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Neighborhood Variability in Obesity in Children in Omaha, Nebraska

Ann Essay

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Abstract

BACKGROUND: The prevalence of childhood obesity is a serious public health concern in the United States. Although several individual-level factors have been found to be associated with obesity in children, neighborhood environmental and social factors likely play an important role. The main goal of this study was to describe the prevalence of child obesity in Omaha, Nebraska by various demographic subgroups, determine if obesity prevalence varies by neighborhood operationalized as zip code, and examine the association between neighborhood-level child obesity prevalence and neighborhood-level socioeconomic status. It was hypothesized that child obesity prevalence varies by demographic subgroup and by zip code and that neighborhood SES is significantly associated with child obesity prevalence.

METHOD: Electronic health record data from Children's Hospital & Medical Center's primary care network was utilized to examine child obesity based on objectively measured heights and weights from a sample of 40,303 children aged two to 20 years in 34 zip codes in Omaha, Nebraska. Chi-square test of independence assessed the association between individual-level demographic variables and obesity. Child obesity was mapped by zip code. Pearson correlation assessed the relationship between neighborhood-level obesity and neighborhood-level median household income and percent of individuals below poverty in a subsample.

RESULTS: Chi-square analyses revealed that obesity is significantly associated with gender ($X^2(1) = 26.42$, $p < .0001$), age ($X^2(3) = 300.69$, $p < .0001$), race ($X^2(7) = 951.40$, $p < .0001$), ethnicity ($X^2(1) = 593.75$, $p < .0001$), and medical insurance provider ($X^2(1) = 629.50$, $p < .0001$). Demographic subgroups more likely to be obese were males, children 12 to 17 years old, Native Hawaiian and Other Pacific Islanders, Hispanics, and those on Medicaid. Obesity prevalence by zip code ranged from 6.7% to 26.7%. Neighborhood-level child obesity, defined by percent obese in each neighborhood, was significantly associated with both neighborhood-level median household income (r=-0.69406, p<.0001) and percent of individuals below poverty (0.72843, p<.0001).

CONCLUSION: This study provides a preliminary cross-sectional analysis of current child obesity prevalence in Omaha, Nebraska. Child obesity prevalence varied by zip code, and significant associations were found between each individual-level variable and child obesity and between both neighborhood-level variables and neighborhood-level child obesity. Future studies should utilize a multi-unit statistical model approach to data analysis, examine obesity trends longitudinally to examine the underlying factors causing obesity, and examine neighborhood variation in child obesity at multiple geographic scales. Future community interventions should include a focus on geospatial areas and use of multi-setting, multi-strategy approaches in order to impact the neighborhood factors influencing child obesity.

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Introduction

The prevalence of childhood obesity is a serious public health concern in the United States. Since the 1970s the prevalence of child and adolescent obesity in the U.S. has more than tripled, with national estimates reporting that in 2015-2016 approximately 18.5% of youth ages two to 19 years were categorized as obese (Fryar, Carroll, & Ogden, 2014; Hales, Carroll, Fryar, & Ogden, 2017). Although obesity rates have increased across all population groups, large disparities also exist among minority and low socioeconomic status (SES) subgroups, with non-Hispanic Black women and children, Mexican-American women and children, and low-SES Black men and White women and children experiencing greater burdens of obesity relative to non-Hispanic White and high-SES subgroups (Ogden et al., 2006; Wang & Beydoun, 2007; Wang & Zhang, 2006)

Childhood obesity negatively impacts physical and mental health by increasing one's risk of other health conditions, including type 2 diabetes, risk factors for heart disease, asthma, and depression (Halfon, Larson, & Slusser, 2013; Lloyd, Langley-Evans, & McMullen, 2012; May, Kuklina, & Yoon, 2012). Additionally, children with obesity are more likely to have obesity as adults (A. S. Singh, Mulder, Twisk, Van Mechelen, & Chinapaw, 2008). Therefore, identifying the underlying causes in order to prevent obesity and halt and reverse the increasing rates is of utmost importance.

The underlying factors influencing obesity, which results from an energy imbalance when consumption exceeds expenditure, are complex (Papas et al., 2007). Several individual-level factors have been found to be associated with obesity in children, including race, ethnicity, and SES (G. K. Singh, Kogan, Van Dyck, & Siahpush, 2008). For example, previous studies have reported lower obesity prevalence among Non-Hispanic Whites than Non-Hispanic Blacks and

Hispanics, as well as an inverse association between family-level income and adiposity in children (Ogden, Carroll, Kit, & Flegal, 2012; Shrewsbury & Wardle, 2008). However, examining only individual-level variables may be an oversimplified approach in identifying underlying causes of obesity because this approach fails to consider potential neighborhood effects impacting one's health status (Merlo, Chaix, Yang, Lynch, & Råstam, 2005). Social ecological approaches show that child obesity is not only influenced by individual-level factors, but also by community factors, such as social, cultural, socioeconomic, and physical conditions (Bronfenbrenner, 1994; Davison & Birch, 2001). Research suggests that the area in which one lives and the neighborhood factors experienced play an important role, perhaps more important role than individual-level characteristics, in the obesity epidemic and the disparities seen across subgroups (Hill & Peters, 1998; Kim, Cubbin, & Oh, 2018; Merlo et al., 2005; Wang & Beydoun, 2007).

Individuals who live in the same area may have more similar health statuses to each other than to individuals with similar personal characteristics who live elsewhere because of the geographical and cultural contexts they experience (Macintyre & Ellaway, 2000). Cultural norms and values at the neighborhood-level can impact the psychosocial context in which people live and can influence behavior and ultimately impact health (Crane, 1991; Jencks & Mayer, 1990). Furthermore, exposure to stressors, factors of the physical environment, food insecurity, and social connectedness are all neighborhood factors that may impact obesity (Drewnowski & Specter, 2004; Harrington & Elliott, 2009; Kawachi & Berkman, 2003; Ross, 2000). These neighborhood-level factors may be particularly impactful on children because of their stage of physical and psychological development (Alvarado, 2016). Because the physical and social characteristics of a geospatial area and the individuals living within that area interact with one another, obesity may be viewed as a health outcome of the geospatial area rather than an individual outcome. This allows us to examine obesity at the neighborhood-level and renders it necessary to investigate the neighborhood-level contextual factors that may explain geospatial disparities in obesity prevalence.

