is married, numbers of visits with family and friends and membership in religious or community organizations (7, 8, 14). A study of a cohort of men in France demonstrated a marked increase in the risk of death among the most socially isolated-those scoring lowest on the measure of social integration (15). A missing link has been the neighborhood context for these associations. How might they be shaped by examination of the conditions within which people live? Specifically, does neighborhood socioeconomic context modify the effect of social relationships on health?

The present study examines whether neighborhood socioeconomic condition and social integration interact and whether these two factors together are associated with time to death within a national US sample. The analysis in the present study is based on the conceptual framework depicted in Figure 1. We developed this framework to describe the differential relationship between social relationships and neighborhood context on mortality. The framework highlights the direct relationship between social integration and mortality and the way that neighborhoods differentially influence health. This conceptual framework puts forward one theoretical approach for understanding how social integration and neighborhood context relate to one another to influence health and guided our analyses examining the joint effect of group-level contexts and individual-level factors on health.

METHODS

Data Sources

Data for this study comes from the Third National Health and Nutrition Examination Survey (NHANES III). The survey, conducted by the Centers for Disease Control and Prevention, employed a complex, multi-stage, stratified sampling design intended to recruit a nationally representative sample of the non-institutionalized, civilian US population. NHANES III was conducted from October 1988-October 1994 and included individuals from age 2 months with no upper age limit. Data collection for the survey consisted of an in-home interview and a series of examinations both in-home and via mobile exam centers (16). The data for the present study were taken entirely from the household interview portion of the NHANES III from all interview years.

The NHANES III Linked Mortality File contains follow-up data for NHANES III participants. The current NHANES III Linked Mortality File is the second mortality follow-up for NHANES III. The first followed participants through December 21, 2000 while the current file followed participants through December 31, 2006. The updated file became available in 2009. Mortality status for NHANES III participants was identified using the National Death Index (NDI) primarily through probabilistic record matching. NCHS used a matching algorithm for NHANES III records specific to this file but similar to that which is the standard used by NDI. It is considered to be a reliable source of mortality follow-up and is intended to be used to conduct an array of investigations of health, risk factors and mortality (17). The public-use Linked Mortality File was used to examine time from household interview to all-cause mortality.

The NHANES III data were geocoded according to participants' home address and matched to 1990 Census tracts. The Census data file used for this study was compiled

by The Public Health Disparities Geocoding Project at the Harvard School of Public Health. This data file contains a variable measuring the percent of people in each census tract living below the poverty line and was computed using 1990 Census data. It is publically available at the Project's website (18). The NHANES III data merged with Census data were made available for restricted-use only by the National Center for Health Statistics (NCHS). The restrictions assure confidentiality of the study participants.

Measures

Social Integration (independent variable). Previously published studies (19, 20) have used items from NHANES III to create a modified Social Network Index (SNI) that captures the four domains first assessed by Berkman and Syme (1). This index was used in the present study. The four domains are marriage or partnership, friends and relatives, religious activity, and voluntary associations. Marital status was assigned as two categories – a value of 1 for married or living as married and 0 for all others (never married, widowed, divorced or separated). The frequency of contacts from two questions (# of times one talks on the phone with family or friends, how often per year do you get together with family or friends) were added and then respondents split into 2 groups with those above 156 contacts assigned a 1 and less than 156 contacts assigned a 0. Frequency of church or religious service attendance was measured and respondents were assigned a 0 if they attended less than four services per year and a 1 if they attended four or more. Finally, those who responded that they were part of a voluntary organization were assigned a 1 with those that did not assigned a 0. The

scores were added to give each individual a score from 0 to 4. This approach has been shown to have good predictive validity (19, 20) and has been written about more extensively in previous papers in this series. For the analyses in this paper we transformed the SNI into a two-level variable where high SNI includes scores 2-4 and low SNI includes scores 0-1.

Neighborhood socioeconomic status measurement (independent variable). In the present study census tracts served as proxies for the neighborhood context. Census tracts have been extensively used in prior neighborhood research (11, 12, 21). These geographic boundaries allow the results of this study to be compared to this previous body of work. To represent neighborhood socioeconomic context, a variable measuring the percent of residents within a census tract living below the federally-defined poverty line was used. This variable has been shown to be a reliable measure of socioeconomic inequality in health studies (18). A two-level categorical grouping of neighborhood poverty was created. The groups were based on the federal definition of "poverty areas" as areas where greater than 20% of the population live below the federal poverty line (11, 22). The values for this dichotomous variable are less than 20% of residents living below poverty (low poverty area) and greater than or equal to 20% of residents living below poverty (high poverty area).

Mortality (dependent variable). The outcome of interest for the present study is time-to-death or more specifically, person-months of follow-up from the interview to December 31, 2006. There are 12-18 years of follow-up for the sample depending on the year of NHANES interview. There is a mean of 167 months (95% CI 162-172) of

follow-up for the weighted study population which is roughly 14 years. There were 20,024 participants eligible for the linkage and 5,360 deaths were identified. This study focuses on all-cause mortality.

Covariates. A number of baseline characteristics were included in the multivariable statistical models. Age, sex, and race and ethnicity were adjusted for in the regression models due to their demonstrated associations with mortality. In addition, individual SES at the time of the baseline interview was accounted for via the participants' household poverty income ratio (PIR) and years of education completed. Age, years of education and PIR were included as categorical variables because their relationships with the outcome are not strictly linear. Individual SES has also been shown to be a strong predictor and therefore 5 levels of the PIR variable were used to account for the fine gradations in its effects (12, 23, 24).

Statistical analysis

NHANES III has a complex, multi-stage probability sample and the appropriate weighting, strata and PSU variables to adjust for the sample design were used to conduct all analyses. This was done using SUDAAN, version 10 (25), software which is designed to address these specialized analysis issues. Descriptive statistics were computed to determine the characteristics of the study population. Frequencies and means were calculated along with their standard errors that take into consideration the sample design and weighting. Descriptive statistics were calculated for the whole sample and by neighborhood poverty group.

We investigated the relationship between social integration, neighborhood poverty and time-to-death using survival analysis techniques. The outcome of interest was time from NHANES household interview to death. If no death was recorded, those subjects were censored at time to December 31, 2006, which is the end of the follow-up period in the linked mortality database. In survival analysis, censoring allows the use of survival data for study subjects even if the exact survival time is unknown (26). In this study the data is considered right-censored because the time from the baseline interview to follow-up is known for all subjects even if their exact survival time is not known. We used Cox proportional hazards regression to model the relationship between neighborhood poverty and time to death while adjusting for age and the other known confounders. It is a semi-parametric model that is usually written in terms of the hazard model formula (26). In this formula, the baseline hazard is a function of time but does not involve the explanatory variables which are considered time-independent. This is an important feature of the model that assumes the risks are proportional between groups. This proportional hazards assumption was examined graphically using Kaplan-Meier curves (27).

