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Exploring the role of peer density in the self-reported oral health outcomes of older adults: A kernel density based approach

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ABSTRACT

Previous research has documented that oral health is inextricably linked with overall health and is an important component of successful aging. Additionally, peer social interactions are known to improve older adults' general well-being by increasing social opportunities and knowledge of local resources. This study examines the relationship between peer density of participants aged 50 and older in the ElderSmile program and self-reported oral health in northern Manhattan. Results from logistic regression models found that higher peer kernel density estimation values are associated with better self-reported oral health. This reinforces the need for place-based health interventions, and provides new evidence of the importance of peer communities for older adults.

1. Introduction

As the baby boomer generation continues to age, the US healthcare system will need to adjust to care for a population with a relatively higher proportion of older adults (Rice and Fineman, 2004). One means of reducing the burden on limited health care resources is through the promotion of successful aging (Minkler and Fadem, 2002; Rowe and Kahn, 1987). That is, by utilizing placed-based strategies to integrate services and support older populations in the communities where they live, health and well-being may be improved and health care costs may be lowered.

An important but often overlooked component of successful aging is oral health (Kiyak, 2000). Socially, good oral health may reinforce interaction with others, thereby encouraging constructive behaviors such as participating in health screenings. Conversely, poor oral health may induce isolation due to embarrassment or pain, removing an affected person from important peer interactions (Slade et al., 1996). Medically, the oral cavity has been described as the gateway to the body, providing a minimally invasive portal where indications of systemic diseases are manifest (US DHHS, 2000). Recent research provides evidence of a direct relationship between the levels of subgingival periodontal bacteria, blood pressure, and hypertension prevalence (Desvarieux et al., 2010). In addition, infection may be a risk factor for type 2 diabetes, and periodontal disease is a chronic infection. A recent study found that periodontal disease was related to A1C progression in diabetes-free participants. (Demmer et al., 2010). Despite the advantages of maintaining good oral health in and of itself (improved nutrition, less pain, enhanced appearance), access to oral health care for older adults is diminished by a number of factors (Institute of Medicine, 2011), including changing expectations about what constitutes good oral health (Locker and Gibson, 2005) and the almost complete lack of coverage for dental services under Medicare (Macek et al., 2004).

This study explores the relationship between the density of older adults living predominantly in the communities of Northern Manhattan and the South Bronx, New York City, and their self-reported oral health using program data from the *ElderSmile* initiative of the Columbia University College of Dental Medicine (Lamster and Northridge, 2008). Given the reinforcing dynamics between social interactions, higher levels of self-esteem and general support, and oral health, a positive association is hypothesized to exist between the density of older adults surrounding peer residences and their self-reported oral health. While related research has found positive relationships between life satisfaction and oral health (Locker et al., 2000), this is the first study to relate peer density with positive oral health outcomes. Exploring how

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the geography of peer density influences self-reported oral health may provide dentists and public health practitioners with a better understanding of what location-based strategies might be leveraged to improve oral health among local populations of older adults.

The next section reviews previous research relating urban density and social support to the health of older adults. Section 3 presents the data, while Section 4 (methods) reviews the logistic regression models used to explore the relationship between density and health outcomes. Subsequently, Section 5 presents the results from the statistical models constructed for this research and Section 6 discusses the results and addresses limitations and future research opportunities.

2. Background

The effects of population density on health have been mixed, to date, in the public health literature (Kirmeyer, 1978). Negative outcomes are generally associated with overcrowding, which in turn is linked to poverty and poor infrastructure. On the other hand, a separate arm of research has explored the relationship between health and ethnic spatial density, finding a positive association between group density and health (Smaje, 1995). The ethnic density effect is believed to reduce levels of discrimination, stigma, and stress experienced by minority population groups, resulting in improved mental and physical health outcomes (Pickett and Wilkinson, 2008). The process by which this happens derives from social support and acceptance within the concerned community. Similar to racial/ethnic minority communities, older adults may face stigmatization from society at large (ageism), along with chronic health conditions, impaired mobility, and memory loss. Given these shared challenges, a higher concentration of peers may engender a cohesive community with enhanced support structures.