One neighborhood-level factor that may impact obesity prevalence is neighborhood SES. In a study by Alvarado (2016), neighborhood deprivation, measured using a composite of several socioeconomic variables, increased the odds of being obese in children and adolescents. Similarly, a study by Oliver and Hayes (2005) reported a statistically significant inverse association between neighborhood SES and the prevalence of overweight among children five to 17 years of age in Canada. In a study of students 11 to 15 years of age from schools across Canada, area-level unemployment rate was positively associated with obesity (Janssen, Boyce, Simpson, & Pickett, 2006). A study using nationally representative data found a significant inverse association between area-level median household income and body mass index (BMI) equal to or greater than the 95^{th} percentile (Nelson, Gordon-Larsen, Song, & Popkin, 2006). Grow et al. (2010) also reported a significant inverse association between child obesity risk and neighborhood-level home ownership and median household income independently.

Although several studies have reported significant associations in the expected direction between neighborhood-level SES and child overweight/obesity, these results are inconsistent. One study examining children in low-income families reported an inverse association between neighborhood-level percent of residents below the poverty line and BMI z-score and obesity prevalence (Lovasi et al., 2013). Further, a study examining a sample of fifth and sixth grade students in New Haven, Connecticut found non-significant associations between neighborhood affluence and disadvantage and BMI (Carroll-Scott et al., 2013). Similarly, Voorhees et al.

(2009) reported a non-significant association between neighborhood-level deprivation and BMI in a sample of girls 11 to 12 years of age. Further, a recent systematic review examining the relationship between neighborhood environment and obesity risk among low SES Black and Hispanic children concluded that few studies showed consistent patterns of association (Johnson et al., 2019). The inconsistency of these results suggests the need for further examination of the association between neighborhood-level factors and child obesity.

Although a number of studies have previously examined the association between neighborhood-level SES and obesity in children, these studies face limitations. Several of these studies have been limited by the use of a composite measure for neighborhood SES that includes a combination of multiple SES factors to establish overall neighborhood SES (Alvarado, 2016; Carroll-Scott et al., 2013; Oliver & Hayes, 2005; Voorhees et al., 2009). The use of a composite measure for SES limits the interpretation of how specific measures of SES influence child obesity, and separate measures of SES are more precise (Braveman et al., 2005; Kim et al., 2018). Other studies examining the association between neighborhood-level SES and child obesity have been limited by the use of self- and/or parent-reported measures of obesity, rather than objective measures (Janssen et al., 2006; Nelson et al., 2006; Oliver & Hayes, 2005). Self- and parent-reported weight and obesity measures may be subject to social desirability or recall bias (Elgar, Roberts, Tudor-Smith, & Moore, 2005; Klesges et al., 2004; Weden et al., 2013). Additionally, these studies differ in their definitions of neighborhood (census tract, census block, zip code), measures of SES, and age ranges of children studied.

This study examines child obesity in Omaha, Nebraska as an individual-level and a neighborhood-level outcome. The objectives are threefold: 1) to examine the current prevalence of child obesity in Omaha, Nebraska at the individual-level and describe obesity prevalence by demographic subgroups; 2) to examine child obesity prevalence at the neighborhood-level and determine if prevalence varies by zip code; and 3) to examine if neighborhood-level SES is associated with neighborhood-level obesity prevalence. The following hypotheses are examined:

1. Obesity prevalence varies by gender, race, ethnicity, and medical insurance provider. When examined independently at the individual-level, the following demographic subgroups have lower obesity prevalence: females compared to males, White individuals compared to individuals of other races, Non-Hispanic individuals compared to Hispanic individuals, individuals with medical insurance providers other than Medicaid compared to individuals on Medicaid.
2. Obesity prevalence varies by neighborhood defined by zip code.
3. Neighborhood-level SES, defined by median household income and percent of individuals below poverty, is associated with neighborhood-level child obesity prevalence. Median household income is inversely associated with child obesity, and percent of individuals below poverty is positively associated with child obesity.

This study improves upon previous studies examining the association between neighborhood SES and child obesity by using two specific measures of neighborhood SES and objectively measured heights and weights collected at clinical visits in a large sample of children. Additionally, this is the first study to our knowledge examining objectively measured child obesity prevalence in Omaha, Nebraska at the neighborhood-level. It is of public health importance to understand if geospatial differences exist in obesity prevalence, what geospatial areas are most impacted by obesity, and what underlying factors are associated with obesity. This information may help inform program planning and population health improvement efforts focused on preventing and overcoming childhood obesity.

Methods

Study Sample

This cross-sectional study was conducted using 2017-2018 electronic health record (EHR) data from Children's Hospital & Medical Center's primary care network. Data was extracted for all patients two to 20 years of age who had demographic and objectively measured height and weight values from a primary care visit during the two-year period. The total sample included 40,303 subjects from 34 zip codes in Omaha, Nebraska, with 31 of these zip codes in Douglas County and three in Sarpy County.

Additional analyses were conducted on a subsample consisting of six to 11 year olds with race/ethnicity of Non-Hispanic White, Non-Hispanic Black, and Hispanic. This age group was selected because it is after the average age of five to six years at which adiposity rebound occurs, or the point at which BMI reaches a minimum before gradually increasing through adolescence (Whitaker, Pepe, Wright, Seidel, & Dietz, 1998). These racial/ethnic subgroups were selected to ensure an adequate sample size, as it was assumed that sample sizes in other racial/ethnic subgroups would be much smaller. The subsample included 11,768 subjects from 33 zip codes. One zip code from the total sample was removed from subsample analyses due to small sample size within this zip code (n<5). The Institutional Review Board at the University of Nebraska Medical Center approved all study procedures.

Individual-Level Variables

The individual-level variables included gender, age, race, ethnicity, medical insurance provider, zip code of residence, and BMI percentile and corresponding weight status category.