An additional requirement in the use of survival analysis is that some meaning be placed on the start time of the study. In a study such as this one where the start time is only significant in that it happens to be the date that data was collected there may be concern about the meaningfulness of the outcome of interest. This may be especially true if the individuals being studied have some varied risk of experiencing the event of interest (death). In the case of the present study, there is an assumption of a “steady

state (28)." That is, one can assume that death (the event of interest) occurs in the study sample at a steady rate equal to that in the target population and that being chosen for the study did not alter this risk in any way for any individual. NHANES uses randomly selected, national probability sample, and subjects were not chosen for any reason connected to their risk of death. For this reason the assumption of a steady state should hold and survival analysis is an appropriate methodology for analyzing this time-to-event data.

In planning the regression analyses, we strongly considered the multilevel nature of the individual-level outcome and the neighborhood-level exposure and how this could be accounted for within the complex sample design of NHANES III. It is likely that individuals living within the same census tract were more similar to each other than to those within other census tracts. This can have an effect on the calculation of variance in the models and there are analytic methods available to account for this effect. When analyzing complex survey data, SUDAAN takes these same issues into consideration using similar analytic methods. People within the same primary sampling units (PSUs) of the NHANES are projected to be more similar to each other than to those sampled from other PSUs. In order to properly account for this, SUDAAN uses generalized estimating equations (population average models) and variances are estimated using the Taylor-series method. As of this writing, SUDAAN is unable to take more than one set of stratification variables into account (G. Gordon Brown, Triangle Research Institute, personal communication, 2012) when fitting statistical models that account for group-level characteristics. Thus, we could only specify the sampling design variable (i.e.,

PSU's) or the neighborhood-level variable (i.e. census tracts) as the higher order group-level variable. This could cause some error in the variance estimations but based on other studies (24), we expect this error to be small and it should not impact the statistical significance of our estimates. We, therefore, decided to preserve and incorporate the sampling design in all of the analyses. This was appropriate because we were not necessarily interested in partitioning the between and within neighborhood variance as in random effects models (29), rather we are modeling the population average effects for the NHANES primary sampling units, which are groupings of census tracts.

Effect modification and the overall impact of neighborhood poverty on the association between social integration and mortality were assessed in two ways. First the Cox regression models were stratified by level of neighborhood poverty to examine differences in the hazard ratios. This stratification assesses multiplicative interaction between neighborhood poverty and social integration. Next, a four-level dummy variable was inserted into the regression model in place of social integration and neighborhood poverty to assess additive interaction (30). The referent category is the category of least risk, in this case high SNI and low neighborhood poverty (dR). The other three categories are high SNI/ high neighborhood poverty (d1), low SNI/low neighborhood poverty (d2), and low SNI/high neighborhood poverty (highest risk group=d3). While the referent group represents the absence of the main effects, the high risk group represents the joint effects of these risk factors and the other two variables represent the independent effect of each risk. The hazard ratios of each group

compared to the referent group are reported as are the following measures of additive effect modification (30, 31): relative excess risk due to interaction (RERI), the synergy index (SI), and attributable proportion due to interaction (AP). These measures were calculated using the hazard ratios (HR) from the Cox regression as follows- RERI= HR_{d3}-HR_{d2}-HR_{d3}+1; S=HR_{d3}-1/(HR_{d2}-1)+(HR_{d1}-1); AP=RERI/HR_{d3}. The RERI and AP are interpreted as being equal to 0 if there is no effect modification or exact additivity; greater than 0 for positive or less for negative, and the SI is interpreted with 1 being exact additivity. The confidence intervals and P-values were calculated using an excel spreadsheet created for this purpose by Knol (32) and made available via the internet. The spreadsheet uses the delta method of standard error estimation.

The full sample of adults over age 17 interviewed as part of NHANES III and eligible for subsequent follow-up was 20,024. Respondents were excluded from the present analysis if their addresses at the time of the interview were not able to be geocoded and matched to a 1990 Census tract (n=2,778). In order to insure that individuals had an opportunity to have their health shaped by the neighborhood where they lived, those who responded that they lived in their city/town/area for less than one year were also excluded (n=1,202). The final analytic sample consists of 16,044 survey respondents. The sample size may be less than 16,044 for some analyses when values for included variables are missing. There are 1,699 individuals (about 10% of the sample) for whom PIR is missing and in those analyses that include PIR these respondents are excluded as well. The group with missing PIR is more likely to be from the extremes in the age spectrum, racial/ethnic minorities, less educated and have lived

in their areas for shorter periods of time when compared to those where PIR is provided. This should be taken into consideration when the results are reviewed.

RESULTS

Table 1 presents the weighted demographic descriptive statistics for the full sample and by neighborhood poverty groups. These results indicate that a little over half of those sampled were women (53%), the majority (74%) was Non-Hispanic white, and most (74%) had completed at least a high school education. Most of the sample lived above the poverty line (82%) and over half (53%) lived in their area of residence for a substantial amount of time (0ver 20 years or their whole life). Over half (61%) of respondents were between 20 and 49 years of age.

In Table 1 it can be seen that those from the sample who lived in the highest poverty areas (at least 20%) were more likely to be female, of a racial or ethnic minority, live below the poverty line themselves and been less educated than those in the areas with less poverty. As neighborhood poverty increases, the proportion of non-Hispanic whites decreases, with the most dramatic change between the higher two categories (from 10-19.9% to 20% and over, from 73% to 42%). The mean person-months of follow-up are steady across categories of neighborhood poverty (166-167 months). However, the percent deceased is higher within the category with the highest amount of neighborhood poverty (21%) when compared with the categories of less poverty (15-18%).

Figure 2 and Table 2 show the main effects of social integration on mortality. Figure 2 displays the Kaplan-Meier survival curves of the high and low SNI groups. The

curves graphically show that the proportional hazards assumption is met and it can be seen that the low SNI group has a greater risk of death than the high SNI group. In the first set of Cox regression models (Table 2), the group with low social network scores has 1.30 (95% confidence interval: 1.17, 1.49) times the risk of death when compared to those with high social network scores. When the model is adjusted for age, gender, race, PIR and years of education the hazard ratio increases to 1.44 (95% confidence interval: 1.31, 1.58). In both of these regression models, the association between SNI group and risk of death is statistically significant. When the models are stratified by neighborhood poverty (as shown in Table 3), the hazard ratios across neighborhood contexts do not differ substantially. In the adjusted model within the low poverty strata (<20%) those with low social network scores have a hazard ratio of 1.41 (95% confidence interval: 1.27, 1.58) and in the high poverty group the hazard ratio is 1.45 (95% confidence interval: 1.18, 1.78).

Table 4 shows that the effect modification of neighborhood poverty on the association between social integration and mortality is further tested by examining interaction on an additive scale. The four-level dummy variable used with high social network score and low neighborhood poverty as the referent when inserted into a Cox regression model controlling for the confounding factors shows an increased risk for the three groups when compared to the referent group. The group theorized to have the highest risk- low social network scores and high neighborhood poverty -has 1.63 times the risk of the referent group (*P* for trend=0.000). However, this increase does not translate to a statistically significant effect modification. The relative excess risk due to

interaction (RERI- a measure of effect modification) is 0.11 indicating a slight positive effect modification that is not statistically significant (p=0.55). The other measures of interaction have similar results.

The Kaplan-Meier survival curves for the dummy variables as seen in Figure 3 graphically show the risk differences among these groups. The referent group with the lowest risk (high SNI/low area poverty) has a curve that depicts a much decreased risk of death over the curves of the other groups. While the hazards for the three higher risk groups do overlap, they are clearly proportional to the risks of the low risk group.