For both older and younger adults, studies have identified links between social support and positive outcomes for general health (Berkman, 1984; Bosworth and Schaie, 1997; Greiner et al., 2004) and oral health in particular (McGrath and Bedi, 2002). Older adults who are socially isolated may be less likely to know about and utilize senior services, placing them at risk of suffering from poor health outcomes (Coulton and Frost, 1982).

An apt manifestation of social support systems among older adults may be found in communities where they reside or relocate in later life (Hunt and Gunter-Hunt, 1986). These "naturally occurring retirement communities" (NORCs) have been studied in an effort to elucidate their effects on health and well-being. NORCs exist on a spectrum with varying degrees of healthfulness: as NORCs grow, the social and market-based influences of the older adult community also grow, resulting in more improvements to infrastructure and consumer and health services tailored to this demographic (Masotti et al., 2006). Higher rates of older adult spatial density observed from census data for the study area may reflect the presence of NORCs in New York City (MacLaren et al., 2007; Masotti et al., 2006). More generally, in places with a higher proportion of older adults, more peer interactions are possible and may result in better access to health services.

As previously discussed, peer interactions and the enhanced utilization of health services encouraged by social support networks may play an important role in successful aging. Prior research using a systems perspective of the factors affecting older adults and oral health has pointed to the reinforcing dynamic between social support and dental health (Metcalf et al., 2011). Even a seemingly minor shift, such as a reluctance to smile due to poor oral health, may drive a vicious cycle of social isolation and disadvantage (Gift and Atchison, 1995). Because of such compounding effects, understanding the relationship between the social environment and oral health may provide insight into the importance and relevance of social support. This study approximates the social environment with kernel density surfaces that compute the concentration of older adults in New York City that surrounds the home residences of *ElderSmile* program participants. Statistical models that describe the association between the self-reported oral health of participants and peer density are used to ascertain the significance of the relationship.

3. Data

The demographic, health, and geographic data for this study are derived from participants and staff of the *ElderSmile* program, as collected from 2006 through 2009. *ElderSmile* provides older adults in northern Manhattan and adjacent communities with prevention and treatment services toward improving oral health (Lamster and Northridge, 2008). Results from and reflections on *ElderSmile* as a model for oral health promotion have been reported previously (Marshall et al., 2009; Northridge et al., 2012; Northridge et al., 2011, and Metcalf et al., 2011). Of the 888 participants in the *ElderSmile* screening program from 2006–2009, this analysis includes only those who provided full home addresses, completed all relevant intake questions, indicated they were 50 years or older, and resided in Manhattan or the Bronx at the time of the screenings ($N=670$ of 888 or 75.5%). For the purposes of this study, an older adult is defined as a participant aged 50 years or older, consistent with healthy aging initiatives and corresponding to the age ranges of data collected by the 2000 US Census (hereafter census). Road networks are utilized for geolocating addresses. Spatial boundary and population data used to construct the kernel density surfaces applied in the statistical models are from the census.

3.1. Variables considered in the logistic models

On the participant intake form, *ElderSmile* participants rated their oral health as being excellent, good, fair, or poor, with the added option of "not knowing." Northridge et al. (2012) used a weighted kappa statistic that demonstrated a significant level of agreement between *ElderSmile* participants' self-rated oral health and dentist-rated oral hygiene; untreated dental caries and severe periodontal inflammation are also significantly related to poor self-rated oral health. Because a distinction can be made between fair or better vs. poor self-rated oral health for this sample of older adults, the self-rated oral health variable was recoded as a binary variable for this analysis, where a value of 1 represents at least fair or better self-rated oral health and a value of 0 represents poor self-rated oral health (Northridge et al., 2012). Participants who responded that they did not know about their oral health are excluded from the models.