For patients with more than one BMI percentile recorded for the two-year period, only the most recent measurement was used. Demographic subgroups were created to match U.S. Census Bureau groupings for age and race. Age was grouped into four categories: under six years, six to 11 years, 12 to 17 years, and 18 years and older. Race groups of American Indian and Alaska Native; Native Hawaiian and Other Pacific Islander; and Black or African American were each combined, and race groups of Hawaiian, Indian, Middle Eastern, Other, and Sudanese were collapsed into Some Other Race. Insurance provider was dichotomized into Medicaid and Other to be used as a proxy for individual-level SES. Medicaid provides health coverage for some people of low-income based on income and household size. In order to qualify in Nebraska, maximum annual household income ranges from $16,146 for a household size of one to $56,365 for a household size of eight (Benefits.gov). BMI percentile was automatically generated in the database based on age- and sex- specific growth charts, with underweight defined as less than the 5^{th} percentile, normal weight defined as the 5^{th} to less than 85^{th} percentile, overweight defined as the 85^{th} to less than 95^{th} percentile, and obese defined as the 95^{th} percentile and greater (Barlow, 2007; Kuczmarski, 2002). Individual-level variables were examined in both the total sample and the subsample.

Neighborhood-Level Variables

Neighborhood was defined by 5-digit zip code. American Community Survey data (5-year estimates for 2013-2017) was used to obtain neighborhood-level median household income and percent of individuals below federal poverty level, indicators used to define neighborhood SES (U.S. Census Bureau). Neighborhood-level variables were examined using only the subsample of six to 11 year olds described above. Neighborhood-level variables were created from the proportion of each individual-level characteristic in each zip code. The resulting neighborhood-level dataset consisted of each zip code and the percent of the zip code as: 1) Medicaid; 2) Other Insurance; 3) Non-Hispanic White; 4) Non-Hispanic Black; 5) Hispanic; and 6) Obese. This dataset was merged with neighborhood-level median household income and percent of individuals below poverty data.

Statistical Analyses

Analyses were conducted on individual-level variables for the total sample and subsample, obesity prevalence was mapped by zip code for both the total sample and the subsample, and neighborhood SES variables were examined in the subsample. For all analyses the outcome was obesity defined as BMI equal to or greater than the 95^{th} percentile (Barlow, 2007). All data analyses were conducted using SAS software (version 9.4, SAS Institute, Cary, NC). Chi-square test of independence assessed the association between each individual-level variable and obesity. Prevalence of obesity was mapped by zip code using Tableau Desktop (version 2019.1.0, Tableau Software, Inc.). Pearson correlation assessed the relationship between neighborhood-level obesity, defined by percent obese in each zip code, and neighborhood SES, defined by zip code median household income and percent of individuals below poverty.

Results

Individual-Level Variables

Demographic characteristics of the total study sample are presented in Table 1. The total population was 51.1% male. Children under six years of age made up 30.8% of the total sample, 33.2% were six to 11, and 30.9% were 12 to 17 years of age. The majority of the sample was White (60.8%), followed by Black or African American (13.1%). The majority of the sample was Non-Hispanic (84.3%), and 33.7% of the total sample was on Medicaid. Overall, 4.2% of the total sample was underweight, 63.8% was normal weight, 16.4% was overweight, and 15.3%

was obese. Characteristics of the subsample of six to 11 year olds were similar to the total study sample, with 52.47% male and 34.95% on Medicaid. The majority of the subsample was Non-Hispanic White (65.79%), followed by Hispanic (19.05%), and Non-Hispanic Black (15.16%). Overall, 3.33% of the subsample was underweight, 63.70% was normal weight, 16.54% was overweight, and 16.43% was obese.

Obesity prevalence in the total sample by demographic subgroup is presented in Figure 1. Chi-square analyses in the total sample revealed a significant association between obesity and gender ($X^2(1) = 26.42$, $p < .0001$). Males were more likely to be obese than females. Obesity and age were significantly associated ($X^2(3) = 300.69$, $p < .0001$), with 12 to 17 year olds more likely to be obese. A significant association existed between obesity and race ($X^2(7) = 951.40$, $p < .0001$), with the highest obesity prevalence found among Native Hawaiian and Other Pacific Islanders. Obesity was also significantly associated with ethnicity ($X^2(1) = 593.75$, $p < .0001$), with Hispanics more likely to be obese than Non-Hispanics. A significant association was found between obesity and medical insurance provider ($X^2(1) = 629.50$, $p < .0001$), with those on Medicaid more likely to be obese.

Significant associations between obesity and gender ($X^2(1) = 13.85$, p 0.0002), obesity and medical insurance provider ($X^2(1) = 272.57$, $p < .0001$), and obesity and race/ethnicity ($X^2(2) = 394.00$, $p < .0001$) were also found in the subsample. Consistent with the total sample, chi-square analyses in the subsample revealed that males were more likely to be obese than females, those on Medicaid were more likely to be obese than those on other insurance, and Non-Hispanic Whites were less likely to be obese than Non-Hispanic Blacks and Hispanics.

Table 1: Demographic Characteristics and Child Obesity Prevalence by Demographic Subgroup (Total Sample, n=40,303)

	% (n)	Proportion Obese (%)
Weight Status		
Underweight	4.2 (1729)	-
Normal	63.8 (25725)	-
Overweight	16.4 (6643)	-
Obese	15.3 (6206)	-
Gender*		
Female	48.8 (19672)	14.4
Male	51.1 (20631)	16.3
Age*		
Under 6 years	30.8 (12414)	10.9
6 to 11 years	33.2 (13396)	16.4
12 to 17 years	30.9 (12488)	18.6
18+ years	4.9 (2005)	14.9
Race*		
White	60.8 (24535)	11.8
Black or African American	13.1 (5282)	20.1
American Indian and Alaska Native	0.2 (94)	21.2
Asian	2.9 (1172)	10.3
Native Hawaiian and Other Pacific Islander	0.1 (41)	29.2
Hispanic	12.1 (4892)	27.4
Some other race	2.5 (1042)	11.7
Two or more races	8.0 (3254)	19.1
Ethnicity*		
Hispanic	15.6 (6319)	25.5
Non-Hispanic	84.3 (33984)	13.5
Insurance Provider*		
Medicaid	33.7 (13613)	21.7
Other	66.2 (26690)	12.1