DISCUSSION

This study supports the work of previous studies by demonstrating a consistent inverse relationship between social integration and mortality. The socially isolated have a 40% higher risk of death than those more socially integrated. Further, we found a strong joint effect of social integration and neighborhood poverty on mortality risk. The 63% increase in risk of death among those in the high poverty, low social integration group when compared to the low poverty, high social integration group is quite striking and it is significantly higher than the risk found for either effect independently. The measures of effect modification were not found to be statistically significant but the findings of the present study are practically significant in their impact on how context and individual social factors should be considered in future work. We have identified a target group that may well benefit from interventions aimed at addressing those neighborhood conditions that shape social support. Based on our findings, such

activities will likely have a major impact on the health and well-being of individuals within communities characterized by concentrated disadvantage.

Previous studies (paper 2 in this series) using the same data found that neighborhood poverty was a weak predictor of mortality. That finding is supported here where it is certainly a weaker predictor than social integration which is confirmed as contributing to mortality risk in this data. However, neighborhood poverty is a distal factor on this causal pathway such that large impacts would not be expected and it has been shown to predict levels of social integration (paper 1 in this series). These facts provide insight that can be useful in learning how to intervene to increase the health of communities. Investigation into what characteristics of high poverty neighborhoods may contribute to the break-down in social support could lead to the development of successful health interventions. As many authors have previously noted, the context within which activities are taking place must now be considered (8-12, 33). Neighborhood-level initiatives that empower residents to take part in improving their communities such as fixing and upgrading infrastructure, cleaning trash from the streets and hosting events where the residents can come together, may foster supportive relationships and pride in communities. The current disconnect between research findings in social epidemiology and the disappointing results from the evaluations of interventions could be linked to contextual effects (9). The present study supports this assertion as it was found that being socially isolated within high poverty neighborhoods put residents at greater risk of death.

Previous studies have demonstrated that neighborhood socioeconomic condition makes a distinct contribution to risk of mortality over and above that of individual-level SES (34-37). It has been demonstrated that neighborhood condition shapes social relationships and that this contribution can account for differences that might have been attributed to individual-level factors, such as race and ethnicity (12). Studies have also shown that individuals' social relationships have a significant effect on health (1-5, 7, 15, 19, 38). Socioeconomic status has been found to be associated with social integration and health within the same populations (13). What has been missing in the literature is the examination of the overlap between individual social integration and neighborhood condition. This study sought to begin this new conversation. We have shown that neighborhood condition and social integration not only individually contribute to mortality risk but as neighborhood poverty increases and social integration decreases the risk of death increases. This study does not definitively provide evidence of an interaction but it certainly demonstrates a need to further investigate this possibility.

These results should be interpreted within the bounds of the study's limitations. These limits include the use of the NHANES III data. These data are meant to be nationally representative however, some segments of the population were oversampled and others were left out entirely. The benefits of this data source are its ample size and that it is national in scope. However, the results can only be generalized to populations of similar composition.

Another limitation is the cross-sectional nature of the data collection. With the exception of the mortality follow-up, the rest of the variables (collected at NHANES interview and via the Census) were captured at one time point only. Therefore, the effects of these as found in the study may not be the same effects as would be seen if they were measured over time. Specifically, social integration and neighborhood of residence could change over time and several theorists have suggested that the time at which one is exposed to these conditions could have an impact on their associations with health. The results of the study, given its limitations, do provide the foundation for future research on this topic. Future research might examine the way that these factors contribute to health at different points during a lifetime and whether their impact is more or less at specific times. The research could be extended to include additional minority groups and specific populations that were missed in the NHANES III.

Strengths of this study include its large sample size and the inclusion of measures at the individual- and neighborhood-levels. This study is the first of its kind to include a national population, introducing new evidence of the relationship between social integration and health. Although the associations found may seem weak, that these associations were found in such a diverse sample population while examining distal health risk factors indicates their importance and strength. In addition, this new look at how neighborhood poverty interacts with social integration on its effect on health is unique and opens the door for future analyses. No other study in the public health literature has examined these constructs in a joint effects model.

The measurement of additive interaction is another strength of the present study. There has been a call in the epidemiology literature for increased use of these measures and others that allow for a clear and standardized examination of health risks (31, 39). The use of these methods are encouraged because they allow for the investigation of effects on focused populations-narrowing in on the segment of the population that is most at risk, thus enabling the creation of targeted interventions aimed at helping those who need it most. We are able to see from the analysis that neighborhood poverty likely modifies the impact of social integration on health. Armed with this knowledge, public health professionals can design and implement interventions aimed at improving aspects of neighborhood condition that dampen the otherwise positive effect of social integration.

The present study is another look at the association between social relationships and mortality. We have demonstrated once again that being well socially integrated decreases one's risk of death. Further, we examined whether neighborhood poverty impacts the established association between social integration and mortality. The results of the tests of interaction indicate a possible effect modification of neighborhood condition on social integration and mortality. These results merit further exploration and have opened the door for future research that places social relationships within a broader social context and examines their joint effects on health.

Figure 1: Conceptual Framework

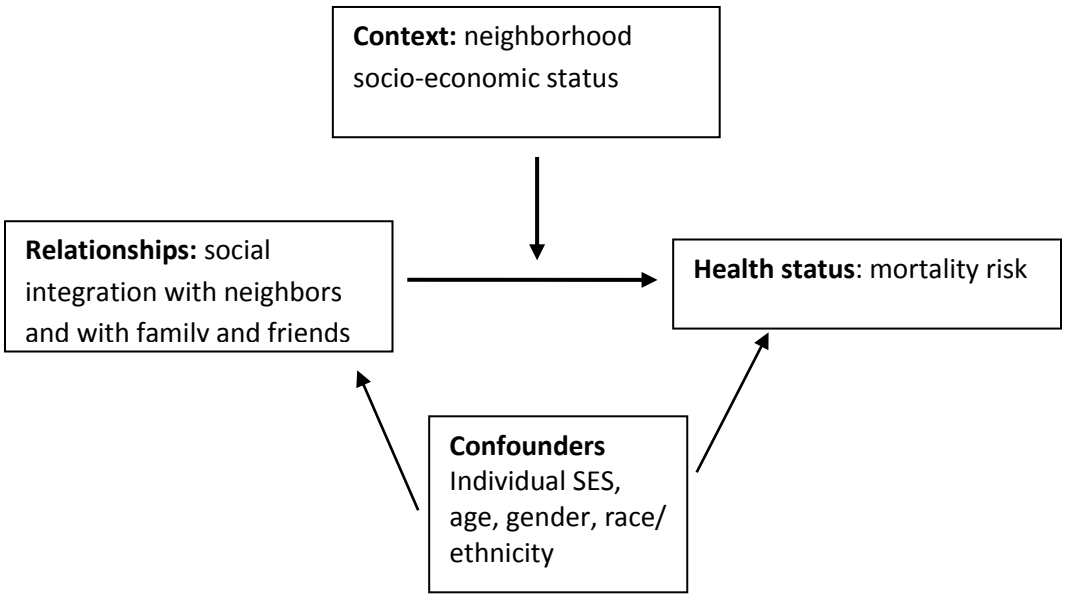


Table 1: Weighted descriptive summary statistics for the total sample (N=16,044) and by neighborhood poverty category. *This table displays column percentages, except in person-months of follow-up which shows the average number of months.*