The recoded self-rated oral health variable is used as the dependent variable in a series of logistic regression models. Independent variables considered in the models include the participants' age (with a maximum value of 99), gender (1=female, 0=male), whether or not they have Medicaid dental insurance (1=has Medicaid dental insurance, 0=does not have Medicaid dental insurance) or private dental insurance (1=has private dental insurance, 0=does not have private dental insurance), if they graduated high school (1=graduated from high school, 0=did not graduate from high school), if English is their first language (1=native English speaker, 0=English as a second language), whether they identify as White (1=White, 0=not White), and the kernel density of older adults at their places of

Table 1
Summary of variables used in the logistic regression. Kernel density estimates (KDE) values have units of number of older adults per square-mile.

Variable	Proportion = 1	Mean	Std. Dev.	Min	Max
Self-rated oral health	0.69	–	–	0	1
Medicaid Dental Ins.	0.30	–	–	0	1
Private Dental Ins.	0.17	–	–	0	1
HS graduate	0.39	–	–	0	1
English 1st language	0.55	–	–	0	1
White	0.21	–	–	0	1
Age (years)	–	73.34	8.76	50	99
KDE, $h=0.25$ mi	–	22,162.60	8332.81	209.66	47,556.59
KDE, $h=0.50$ mi	–	18,668.15	5729.24	2556.71	38,098.86
KDE, $h=1.00$ mi	–	15,073.64	3411.37	3590.28	28,106.89
KDE, $h=1.50$ mi	–	13,325.62	2840.70	2530.95	21,595.70

residence (the derivation of which is discussed further in Section 4). All independent variables are dummy variables with the exception of age and kernel density. A summary of these variables is presented in Table 1.

Before presenting the models, it is important to discuss the demographics of the *ElderSmile* participants used for this analysis in more detail to help with the interpretation of the results. The communities of northern Manhattan and the south Bronx are generally poorer than average for New York City, with a high proportion of racial/ethnic minority residents. Respondents were asked to choose a racial category (e.g., White, Black) in addition to an ethnic category (i.e., Latino, not Latino). The overwhelming majority (532 of 670 or 79%) of *ElderSmile* participants did not identify as White, while a majority identified as Latino (244 of 312 or 78%) but did not select a racial category. Additionally, 246 of the 262 (94%) self-identified Black participants and 91 of the 138 (66%) self-identified White participants reported that they are native English speakers, while only 34 of 312 (11%) of self-identified Latino participants reported English as their native language.

Because there is a strong negative correlation between self-identifying as Latino and being a native English speaker (Pearson's correlation coefficient of -0.82), either the self-identified Latino variable or the native English speaker variable ought to be excluded from the logistic regression models to eliminate the high degree of multicollinearity. After fitting models with both variables, it was determined that the native English speaker variable resulted in better fitting models, as determined by McFadden's pseudo-R^2 values (McFadden, 1974). For this reason, the variable describing participants' self-identification as Latino is excluded. Note, however, that the effect of being a member of the Latino population is effectively captured by the (non-)native English speaker variable.

4. Methods

To test the hypothesis that social interaction is positively associated with oral health, logistic regression models predicting good self-reported oral health are fitted to an independent measure of density that represents the potential for interaction between an older adult and her/his peers. In order to relate the density of older adults surrounding *ElderSmile* participants, their residences are first geocoded in a Geographic Information System (GIS). Within the GIS, participant residences are then integrated (overlaid) with census block data for Manhattan and the Bronx (Fig. 1).

One method for associating peer density to an *ElderSmile* participant is to calculate a raw density metric (e.g., the number of older adults divided by some area) using spatial boundary data as collection areas. For example, the number of older adults per square-mile could be calculated for each census block (see Fig. 1), and a GIS could then link an *ElderSmile* participant to the density value calculated for the block in which s/he resides. While straightforward, this approach is limited by the explicit linkage of each participant to the presence of her/his age-group peers within an arbitrarily defined discrete areal unit. This areal basis excludes neighborhood effects from concentrations of older adults in other nearby census blocks. The boundary effects identifiable for census blocks in Fig. 1 reveal the limitation of the raw density metric.