* Statistically significant association with obesity

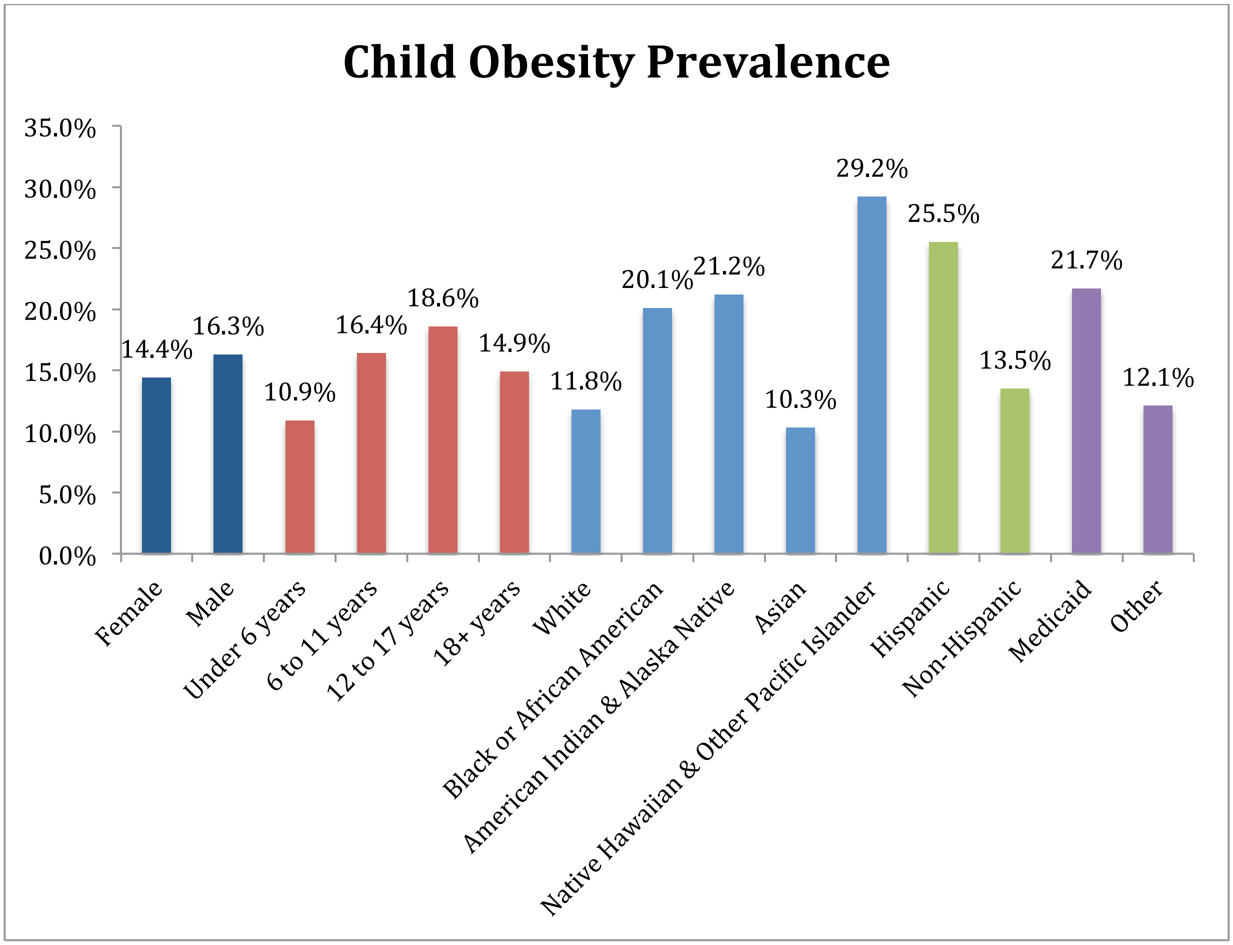

Figure 1: Child Obesity Prevalence by Demographic Subgroup (Total Sample, n=40,303)

Neighborhood-Level Variables

Obesity prevalence mapped by zip code for the total sample is presented in Figure 2. Obesity prevalence mapped by zip code for the subsample is presented in Figure 3. Obesity prevalence by zip code for the total sample ranged from 6.7% to 26.7%, and prevalence in the subsample ranged from 6.99% to 30.85%.

