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GEOSPATIAL CLUSTERING IN SUGAR-SWEETENED BEVERAGE CONSUMPTION AMONG BOSTON YOUTH

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Abstract

The objective was to detect geospatial clustering of sugar-sweetened beverage (SSB) intake in Boston adolescents (Age=16.3 ±1.3 years [range: 13–19]; Female= 56.1%; White= 10.4%, Black= 42.6%, Hispanics=32.4%, and others=14.6%) using spatial scan statistics. We used data on self-reported SSB intake from the 2008 Boston Youth Survey Geospatial Dataset (n=1,292). Two binary variables were created: consumption of SSB (never versus any) on: 1) soda and 2) other sugary drinks (e.g., lemonade). A Bernoulli spatial scan statistic was used to identify geospatial clusters of soda and other sugary drinks in unadjusted models and models adjusted for age, gender, and race/ethnicity. There was no statistically significant clustering of soda consumption in the unadjusted model. In contrast, a cluster of non-soda SSB consumption emerged in the middle of Boston (Relative Risk=1.20, p=0.005), indicating that adolescents within the cluster had a 20% higher probability of reporting non-soda SSB intake than outside the cluster. The cluster was no longer significant in the adjusted model, suggesting spatial variation in non-soda SSB drink intake correlates with the geographic distribution of students by race/ethnicity, age, and gender.

Keywords

Geospatial clustering; spatial scan statistic; sugary drink intake; adolescents

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Informed Consent
Passive consent was obtained from parents (i.e., they had the opportunity to opt out from the study) and students read the informed assent prior to the survey administration.

Conflict of Interest
Authors report no conflicts of interest.

Introduction

Diet-related diseases, including obesity and type 2 diabetes, are partly linked to overconsumption of sugar sweetened beverages (SSBs) (Wang et al. 2014, Ambrosini et al. 2013), defined as beverages containing added sugars such as soda, sweet tea, and energy drinks (US Department of Health and Human Services et al. 2015). Consumption of SSB among adolescents aged 12–19 years in the United States has declined from 13.5% (309 kcal/day) of the total caloric intake in 1999–2000 to 10.4% (225 kcal/day) in 2009–2010 (Kit et al. 2013). Specifically, Mexican-American adolescents aged 12–19 consumed more than Non-Hispanic White and Black youth in 2009–2010 (249 vs. 229 and 228 kcal/day, respectively), yet the trends from 1999–2000 to 2009–2010 showed a decrease in SSB consumption over time in each race/ethnic group (Kit et al. 2013). One contribution to this decline is that soda consumption has decreased, previously the highest contributor to SSB intake among adolescents (Wang et al. 2008). The decline has been partially attributed to increasing public awareness about the health consequences associated with SSB consumption (Welsh et al. 2013), which has motivated beverage companies to increase promotion and availability of less sugary options (McGuire 2012). However, consumption of other sugary drinks, specifically energy drinks, has tripled from 4% in1999 to 12% in 2008 among adolescents aged 12–19 years in the U.S. (Han and Powell 2013). Despite this overall decline in SSB consumption over the decade, it still exceeds the American Heart Association guideline of 450 kcal/week from sugar sweetened beverages (approximately equivalent to 3.2 cans [12 oz can = 140 kcal, regular soda such as Coke]) (Lloyd-Jones et al. 2010).

Although sugary drinks are the largest calorie source in adolescents' diets, the recent studies have demonstrated that SSB consumption varied by demographic characteristics (Ervin et al. 2012, Han and Powell 2013). Individuals with greater consumption of SSBs appear to be adolescents, male, and non-Hispanic blacks (Ervin et al. 2012, Han and Powell 2013, Bleich and Wolfson 2015). A geospatial cluster, defined as unusually concentrated individuals with a specific outcome in space (CDC 1990), have been understudied in the context of SSB consumption patterns, although these patterns identify characteristics that could be prime targets for intervention (e.g. zoning laws). The few studies that have investigated spatial variation in SSB intake focused on adult consumption at the state level (Park et al. 2014a, Park et al. 2014b, Kumar et al. 2014, Park et al. 2015). One recent study using the 2012 Behavioral Risk Factor Surveillance System (BRFSS) showed that the state with the highest prevalence of SSB consumption (i.e., at least once a day) among adults from the 18 states included in the BRFSS was Mississippi (41.4%) and the state with the lowest prevalence was Hawaii (20.4%) (Kumar et al. 2014).