A more comprehensive depiction of peer-group density can be achieved through using kernel density estimation (KDE). This measure creates a continuous density surface that accounts for the concentration of older adults in nearby blocks, as it is assumed that an older adult's social space is not constrained by census boundaries. Similar to the raw density metric, the units of a KDE at any point on the density surface are the number of older adults per area. The general kernel density estimation function f at a point x on a two-dimensional plane is calculated as follows:

$$\hat{f}(x)=\frac{1}{nh^2}\sum_{i=1}^{n}K\left(\frac{x-X_i}{h}\right) \quad (1)$$

where X_1, X_2, … X_i are n observed points and $K(\bullet)$ is the kernel function with a bandwidth of h and an input of the distance between x and one of the observed points (Silverman, 1986).

An important input when computing a KDE is the bandwidth parameter of the kernel function, which effectively smooths the density surface, with larger bandwidths generating smoother density estimates over space. Bandwidth is analogous to the spatial reach of the weighted centroids, with higher bandwidths resulting in more area being influenced at lower magnitudes. Because the bandwidth affects the calculated peer-group density at any point in the study area, four density surfaces are calculated using bandwidths of 0.25, 0.50, 1.00, and 1.50 miles. These particular bandwidth values are chosen to reflect the radii of areas within a walkable distance surrounding a participant's residence, where participants may socialize. An exploration of the effect that the kernel bandwidth has on the logistic regression models is presented in the following section.

For this analysis, a GIS is constructed to calculate the kernel density estimation surfaces of older adults in Manhattan and the Bronx, using the centroids of census blocks, weighted by the population of adults 50 years or older, as the observed points (Fig. 2). After the KDE surfaces are calculated for selected bandwidths, each *ElderSmile* participant is associated with the value of the KDE surface at the location of her or his residence.

5. Results

Four logistic regression models are run using the computed kernel density surfaces and survey data from *ElderSmile* participants. Self-reported measures of oral health have been shown to accurately reflect a person's true state of oral health, thereby providing a reasonable outcome variable for statistical models (Calabrese et al., 1999; Pitiphat et al., 2002).

Prior to fitting the models to be presented in this section, diagnostics are run to test for multicollinearity between all of the independent variables, including the various KDEs. The variance inflation factor (VIF), which quantifies how much of a coefficient's variance increases as a result of multicollinearity, is computed for each predictor variable and is presented in Table 2. The values of