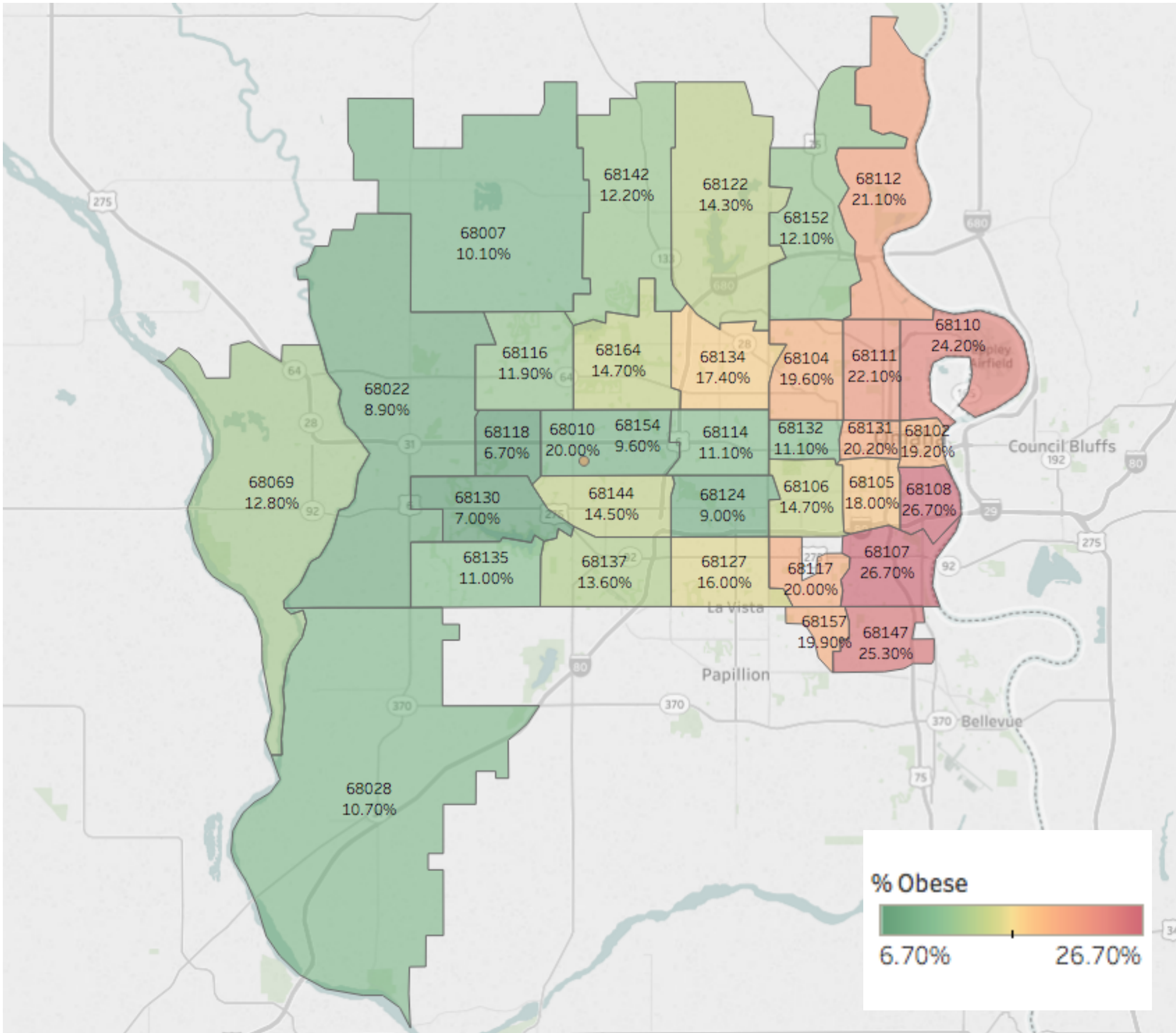

Figure 2: Child Obesity Prevalence by Zip Code (Total Sample)

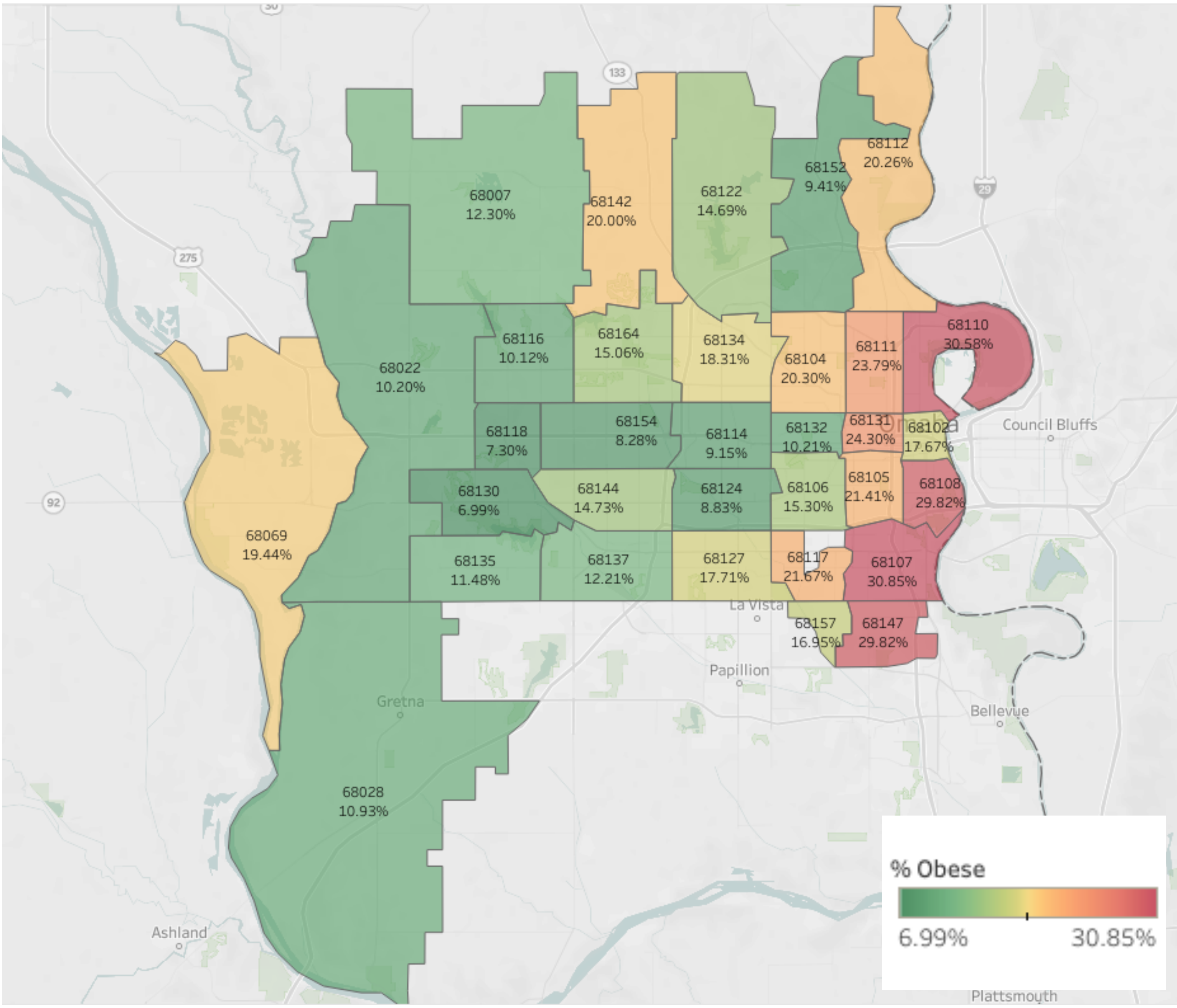

Figure 3: Child Obesity Prevalence by Zip Code (Subsample)

Table 2 presents Pearson correlation results assessing the relationship between neighborhood-level obesity and neighborhood SES variables in the subsample. Both neighborhood-level median household income and percent of individuals below poverty were significantly associated with obesity in the expected direction. Figure 4 presents the association between obesity and median household income. Figure 5 presents the association between obesity and percent of individuals below poverty.