Variable	*Total Sample % (SE)*	*0-4.9% neighborhood poverty*	*5-9.9% neighborhood poverty*	*10-19.9% neighborhood poverty*	*≥20% neighborhood poverty*
Neighborhood Poverty					
0-4.9%	30.9 (1.87)				
5-9.9%	25.4 (1.29)				
10-19.9%	25.1 (1.59)				
≥20%	18.7 (1.22)				
Individual level predictors:					
Age groups					
17-19 years	4.8 (0.35)	4.1 (0.66)	4.7 (0.53)	4.7 (0.53)	6.0 (0.51)
20-29 years	19.8 (0.81)	14.7 (1.07)	20.2 (1.54)	21.9 (1.27)	24.8 (1.55)
30-39 years	23.7 (0.75)	22.5 (1.48)	26.0 (1.45)	23.7 (1.47)	22.6 (1.33)
40-49 years	17.9 (0.62)	22.1 (1.47)	17.3 (1.03)	14.9 (0.93)	15.5 (1.06)
50-59 years	11.9 (0.41)	13.8 (0.96)	11.8 (0.93)	11.3 (0.81)	9.7 (0.63)
60-69 years	10.9 (0.49)	11.7 (1.19)	10.2 (0.83)	11.2 (0.80)	10.2 (0.74)
70-79 years	7.6 (0.41)	7.8 (0.93)	6.6 (0.62)	8.6 (0.56)	7.4 (0.62)
80+ years	3.4 (0.29)	3.2 (0.49)	3.1 (0.49)	3.7 (0.37)	3.7 (0.39)
Sex					
Male	47.1 (0.47)	48.0 (0.98)	48.2 (1.09)	47.6 (0.75)	43.6 (0.92)
Female	52.9 (0.47)	52.0 (0.98)	51.8 (1.09)	52.4 (0.75)	56.4 (0.92)
Race/Ethnicity					
Non-Hispanic White	73.6 (1.35)	89.5 (1.32)	77.8 (2.66)	72.9 (2.38)	42.4 (2.30)
Non-Hispanic Black	12.3 (0.74)	3.6 (0.53)	8.5 (1.16)	11.0 (1.02)	33.5 (2.07)
Mexican-American	5.6 (0.48)	1.8 (0.31)	4.4 (0.81)	6.3 (0.76)	12.6 (1.06)
Other	8.5 (0.93)	5.1 (1.14)	9.2 (1.82)	9.8 (1.52)	11.5 (1.72)
Living below poverty (PIR<1)	12.7 (0.90)	3.3 (0.64)	8.4 (1.48)	16.1 (1.49)	30.6 (1.86)
Highest year of school completed					
0-8 years	11.1 (0.61)	4.5 (0.42)	7.7 (1.06)	13.9 (0.97)	22.7 (1.11)
9-11years	14.8 (0.60)	8.8 (0.86)	13.1 (1.14)	18.7 (1.10)	21.7 (0.90)
12 years	32.8 (0.83)	29.9 (1.59)	36.2 (1.75)	33.7 (1.25)	31.9 (1.48)
13+ years	41.3 (1.27)	56.8 (2.08)	43.0 (2.14)	33.6 (1.61)	23.8 (1.29)
How long lived in city/town/area					
Whole life	26.8 (1.14)	24.7 (2.04)	25.1 (2.08)	27.2 (1.69)	31.9 (1.35)
>20 years	26.6 (0.89)	27.3 (2.00)	26.2 (1.26)	26.1 (1.56)	26.8 (1.45)
11-20 years	15.6 (0.72)	17.5 (1.51)	15.7 (1.31)	14.9 (1.15)	13.3 (1.03)
5-10 years	14.6 (0.76)	15.9 (1.41)	15.3 (1.20)	14.3 (1.28)	11.9 (0.97)
3-4 years	7.6 (0.48)	6.4 (0.86)	8.4 (0.87)	8.2 (0.81)	7.6 (1.00)
1-2 years	8.7 (0.59)	8.1 (1.00)	9.2 (1.14)	9.2 (0.82)	8.4 (1.45)
Outcome:					
Assumed deceased	17.2 (0.70)	15.4 (1.20)	15.1 (1.14)	18.6 (1.01)	21.2 (1.05)
Person-months of follow-up*	166.7 (2.43)	167.5 (3.03)	166.7 (2.86)	166.1 (2.90)	166.0 (2.32)

Table 2. Cox proportional hazards regression models of the association between social network index score and mortality

Social network index	Model 1: Crude Model (unadjusted)		Model 2: includes confounders: sex, race, age, individual PIR, highest yr of education	
	Hazard Ratio	**95%CI**	**Hazard Ratio**	**95%CI**
Low (0,1)	1.30	1.17, 1.49	1.44	1.31, 1.58
High (2-4)	1.00	ref	1.00	ref

Figure 2. Kaplan-Meier curves of cumulative survival for the social network index (SNI) groups.