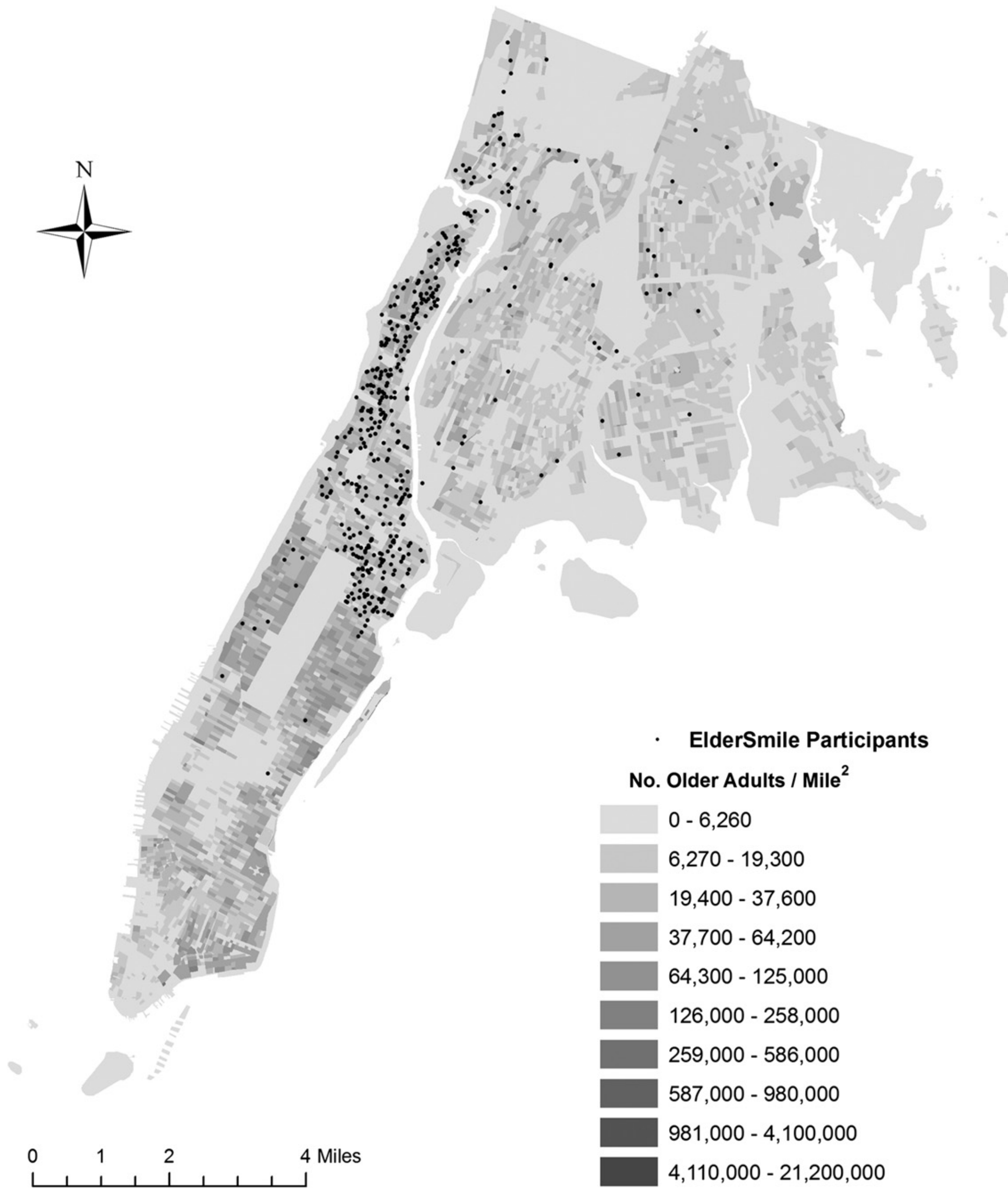

Fig. 1. Point locations of residences of *ElderSmile* participants who are aged 50 years and older from Manhattan and the Bronx, New York City, overlaid on top of census block-level density of the total population aged 50 years and older.

the VIFs are all close to 1 and below the acceptable threshold of 9, suggesting that the results from the logistic regression models do not suffer from high degrees of multicollinearity (Hoffman, 2004).

The results of the four models, all with a sample size of 670, are presented in Table 3, with the models corresponding to: (1) the KDE surface with a bandwidth of 0.25 miles, (2) the KDE surface with a bandwidth of 0.50 miles, (3) the KDE surface with a bandwidth of 1.00 miles, and (4) the KDE surface with a bandwidth of 1.50 miles. Because these tests are conducted for exploratory purposes, significance levels of 1%, 5%, and 10% are reported. Kernel density is significant at the 10% level in model 2, and as hypothesized, the magnitudes of the KDE coefficients for all models are positive. Note that the small coefficients are due to the large nature of the kernel density values, which are generally in the thousands to tens of thousands.

6. Discussion

Results from these models suggest that a connection exists between peer density and the oral health of older adults. The most significant link between kernel density and self-rated oral health was found in model 2, which had a KDE bandwidth parameter of 0.50 mile. The reported McFadden's pseudo R^2 for this model is also the largest, which means that model 2 has the greatest likelihood thereof the four models tested (McFadden, 1974). This suggests that the density of older adults within a half-mile radius around an *ElderSmile* participant is most likely to influence how she or he will self-rate her or his own oral health. Holding all other variables equal, larger KDE values result in greater odds of an *ElderSmile* participant rating their oral health as excellent, good, or fair.