Table 2: Correlation between Neighborhood-Level Obesity and SES (n=33)

Neighborhood-Level Variable	R	p-value
Median Household Income	-0.69406	<.0001
Percent of Individuals Below Poverty	0.72843	<.0001

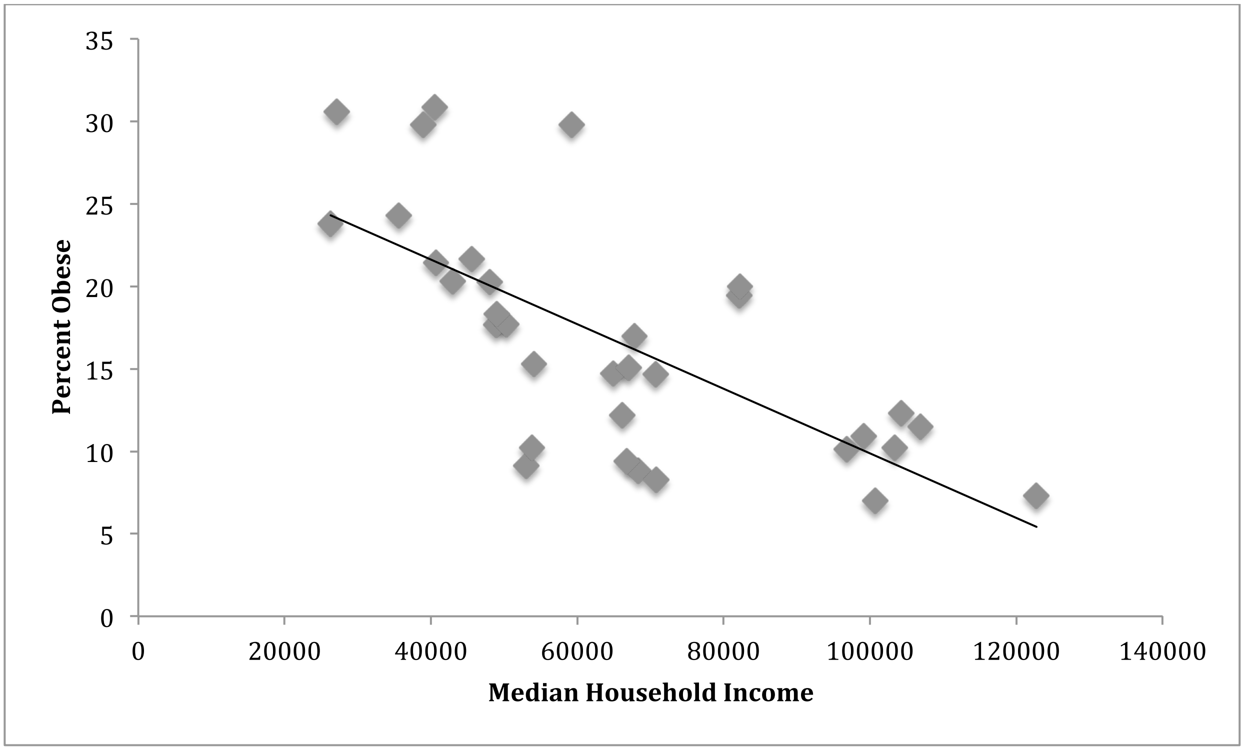

Figure 4: Scatter Plot of Percent Obese and Median Household Income (n=33)

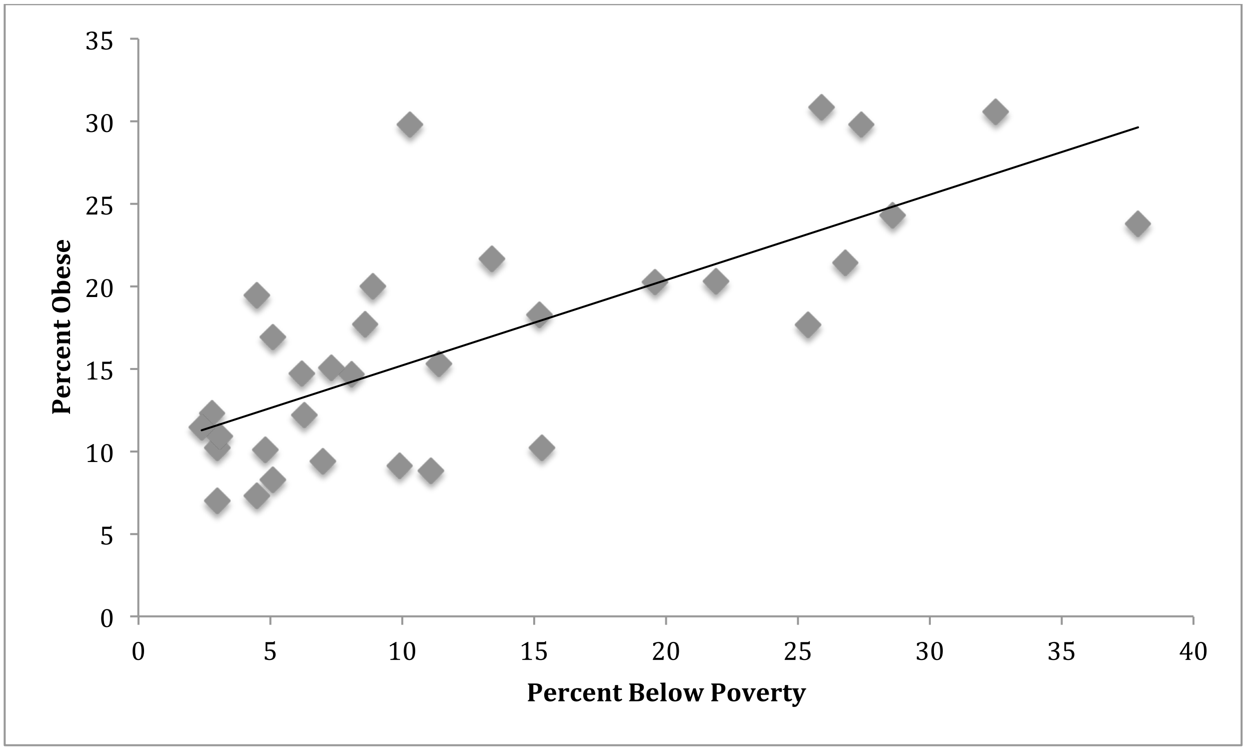

Figure 5: Scatter Plot of Percent Obese and Percent Below Poverty (n=33)

Discussion

The purpose of this study was to examine the current prevalence of child obesity in Omaha, Nebraska at the individual-level and describe obesity prevalence by demographic subgroups, to examine child obesity prevalence at the neighborhood-level and determine if prevalence varies by neighborhood defined by zip code, and to examine if neighborhood-level SES is associated with neighborhood-level obesity prevalence. Overall, 16.4% of the total sample used in this analysis was overweight, and 15.3% was obese. The results revealed significant associations between all individual-level variables and obesity. When examined separately, youth who were male, 12 to 17 years of age, of Native Hawaiian and Other Pacific Islander race, of Hispanic ethnicity, or on Medicaid were more likely to be obese than other demographic subgroups. Obesity prevalence varied by zip code with a range of 6.7% to 26.7% obese in the total sample and a range of 6.99% to 30.85% obese in the subsample. When examining the subsample of youth six to 11 years of age and of Non-Hispanic White, Non-Hispanic Black, or Hispanic race/ethnicity, neighborhood-level obesity had a significant correlation with both neighborhood-level median household income and percent of individuals below poverty in the expected direction.