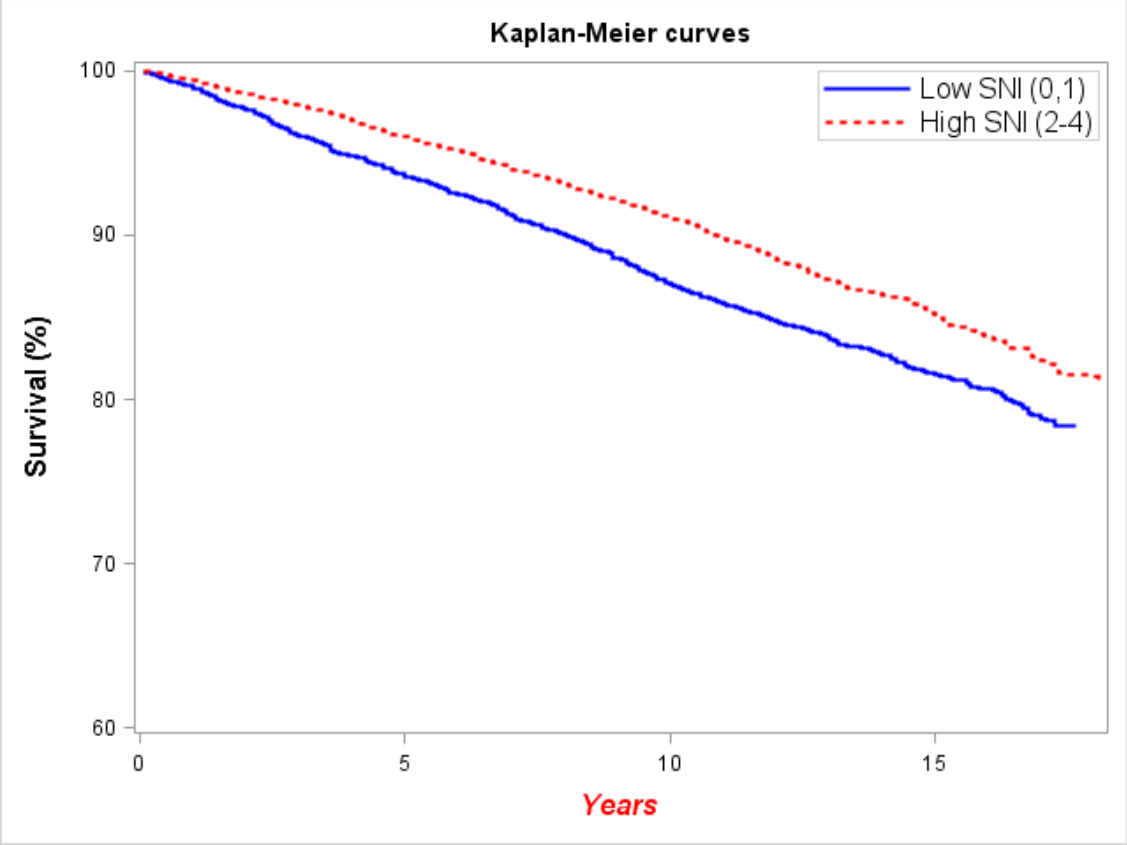


Table 3. Stratified Cox PH models of relative risk of death for social network index by neighborhood poverty

Neighborhood poverty	**SNI**	Model 1: Crude Model (unadjusted)		Model 2: includes confounders: sex, race, age, individual PIR, highest yr of education	
		hazard Ratio	**95% CI**	**Hazard ratio**	**95% CI**
<20%	**Low (0,1)**	1.34	1.19, 1.53	1.41	1.27, 1.58
	High (2-4)	1.00	ref	1.00	ref
≥20%	**Low (0,1)**	1.07	0.85, 1.35	1.45	1.18, 1.78
	High (2-4)	1.00	ref	1.00	ref

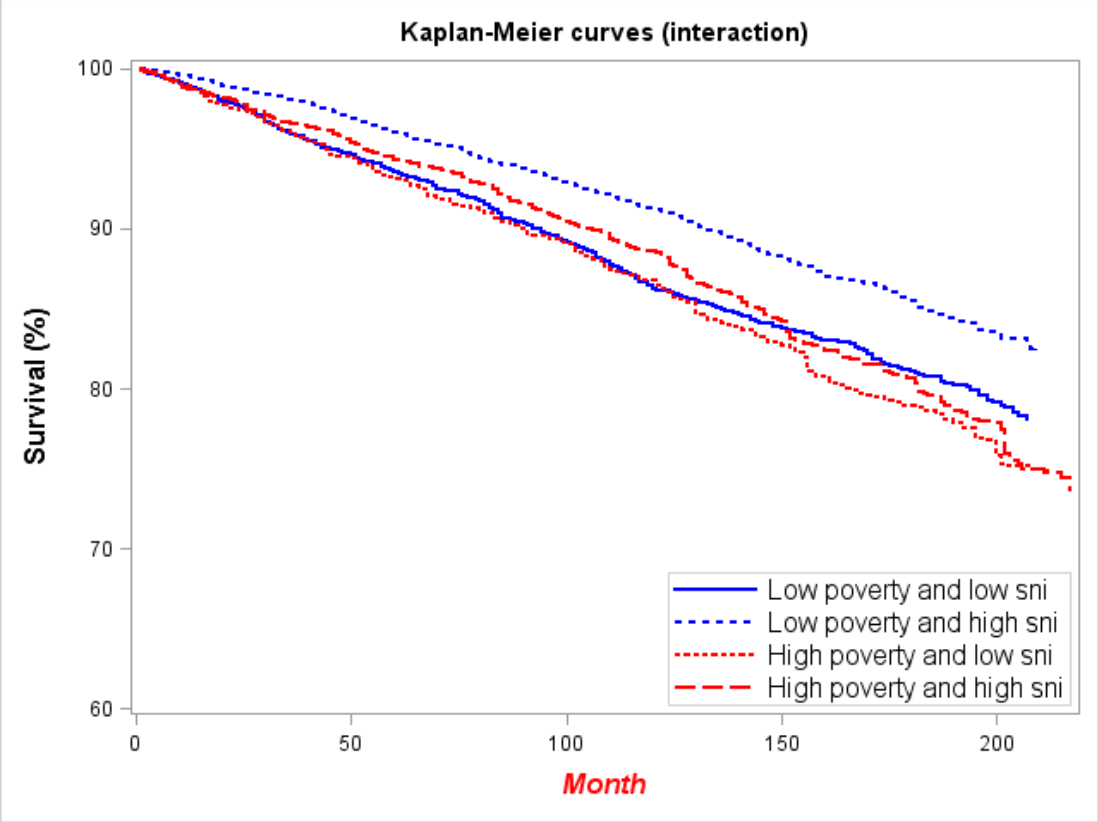
Table 4. Cox regression models examining neighborhood poverty as an effect modifier of the association between social network index score and mortality

	High SNI score	**Low SNI score**
	HR (95% CI)	**HR (95% CI)**
Neighborhood poverty <20%	1.00 (referent)	1.42 (1.28, 1.59) *P*=0.0000
Neighborhood poverty ≥20%	1.10 (0.95, 1.28) *P*=0.1860	1.63 (1.35, 1.96) *P*=0.0000

Measures of effect modification on additive scale: RERI (95% CI) =0.11 (-0.25, 0.46) *P*=0.55; SI=1.21 (0.66, 2.20) *P=0.54*; AP=0.07 (-0.14, 0.27) *P=0.53*

HRs are adjusted for age, gender, race/ethnicity, individual poverty income ratio, education

Figure 3. Kaplan-Meier curves of cumulative survival for effect modification of social network index score by neighborhood poverty