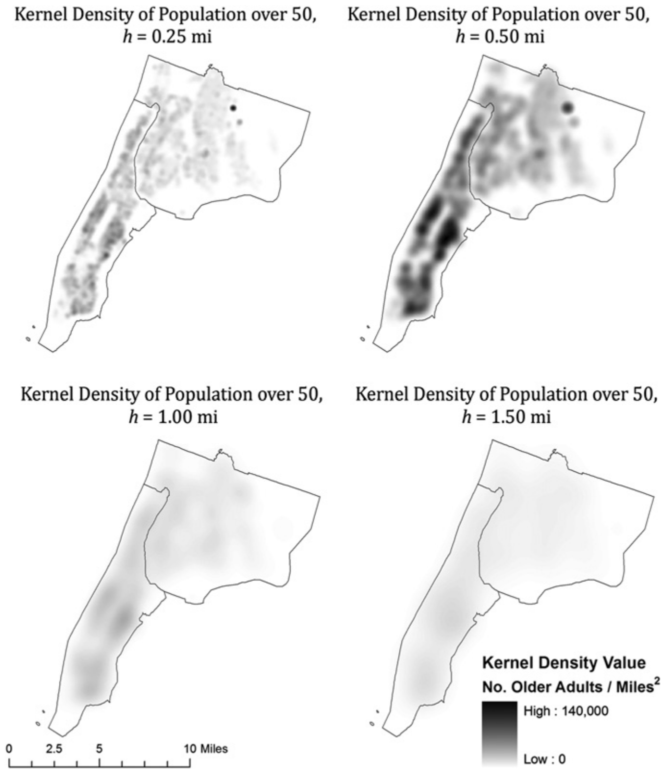

Fig. 2. Kernel density estimation surfaces with varying bandwidths (h) of the population over 50 years old in Manhattan and the Bronx, New York City. Kernel density estimates (KDE) values have units of number of older adults per square-mile.

Table 2
Variance inflation factors on all independent variables used in the logistic regression.

Variables	VIF (Variables for model 1)	VIF (Variables for model 2)	VIF (Variables for model 3)	VIF (Variables for model 4)
Medicaid Dental Ins.	1.18	1.18	1.18	1.18
Private Dental Ins.	1.12	1.13	1.13	1.14
Age (years)	1.02	1.02	1.03	1.03
Female	1.02	1.02	1.02	1.02
HS graduate	1.03	1.03	1.03	1.03
English 1st lang.	1.17	1.16	1.11	1.10
White	1.07	1.07	1.13	1.22
KDE, $h=0.25$ mi	1.09	–	–	-
KDE, $h=0.50$ mi	–	1.12	–	–
KDE, $h=1.00$ mi	–	–	1.13	–
KDE, $h=1.50$ mi	–	–	–	1.23

The significance of peer-group density on oral health outcomes at a bandwidth distance of 0.5 mile is consistent with previous research noting that many older adults are still capable of walking a half-mile (Jette and Branch, 1981). The fact that the 0.5 mile bandwidth is the most significant density variable may be related to this half mile activity-space. Given the assumption that higher peer-group KDE values capture the effects of more vibrant activity-spaces and greater levels of social interaction and support, the significant and positive relationship between kernel density and better self-reported oral health provides further evidence of the importance of successful aging.

The positive relationships between self-rated oral health and other factors including Medicaid dental insurance coverage and White race are consistent with previous findings. Participation in the Medicaid dental insurance program provides older adults with limited yet vital financial coverage for dental care, thereby incentivizing the use of such services. Although White older adults constitute a minority of *ElderSmile* participants, those who participate may benefit from the external effects of social capital and lack of racial stigmatization. Additionally, oral health reflects the accumulation of lifelong advantages and disadvantages. White older adults would likely have had less exposure to racial/ethnic discrimination throughout their lives than their Black and Latino peers. The reason for the significant and negative association between self-rated oral health and being a native English speaker is requires careful consideration of the study sample. Since the majority of native English speakers among *ElderSmile* participants are Black participants, they may face additional disadvantages related to discrimination, poverty, and lack of dental providers in their communities who accept public insurance.