This analysis revealed current child overweight and obesity prevalence in Omaha, Nebraska to be 31.7%, with 15.3% obese. These results are similar to the 2017 Youth Risk Behavior Surveillance System (YRBSS), which reported that 16.6% of students in grades nine to 12 in Nebraska are overweight and 14.6% are obese (Kann et al., 2018). However, the results from this analysis show lower child overweight and obesity prevalence than the 2018 Professional Research Consultants (PRC) Child and Adolescent Health Needs Assessment for the Omaha Metropolitan Area, which reported that 35.9% of children age five to 17 years are overweight or obese and 22.8% are obese (Professional Research Consultants Inc., 2018). The sample used in the PRC report was made up of 65.5% White, 16.1% Hispanic, and 35.8% low-income individuals, which is comparable to the sample used in the present analysis. However, the sample was based on the entire Omaha Metropolitan Area, including all of Douglas, Sarpy, and Pottawattamie counties. PRC reported highest prevalence of overweight and obesity in Pottawattamie County, which may contribute to the differences seen with the present analysis. Another possible explanation for the discrepancy is that the PRC results are based on a smaller sample of parent-reported data, which may be subject to bias (Elgar et al., 2005; Klesges et al., 2004; Weden et al., 2013).

Compared to national data, the prevalence of child overweight and obesity is slightly lower in Omaha, Nebraska. National estimates report that approximately 18.5% of youth ages two to 19 years are obese (Hales et al., 2017). The 2017 YRBSS reports that among high school students in the United States, 14.8% are obese and 15.6% are overweight (Kann et al., 2018). However, child obesity prevalence in Omaha, Nebraska is higher than the Healthy People 2020 target of 14.5% (Office of Disease Prevention and Health Promotion, 2019, March 3). This highlights child obesity as a priority health need at the local level.

The results of this analysis revealed significant associations between obesity and individual-level variables of gender, age, race, ethnicity, and medical insurance provider. These results are consistent with previous studies that have found higher prevalence of obesity among boys than girls (Ogden et al., 2011; Sundblom, Petzold, Rasmussen, Callmer, & Lissner, 2008). Consistent with the results of this analysis, previous studies have also reported lower overweight and obesity prevalence in preschool age children than older children and lower prevalence in Non-Hispanic Whites than Non-Hispanic Blacks and Hispanics (Ogden et al., 2012). Further, children with Medicaid insurance, used as a proxy for SES, were more likely to be obese than children with other insurance providers. This is consistent with a systematic review that concluded a predominantly inverse association between family-level SES and adiposity in children (Shrewsbury & Wardle, 2008).

This study included individual-level analysis of variables associated with child obesity and found results consistent with previous studies. However, by studying only individual-level factors, we can neglect the effect of one's neighborhood on the outcome (Merlo et al., 2005). Therefore, this study also examined obesity at the neighborhood level, and we found that obesity prevalence varies by neighborhood, ranging from 6.7% obese to 26.7% obese in the total sample of two to 20 year olds and from 6.99% to 30.85% obese in the subsample of six to 11 year olds with race/ethnicity of Non-Hispanic White, Non-Hispanic Black, and Hispanic. Both maps show that neighborhoods in the eastern part of Omaha have higher concentrations of child obesity than the neighborhoods in western Omaha. Although this is the first study to our knowledge to map Omaha child obesity prevalence by areas as small as zip code, this is consistent with the results of the 2018 PRC Child and Adolescent Health Needs Assessment for the Omaha Metropolitan Area, which reports that Southeast Omaha followed by Northeast Omaha have the highest prevalence of child overweight and obesity (Professional Research Consultants Inc., 2018).

This study also supported the hypothesis that neighborhood-level SES, defined by zip code median household income and percent of individuals below poverty, is strongly correlated with neighborhood-level obesity, which is consistent with previous findings. For example, Grow et al. (2010) found that lower census tract-level median household income and home ownership were significantly associated with child obesity risk in a sample of six to 18 year old children with objectively measured heights and weights. This is also consistent with previous findings on adult obesity. Drewnowski, Rehm, and Solet (2007) found that zip code median household income was a significant predictor of zip code-level obesity prevalence using Behavioral Risk Factor Surveillance System (BRFSS) data from a sample of adults 18 years of age and older in King County, Washington. The findings from the current study provide support that neighborhoods play a role in child obesity prevalence and that neighborhoods of high SES may present an environment more conducive to healthy behaviors related to obesity.

Several processes may explain the neighborhood variability in child obesity prevalence. One geospatial process that may explain the neighborhood variability in child obesity prevalence is neighborhood economic resources. Living in a lower SES neighborhood can influence weight outcomes through the availability of healthy foods and places to be physically active. Children living in lower SES neighborhoods may experience a lack of supermarkets or other healthy food options which can result in increased consumption of unhealthy foods, increasing their risk of becoming overweight or obese (Drewnowski & Specter, 2004). Lower SES neighborhoods may also have fewer opportunities for children to be physically active, another weight-influencing behavior. Prior studies have suggested that lower SES neighborhoods may have fewer physical activity facilities and can be perceived as less safe and less adequate for youth physical activity, which can impact physical activity behavior and ultimately weight outcomes (Gordon-Larsen, Nelson, Page, & Popkin, 2006; Holt et al., 2009).

Another process may be through geospatially located social networks, as healthy or unhealthy behaviors can be passed through these networks and can influence the adoption of behaviors among people living in the same geospatial area (Alvarado, 2016). This can impact the environment in which particular health-related behaviors and attitudes become normative. These norms and values can be passed through social networks within a geospatial area and can ultimately impact health outcomes for the people living within the area (Alvarado, 2016; Crane, 1991; Jencks & Mayer, 1990; Kawachi & Berkman, 2003; Sampson, 2003). The dietary and physical activity behaviors that result from a neighborhood's structural environment can also become normative and be passed through social networks.