REFERENCES

1. Berkman LF, Syme SL. Social networks, host resistance, and mortality: A nine-year follow-up study of Alameda County residents. *American Journal of Epidemiology* 1979;109(2):186-204.
2. Cohen S, Doyle WJ, Skoner DP, et al. Social ties and susceptibility to the common cold. *JAMA : The Journal of the American Medical Association* 1997;277(24):1940-4.
3. Holt-Lunstad J, Smith TB, Layton JB. Social relationships and mortality risk: a meta-analytic review. *PLoS Medicine* 2010;7(7):e1000316.
4. House JS, Landis KR, Umberson D. Social relationships and health. *Science* 1988;241(4865):540-5.
5. Kaplan GA, Salonen JT, Cohen RD, et al. Social connections and mortality from all causes and from cardiovascular disease: Prospective evidence from Eastern Finland. *American Journal of Epidemiology* 1988;128(2):370-80.
6. Kawachi I, Berkman LF. Social ties and mental health. *Journal of Urban Health : Bulletin of the New York Academy of Medicine* 2001;78(3):458-67.
7. Seeman TE. Social ties and health: The benefits of social integration. *Annals of Epidemiology* 1996;6(5):442-51.
8. Berkman LF, Glass T, Brissette I, et al. From social integration to health: Durkheim in the new millennium. *Social Science & Medicine* 2000;51(6):843-57.
9. Berkman LF. Social Epidemiology: Social determinants of health in the United States: Are we losing ground? *Annual Review of Public Health* 2009;30:27-41.
10. Diez Roux AV. Next steps in understanding the multilevel determinants of health. *Journal of Epidemiology and Community Health* 2008;62(11):957-9.
11. Subramanian SV, Chen JT, Rehkopf DH, et al. Racial disparities in context: A multilevel analysis of neighborhood variations in poverty and excess mortality among Black populations in Massachusetts. *American Journal of Public Health* 2005;95(2):260-5.
12. Small ML. Racial differences in networks: Do neighborhood conditions matter? *Soc Sci Q* 2007;88(2):320-43.
13. Stringhini S, Berkman L, Dugravot A, et al. Socioeconomic status, structural and functional measures of social support, and mortality: The British Whitehall II Cohort Study, 1985-2009. *American Journal of Epidemiology* 2012;175(12):1275-83.
14. Berkman LF, Glass T. Social Integration, Social Networks, Social Support, and Health. In: Berkman LF, Kawachi I, eds. *Social Epidemiology*. New York, NY: Oxford University Press, 2000.
15. Berkman LF, Melchior M, Chastang JF, et al. Social integration and mortality: A prospective study of French employees of Electricity of France-Gas of France: the GAZEL Cohort. *American Journal of Epidemiology* 2004;159(2):167-74.
16. National Center for Health Statistics. Third National Health and Nutrition Examination Survey, 1988-1994, NHANES III Household Adult Data File and Documentation. Hyattsville, MD: Centers for Disease Control and Prevention, 1996, (US Department of Health and Human Services publication no. 77560)
17. National Center for Health Statistics. The Third National Health and Examination Survey (NHANES III) Linked Mortality File, Mortality Follow-up through 2006: Matching Methodology. Hyattsville, MD, 2009.
18. The Public Health Disparities Geocoding Project . U.S. Census Tract Poverty Data. Boston, MA: Harvard School of Public Health; 2004.

(http://www.hsph.harvard.edu/thegeocodingproject/webpage/monograph/povdata.htm). (Accessed June 29, 2013).
19. Ford ES, Loucks EB, Berkman LF. Social integration and concentrations of C-reactive protein among US adults. *Annals of Epidemiology* 2006;16(2):78-84.
20. Obisesan TO, Gillum RF. Cognitive function, social integration and mortality in a U.S. national cohort study of older adults. *BMC Geriatrics* 2009;9:33.
21. Krieger N, Chen JT, Waterman PD, et al. Painting a truer picture of US socioeconomic and racial/ethnic health inequalities: The Public Health Disparities Geocoding Project. *American journal of public health* 2005;95(2):312-23.
22. Bishaw A. Areas with Concentrated Poverty: 2006-2010. Washington, DC: US Census Bureau, 2011, (American Community Survey Briefs)(US Department of Commerce publication no. ACSBR/10-17)
23. Campbell KE, Lee BA. Sources of personal neighbor networks: Social integration, need, or time? *Social Forces* 1992;70(4):1077-100.
24. Merkin SS, Basurto-Davila R, Karlamangla A, et al. Neighborhoods and cumulative biological risk profiles by race/ethnicity in a national sample of U.S. adults: NHANES III. *Annals of Epidemiology* 2009;19(3):194-201.
25. Shah VBBB, Bieler GS. *SUDAAN User's Manual*. Research Triangle Park, NC: Research Triangle Institute; 2005.
26. Kleinbaum DG, Klein M. *Survival Analysis : A Self-Learning Text*. 2nd ed. New York, NY: Springer; 2005.
27. Persson I. *Essays on the Assumption of Proportional Hazards in Cox Regression* [Dissertation]. Uppsala, Sweden: Uppsala University; 2002.
28. Szklo M, Nieto FJ. *Epidemiology : Beyond the Basics*. 3rd ed. Burlington, Mass.: Jones & Bartlett Learning; 2014.
29. Hubbard AE, Ahern J, Fleischer NL, et al. To GEE or not to GEE: Comparing population average and mixed models for estimating the associations between neighborhood risk factors and health. *Epidemiology* 2010;21(4):467-74.
30. Knol MJ, VanderWeele TJ, Groenwold RHH, et al. Recoding preventive exposures to get valid measures of interaction on an additive scale. *European Journal of Epidemiology* 2011;26(10):825-6; author reply 6.
31. Knol MJ, VanderWeele TJ. Recommendations for presenting analyses of effect modification and interaction. *International Journal of Epidemiology* 2012;41(2):514-20.
32. Knol MJ. Spreadsheet for measures of additive interaction with confidence intervals and p-values using the delta method. Utrecht, The Netherlands: Julius Center, 2011.
33. Subramanian SV, Lochner KA, Kawachi I. Neighborhood differences in social capital: a compositional artifact or a contextual construct? *Health & Place* 2003;9(1):33-44.
34. Winkleby M, Cubbin C, Ahn D. Effect of cross-level interaction between individual and neighborhood socioeconomic status on adult mortality rates. *American Journal of Public Health* 2006;96(12):2145-53.
35. Yen IH, Kaplan GA. Neighborhood social environment and risk of death: Multilevel evidence from the Alameda County Study. *American Journal of Epidemiology* 1999;149(10):898-907.
36. Diez Roux AV, Borrell LN, Haan M, et al. Neighbourhood environments and mortality in an elderly cohort: results from the cardiovascular health study. *Journal of Epidemiology and Community Health* 2004;58(11):917-23.
37. Haan M, Kaplan GA, Camacho T. Poverty and health. Prospective evidence from the Alameda County Study. *American Journal of Epidemiology* 1987;125(6):989-98.

38. Seeman TE, Kaplan GA, Knudsen L, et al. Social network ties and mortality among the elderly in the Alameda County Study. *American Journal of Epidemiology* 1987;126(4):714-23.
39. Vandenbroucke JP, von Elm E, Altman DG, et al. Strengthening the Reporting of Observational Studies in Epidemiology (STROBE): explanation and elaboration. *PLoS Medicine* 2007;4(10):e297.

CONCLUSION

The present dissertation contributes to the public health literature that explores the social determinants of health. Specifically, we looked to examine social integration and neighborhood context; both the independent and joint associations that these factors have with mortality risk. We believe that deciphering how neighborhood condition modifies the health effects of social integration can provide background for future targeted public health interventions. Berkman (1), in her review of progress made in social epidemiology, highlighted how policy changes and public health interventions that were developed based on previous research have not proven to be as successful as was anticipated. There are still missing pieces to the puzzle of the social determinants of health. Both Berkman (1) and Diez Roux (2) in their recent reviews make suggestions for how to improve upon previous research and this study attempted to implement several of these suggestions in the hope of advancing the field of social epidemiology.

This dissertation research has sought to encourage the improved use of standard definitions and measures for social concepts that have been tested in various ways over many years. Social relationships have been shown to impact health (3-10) but the ways in which they are defined can be so varied as to make the interpretation of the results for meaningful use difficult (11-13). Neighborhood context has also been linked to the health status of individuals (14-19) but again the ways it has been measured –both the geographical boundaries of neighborhoods and the constructs that indicate condition-

have varied drastically (2, 20-27). In this study we used a measure of social integration, defined as the number and frequency of social ties, which has been used in previous studies (4, 5). We used neighborhood poverty, defined as the proportion of residents in a census tract living below the federally-defined poverty line, to assess neighborhood socioeconomic condition. This measure has also been used reliably in previous studies (18, 26-29).