The negative association found between being female and poor self-rated oral health was unexpected. Previous studies have reported lack of a clear link between gender and self-reported health. Among adolescents, females have been shown to have a greater awareness of their oral health than their male counterparts (Östberg et al., 1999). Nonetheless, other investigators have failed to find any relationship between self-rated oral health and gender (Benyamini et al., 2004). One possibility for the discrepancy in the present study is that there may be differentiation in awareness of oral health by gender. That is, being more aware of oral health may lead to more critical assessments, which in turn may result in a higher likelihood of reporting poor oral health. Another possibility is that there is a survivor effect, where women live longer than men, and men with poor self-rated oral health experienced premature mortality. This is perhaps reflected by the larger number of women participants in *ElderSmile*. As women continue to age they are likely to face more oral health issues, due to the continual wear on their mouths and teeth, thereby resulting in the degradation of oral health. A final possibility for this disparity is that women with oral health problems may differentially present at *ElderSmile* screenings. Previous research has noted that there are significant differences in how older adults of different genders access different types of healthcare (Dunlop et al., 2002).

A limitation to this analysis is that the *ElderSmile* participants studied in the logistic regression model represent a self-selected sample of older adults. Because *ElderSmile* participants are necessarily those who decided to visit a senior center and participate in the screenings, they reflect a relatively mobile and social population. An important at-risk population not accounted for in the *ElderSmile* screenings is older adults with limited mobility or less of a desire to socialize. Future research on the effect of social influences on oral health would benefit from the inclusion of older adults in home and institutional settings to understand how peer density influences their self-reported oral health and overall well-being. Another limitation of this study is that the presented methods are less transferable to rural and suburban settings than they are to denser urban areas with relatively small census blocks. In the case of New York City, census blocks are comparable to city blocks. For a scenario in which census block centroids are used to create a KDE surface, but the blocks themselves are relatively large, higher values for the distance bandwidth would be necessary to capture the interaction between neighboring blocks.

Despite these limitations, this research finds compelling evidence that the self-rated oral health of older adults is affected by peer density. This is an important finding for a number of reasons. First, the results presented here further confirm the importance of promoting placed-based programs that encourage successful aging. Second, there are potential policy implications. Since older adults who reside in areas with lower levels of peer density are more likely to self-report their oral health as being poor, this

Table 3
Adjusted odds ratios from four logistic regression models, with each kernel density surface model using a different distance bandwidth h.

Variables	(1) Odds ratio (90% C.I.)	(2) Odds ratio (90% C.I.)	(3) Odds ratio (90% C.I.)	(4) Odds ratio (90% C.I.)
Medicaid Dental Ins.	1.621** (1.148, 2.290)	1.601** (1.132, 2.263)	1.610** (1.066, 2.431)	1.612** (1.068, 2.435)
Priv. Dental Ins.	1.359 (0.914, 2.020)	1.417 (0.950, 2.112)	1.419 (0.879, 2.288)	1.398 (0.866, 2.255)
Age (years)	1.000 (0.984, 1.017)	1.001 (0.985, 1.017)	1.001 (0.982, 1.020)	1.001 (0.982, 1.021)
Female	0.699* (0.509, 0.960)	0.698* (0.507, 0.959)	0.691* (0.473, 1.009)	0.689* (0.472, 1.006)
HS graduate	1.223 (0.911, 1.641)	1.230 (0.916, 1.652)	1.217 (0.857, 1.729)	1.211 (0.853, 1.719)
English 1st lang.	0.515*** (0.378, 0.702)	0.531*** (0.390, 0.723)	0.500*** (0.349, 0.716)	0.487*** (0.339, 0.698)
White	1.529* (1.053, 2.221)	1.568** (1.078, 2.281)	1.667** (1.050, 2.649)	1.674** (1.033, 2.714)
KDE, $h=0.25$ mi	1.000011 (0.9999931, 1.000029)	–	–	–
KDE, $h=0.50$ mi	–	1.000029* (1.000003, 1.000056)	–	–
KDE, $h=1.00$ mi	–	–	1.000041 (0.9999884, 1.000094)	–
KDE, $h=1.50$ mi	–	–	–	1.000035 (0.999969, 1.000101)
No. of observations (N)	670	670	670	670
McFadden's R^2	0.0397	0.0424	0.0413	0.0397

*** $p<0.01$.
** $p<0.05$.
* $p<0.10$.

method can be used to target geographical regions with a higher risk of poor oral health. The kernel density method can be applied to any urban region, thereby assisting social scientists and public health practitioners in understanding how peer networks may abet successful aging strategies.

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