Overall, a neighborhood consists of numerous interacting physical and social characteristics that can impact the health outcomes of all residents within a given geospatial area. The results of this analysis support the hypothesis that neighborhood SES may be one factor impacting the neighborhood-level outcome of child obesity. Therefore, obesity may be viewed as a neighborhood-level health outcome that is influenced by the social environment residents of a given geospatial area experience.

While individual-level differences in obesity based on demographic subgroups were found in this analysis, these differences may be attributed to the interaction between individual-and neighborhood-level factors. In a paper examining retail food environments and disparities in obesity prevalence, Ford and Dzewaltowski (2008) explain that the relationship between a health behavior, such as healthy eating, is both moderated by environmental factors and mediated by individual-level factors. In order for individuals to adopt healthy behaviors, such as healthy eating or physical activity, environments must be conducive to such behaviors. However, these environments do not ensure the adoption of healthy behaviors. It is critical to recognize the complex, multilevel influences of neighborhoods on obesity.

Limitations of the present study are necessary to consider when interpreting the results. This study presents a cross-sectional analysis using chi-square and Pearson correlation analysis, meaning we cannot establish causation between our individual- and neighborhood-level variables and child obesity. In addition, the statistical model used in this analysis examined child obesity at the individual-level and the neighborhood-level separately. In examining only individual-level factors, we can neglect the impact of neighborhood on the outcome. In examining obesity at the neighborhood-level only, we can neglect the individual-level factors. A multi-level model examining both the individual- and neighborhood-level factors should be explored.

Another limitation is that representativeness and generalizability of the sample used in this analysis is not fully known. Using data from a single hospital system may introduce sampling bias, in which our sample is not representative of the overall target population. Our sample had a greater proportion of White individuals but is otherwise comparable to the U.S. Census Bureau population estimates for children under 18 years in Omaha, Nebraska, in which 70.7% of the child population is White, 15.0% is Black or African American, and 22.7% is Hispanic (U.S. Census Bureau). This suggests that the results are likely generalizable to Omaha. However, population estimates for children under 18 years at the zip code level were not readily available for every zip code used in this analysis. Therefore, we cannot determine if the sample in each zip code is representative of the zip code population. Additionally, although this sample was restricted to a single city, the demographic characteristics are fairly similar to the population estimates for children under 18 years of age in the United States, suggesting potential for generalizable findings (U.S. Census Bureau).

Finally, the use of zip code as the definition of neighborhood may not accurately depict the geospatial area in which individuals fully live their lives. Additionally, zip code areas are designed for efficient mail delivery and may not remain static, as other geographic boundaries such as census tract or block group do (Krieger et al., 2002). However, zip code was the finest geospatial scale available with this dataset, and this is the first study to our knowledge to map obesity prevalence on this scale for Omaha, Nebraska.

Despite these limitations, this study provides important information on the current prevalence of child obesity in Omaha, Nebraska and insight into underlying factors associated with child obesity. This analysis utilized a large sample (n=40,303) of subjects with objectively measured BMI percentiles. Current overweight and obesity data for Omaha, Nebraska is based on a much smaller sample (n=995) in which parents reported the height and weight of one randomly selected child between five and 17 years of age in their household (Professional Research Consultants Inc., 2018). As parent-reported data may be subject to bias, utilizing objectively measured data is a significant strength of the present study (Weden et al., 2013). Additionally, child obesity prevalence for Omaha has not been mapped at this scale, so this study provides important insight into the geospatial areas most impacted by obesity.

The EHR data utilized in this analysis presents significant opportunity for future research. Future studies should take a longitudinal approach to examining the impact of neighborhood SES on child obesity. Additionally, other definitions of neighborhood should be explored. Using geographic information system (GIS) software would allow for the exploration of various geospatial areas, such as census tracts, block groups, and buffers around one's place of residence. Future studies should also pursue other data sources to obtain population demographic information in order to fully determine the representativeness of this sample. Other neighborhood-level contextual factors beyond median household income and percent of individuals below poverty should also be explored in relation to obesity. These include other indicators of neighborhood SES, such as percent home ownership, percent with high school education, and percent single parent households. These also include factors of the built environment, such as availability of supermarkets, fast food outlets, and recreation spaces and facilities. These neighborhoods should be more fully examined to identify other physical and social factors that may explain the variability in child obesity. Finally, future analyses should utilize a multilevel model that examines the individual-level factors and the neighborhood-level factors simultaneously. A multilevel model would overcome the limitations of the present analysis by considering the clustering of individual-level obesity within neighborhoods and examining the differences in obesity between the individual-level and the neighborhood-level.

This analysis also provides direction for future community program planning and policy change at the local level. The results of the examination of child obesity prevalence by zip code suggest the need for interventions to be focused on geospatial areas, rather than on individuals categorized by demographic groups. Future community programs should investigate the physical and social environments of the geospatial areas most impacted and should include the community members in planning in order to fully understand the contexts they experience. A social change approach at the community-level may work to create environments more supportive of healthy behaviors, beyond simply supplying tools to prevent and overcome obesity at the individual-level (Hill, Wyatt, Reed, & Peters, 2003). Further, approaches that target multiple settings and use multiple strategies are more likely to work than single strategy or single setting approaches (Bell, Simmons, Sanigorski, Kremer, & Swinburn, 2008). Finally, approaches should include a focus on community capacity building, in order to develop the knowledge, skills, structures, and systems for communities to create and sustain health promotion programs and environments conducive to healthy behaviors (Bell et al., 2008; Smith, Tang, & Nutbeam, 2006).

Conclusion

Understanding the geospatial areas most impacted by child obesity and the underlying factors influencing obesity prevalence may help inform future public health interventions. This study found that individual-level factors of gender, age, race, ethnicity, and medical insurance provider are associated with child obesity. This study also found that child obesity varies by neighborhood and that neighborhood-level SES is significantly correlated with child obesity prevalence. Future studies should examine the relationship between child obesity prevalence and neighborhood SES longitudinally and should examine neighborhood variation in child obesity prevalence at finer geographic scales. Future community interventions should focus on geospatial areas and utilize multi-setting, multi-strategy, capacity building approaches in order to impact the physical and social environments in which people live, learn, work, and play, in order to create sustainable change in the prevention of child obesity.

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