A simple conceptual framework that can be tested using available resources is a contribution to the field. This study presents a framework that considers the dynamic relationship between individual and neighborhood-level social constructs. Three sets of specific aims were laid out to test it this framework. In the first manuscript we sought to evaluate the relationship between neighborhood socioeconomic context and distinct forms of social integration. We did this by 1) assessing the relationship between neighborhood socioeconomic context and social integration with neighbors in the NHANES III/Linked Mortality file dataset and 2) assessing the relationship between neighborhood socioeconomic context and social integration overall (i.e., with family, friends and neighbors) in the NHANES III/Linked Mortality file dataset.

In manuscript two we sought to examine whether neighborhood socioeconomic context influences time-to-death within this sample and while controlling for confounders. This was achieved by assessing whether the accepted relationship between neighborhood poverty and all-cause mortality risk holds within the updated NHANES III Linked Mortality File for those over age 17 while controlling for known confounders.

In the third manuscript we explored whether neighborhood socioeconomic context and social integration together have an impact on time-to-death. This was achieved by assessing whether the accepted relationship between social integration and all-cause mortality risk existed within the updated NHANES III Linked Mortality File for those over age 17 while controlling for known confounders. We then looked at whether the relation between social integration and mortality risk differs by neighborhood socioeconomic context.

The household interview of the Third National Health and Nutrition Examination Survey (NHANES III), a national, probability sample of non-institutionalized US adults was used to measure social integration generally and with neighbors. This data was merged with the NHANES III Linked Mortality File to examine mortality risk among the respondents and these data were geocoded and merged with Census data to provide a measure of neighborhood socioeconomic condition. The measures used in the study are all measures that have been used in past studies and can be replicated for future use. Thus, allowing the results to be re-tested and analyses to be applied to other samples. The confounding risk factors included in the study are simple and replicable as well. The conceptual framework was used to ensure that these factors were not on the causal pathway between neighborhood condition, social integration and mortality so as not to obscure the results. The same factors are used in all three manuscripts so that they can be interpreted either independently or as contributing to one larger theme.

In the first manuscript, it was found that neighborhood poverty was significantly associated with social integration generally and with frequency of visits with neighbors.

The results were contrary to expectations in that although high neighborhood poverty was associated with increased general social isolation as measured by the social network index, living in a neighborhood with high poverty was also strongly associated with having more frequent visits with neighbors. This result is consistent with results from past studies of urban populations (30, 31) and that we confirmed this using a national sample is enlightening. These results suggest that there are additional social processes at work which should be investigated.

In the second manuscript, we found that there is an increased risk of mortality associated with high neighborhood poverty in our adult, NHANES III sample. When stratified by gender, this risk was significant among men but not women. This result is also consistent with past studies (18, 19, 32) and suggests that the methods used were reliable and should be explored further. That the effect size was small reflects the distal position of neighborhood condition as a risk factor for health. It does not, however, negate its importance. The use of neighborhood poverty as a proxy for other neighborhood conditions is still an open discussion. If proven to be valid and reliable its ease of use and applicability to real-world research and interventions is intriguing.

In the third manuscript, we pull the pieces of the story together still further. Using an identical sample and measures to that in the previous two manuscripts, we assessed the joint association of social integration and neighborhood poverty with mortality risk. Here it was seen that the association between social integration and mortality risk, adjusted for confounding risk factors, was similar to that found in previous research (3, 4, 7, 8). The more socially isolated had increased risk for death

within the follow-up period, after adjusting for age, race/ethnicity, and individual socioeconomic status. When the Cox regression models were stratified by neighborhood poverty, the association between social integration and mortality remained essentially the same. Further, cross-level tests of interaction were carried out using a 4-level variable with the following categories: low neighborhood poverty and high social integration (lowest risk category), low neighborhood poverty and low social integration, high neighborhood poverty and high social integration, and high neighborhood poverty and low social integration (highest risk category). Here additive interaction was indicated, although it was not found to be statistically significant. We did see that those in the highest risk category, exposed to both high neighborhood poverty and low social integration, had a significant increase in mortality risk when compared to those in the lowest risk category, where both factors were absent, and that the joint risk was higher than that for individuals exposed only to high neighborhood poverty or poor social integration.

In summary, these analyses build a body of evidence for the association between social integration and neighborhood poverty. It shows these associations to be consistent and that both independently and together, these social constructs impact mortality risk. We have demonstrated that the use of simple, well-defined measures is effective in assessing risk and that these measures can and should be used to explore these connections further. These analyses would likely be enhanced by a focus on a life-course perspective, integrating measures of mediation for factors on the causal pathway, and an evaluation of causality using newer statistical methods. Examining

how much risk is attributable to each level may also enhance future research and as statistical packages that can handle these myriad issues are developed, this work will be more frequently seen.

Despite the limitations of the present study and the future research needs outlined above, this unique research can inspire policy changes and interventions on its own merit. This work suggests that neighborhood-level interventions aimed at improving conditions in communities with high proportions of residential poverty can impact the health of the people who live there. This work supports hypotheses that individuals – their social relationships and their health- are affected by the places where they live. Decreasing stress caused by living in conditions associated with high poverty can free individuals to have positive, quality social interactions that foster good health and well-being (33). Creating neighborhood environments that encourage collective efficacy (20, 21) will in turn modify the health behaviors of those who live there (34). Healthy and empowered people are more likely to give back to their communities and thus we can create a cycle that will promote good public health (35). These notions are not new to the social sciences; however, studying them and then planning public health interventions and policy changes based on these principles may lead to new and positive results.

REFERENCES

1. Berkman LF. Social Epidemiology: Social determinants of health in the United States: Are we losing ground? *Annual Review of Public Health* 2009;30:27-41.
2. Diez Roux AV. Next steps in understanding the multilevel determinants of health. *Journal of Epidemiology and Community Health* 2008;62(11):957-9.
3. Berkman LF, Melchior M, Chastang JF, et al. Social integration and mortality: A prospective study of French employees of Electricity of France-Gas of France: the GAZEL Cohort. *American Journal of Epidemiology* 2004;159(2):167-74.
4. Berkman LF, Syme SL. Social networks, host resistance, and mortality: A nine-year follow-up study of Alameda County residents. *American Journal of Epidemiology* 1979;109(2):186-204.
5. Ford ES, Loucks EB, Berkman LF. Social integration and concentrations of C-reactive protein among US adults. *Annals of Epidemiology* 2006;16(2):78-84.
6. Kawachi I, Berkman LF. Social ties and mental health. *Journal of Urban Health : Bulletin of the New York Academy of Medicine* 2001;78(3):458-67.
7. Seeman TE, Kaplan GA, Knudsen L, et al. Social network ties and mortality among the elderly in the Alameda County Study. *American Journal of Epidemiology* 1987;126(4):714-23.
8. Stringhini S, Berkman L, Dugravot A, et al. Socioeconomic status, structural and functional measures of social support, and mortality: The British Whitehall II Cohort Study, 1985-2009. *American Journal of Epidemiology* 2012;175(12):1275-83.
9. Cohen S, Doyle WJ, Skoner DP, et al. Social ties and susceptibility to the common cold. *JAMA : The Journal of the American Medical Association* 1997;277(24):1940-4.
10. Kaplan GA, Salonen JT, Cohen RD, et al. Social connections and mortality from all causes and from cardiovascular disease: Prospective evidence from Eastern Finland. *American Journal of Epidemiology* 1988;128(2):370-80.
11. Berkman LF, Glass T, Brissette I, et al. From social integration to health: Durkheim in the new millennium. *Social Science & Medicine* 2000;51(6):843-57.
12. Holt-Lunstad J, Smith TB, Layton JB. Social relationships and mortality risk: A meta-analytic review. *PLoS Medicine* 2010;7(7):e1000316.
13. Seeman TE. Social ties and health: the benefits of social integration. *Annals of Epidemiology* 1996;6(5):442-51.
14. Diez Roux AV, Borrell LN, Haan M, et al. Neighbourhood environments and mortality in an elderly cohort: Results from the cardiovascular health study. *Journal of Epidemiology and Community Health* 2004;58(11):917-23.
15. Diez Roux AV, Merkin SS, Arnett D, et al. Neighborhood of residence and incidence of coronary heart disease. *The New England Journal of Medicine* 2001;345(2):99-106.
16. Diez-Roux AV, Nieto FJ, Muntaner C, et al. Neighborhood environments and coronary heart disease: A multilevel analysis. *American Journal of Epidemiology* 1997;146(1):48-63.
17. Echeverria S, Diez-Roux AV, Shea S, et al. Associations of neighborhood problems and neighborhood social cohesion with mental health and health behaviors: The Multi-Ethnic Study of Atherosclerosis. *Health & Place* 2008;14(4):853-65.
18. Haan M, Kaplan GA, Camacho T. Poverty and health. Prospective evidence from the Alameda County Study. *American Journal of Epidemiology* 1987;125(6):989-98.

19. Yen IH, Kaplan GA. Neighborhood social environment and risk of death: Multilevel evidence from the Alameda County Study. *American Journal of Epidemiology* 1999;149(10):898-907.
20. Sampson RJ, Morenoff JD, Gannon-Rowley T. Assessing "neighborhood effects": Social processes and new directions in research. *Annu Rev Sociol* 2002;28:443-78.
21. Sampson RJ, Raudenbush SW, Earls F. Neighborhoods and violent crime: A multilevel study of collective efficacy. *Science* 1997;277(5328):918-24.
22. Diez Roux AV. Towards a realistic and relevant public health: the challenges of useful simplification. *Journal of Public Health* 2008;30(3):230-1; discussion 2-3.
23. Diez Roux AV, Auchincloss AH. Understanding the social determinants of behaviours: Can new methods help? *The International Journal on Drug Policy* 2009;20(3):227-9.
24. Krieger N. Historical roots of social epidemiology: Socioeconomic gradients in health and contextual analysis. *International Journal of Epidemiology* 2001;30(4):899-900.
25. Krieger N. A century of census tracts: health & the body politic (1906-2006). *Journal of Urban Health : Bulletin of the New York Academy of Medicine* 2006;83(3):355-61.
26. Krieger N, Chen JT, Waterman PD, et al. Painting a truer picture of US socioeconomic and racial/ethnic health inequalities: The Public Health Disparities Geocoding Project. *American Journal of Public Health* 2005;95(2):312-23.
27. Krieger N, Chen JT, Waterman PD, et al. Race/ethnicity, gender, and monitoring socioeconomic gradients in health: A comparison of area-based socioeconomic measures--The Public Health Disparities Geocoding Project. *American Journal of Public Health* 2003;93(10):1655-71.
28. Krieger N. A glossary for social epidemiology. *Journal of Epidemiology and Community Health* 2001;55(10):693-700.
29. Subramanian SV, Chen JT, Rehkopf DH, et al. Racial disparities in context: A multilevel analysis of neighborhood variations in poverty and excess mortality among black populations in Massachusetts. *American Journal of Public Health* 2005;95(2):260-5.
30. Campbell KE, Lee BA. Sources of personal neighbor networks: Social integration, need, or time? *Social Forces* 1992;70(4):1077-100.
31. Small ML. Racial differences in networks: Do neighborhood conditions matter? *Soc Sci Q* 2007;88(2):320-43.
32. Major JM, Doubeni CA, Freedman ND, et al. Neighborhood socioeconomic deprivation and mortality: NIH-AARP Diet and Health Study. *PloS One* 2010;5(11):e15538.
33. Hobfoll SE, Jackson AP. Conservation of resources in community intervention. *American Journal of Community Psychology* 1991;19(1):111-21.
34. McLeroy KR, Bibeau D, Steckler A, et al. An ecological perspective on health promotion programs. *Health Education Quarterly* 1988;15(4):351-77.
35. Holahan C, Spearly J. Coping and ecology: An integrative model for community psychology. *American Journal of Community Psychology* 1980;8(6):671-85.

APPENDIX A: Alternate tables from the analysis for manuscript 3.

The following tables were originally intended to be part of manuscript 3. Table 1 shows the association between the frequency of yearly visits with neighbors- our measure of an individuals' social integration with neighbors- and mortality risk. Table 2 displays these associations stratified by level of neighborhood poverty and Table 3 displays the measures of additive interaction. These measures did not generally yield statistically significant results once confounding factors were adjusted for in the Cox regression models.

Table 1: Cox proportional hazards regression models of the risk of death within the 2-level visits with neighbors groupings

Neighbor visits	Model 1: Crude Model		Model 2: includes confounders: sex, race, age, individual PIR, highest yr of education	
	Hazard Ratio	**Hazard Ratio**	**Hazard ratio**	**95% CI**
Low (<52)	0.78	0.70, 0.87	0.93	0.83, 1.03
High (>=52)	1.00	ref	1.00	ref

Table 2: Stratified Cox PH models: modeling relative risk of death for **2-level visits with neighbors** by **2 levels of neighborhood poverty**

Neighborhood poverty	**Visits with neighbors**	Model 1: Crude Model (unadjusted)		Model 2: includes confounders: sex, race, age, individual PIR, highest yr of education	
		hazard Ratio	**95% CI**	**Hazard ratio**	**95% CI**
<20%	**Low (<52)**	0.76	0.67, 0.87	0.92	0.81, 1.05
	High (>=52)	1.00	ref	1.00	Ref
>=20%	**Low (<52)**	0.91	0.74, 1.11	1.00	0.84, 1.20
	High (>=52)	1.00	ref	1.00	Ref

Table 3: Cox regression models examining effect modification of neighborhood poverty and visits with neighbors

	High visits with neighbors	low visits with neighbors
	HR (95% CI)	HR (95% CI)
Neighborhood poverty <20%	1.00 (referent)	0.90 (0.80, 1.03) *P*=0.1190
Neighborhood poverty ≥20%	1.06 (0.86, 1.30) *P*=0.6039	1.08 (0.93, 1.26) *P*=0.2930

Measure of effect modification on additive scale: RERI (95% CI) =0.13 (-0.10, 0.35) *P*=0.27
HRs are adjusted for age, gender, race/ethnicity, PIR, education