Little is known, however, about how localized geographic patterns of SSB intake vary among adolescents, including at a city-level. According to the Youth Risk Behavior Survey 2009 (CDC 2009), the prevalence of SSB (i.e., at least a can of soda per week) was 80.6% among high school students at the U.S. Specifically, in Massachusetts and Boston, the prevalence of SSB consumption was 77.4% and 81.1%, respectively (CDC 2009). Research is needed to examine geospatial analysis of diet-related diseases risk factors, such as SSB intake among adolescents. This line of work can be utilized as a tool to explore future epidemiological and interventional research on SSB intake among adolescents. Geospatial analysis of SSB intake among adolescents can also be used to design and implement locally tailored interventions aiming at reducing adolescent SSB exposure. Therefore, the purpose of this study was to detect localized clustering of SSB intake among a population-based sample of adolescents in Boston, Massachusetts. The prevalence of SSB intake among Boston high school students was higher than those of the Massachusetts and national levels. Thus it is relevant and important to study geospatial clustering of SSB consumptions among Boston adolescents.

Materials and methods

Study participants

We used data from the 2008 Boston Youth Survey (BYS) Geospatial Dataset, survey responses from 9th-12th-graders in public high schools in Boston, Massachusetts (Duncan et al. 2012, Duncan et al. 2013, Almeida et al. 2015, Duncan et al. 2016). Twenty-two public high schools in Boston took part in the 2008 BYS (all 32 schools were eligible). A list of classrooms within each school was used to create classroom-level sample, stratified by grade. Classrooms are randomly selected for survey administration. Approximately 100–125 students were sampled for each participating school. Initially 2,725 students were enrolled for participation and 1,878 (response rate = 68.9%) of them completed the survey. For the 1,292 (68.8%) who provided their complete residential addresses, we completed geocoding their addresses to the nearest intersection. Passive consent from parents was obtained and students read the informed assent prior to the survey administration. The Institutional Review Board at the Harvard School of Public Health approved the original study protocols.

Sugar-sweetened beverage intake

Using the 2008 BYS items adapted from the Youth Risk Behavior Surveillance System, we assessed SSB consumption in the past 7 days: “how often did you drink soda (1 can or glass)?” and “how often did you drink Hawaiian punch, lemonade, Kool-Aid or another sweetened fruit drink?” The response options for both items included: never or <1 can, 1 can in the past 7 days, 2–4 cans in the past 7 days, 5–6 cans in the past 7 days, 1 can per day, 2 cans per day, 3 or more cans per day. Consistent with previous work (Almeida et al. 2015), we evaluated consumption of soda and other sugary drinks as a binary variable (any versus never).

Covariates

The 2008 BYS survey was used to assess age, gender and race/ethnicity. We assessed age with response options: 13 or younger, 14, 15, 16, 17, 18, and 19 years or older. Gender was defined as either female or male. Race/ethnicity includes non-Hispanic White, non-Hispanic Black, Hispanic, Asian, and other.

Statistical analyses—We used a Bernoulli spatial scan statistic (Kulldorff 1997, Kulldorff and Nagarwalla 1995) to separately detect spatial clusters of soda and other sugary drink consumption (any vs. never) centered on individual respondents among a population-based sample of Boston adolescents using SaTScan™ software (Kulldorff 2005). Based on a likelihood ratio test for the Bernoulli model, the null hypothesis was that there is no spatial clustering of self-reported SSB consumption. If rejected, respondents within the cluster have a higher probability of reporting SSB consumption than respondents outside the cluster. We performed clustering analyses at the individual level, which allows us to identify smaller clusters than administrative units such as a county (Tamura et al. 2014). Previous research indicated that the data aggregated to larger scales can reduce the power to detect clustering (Ozonoff et al. 2007).

As SaTScan™ allows up to 12 categories for covariate adjustment, we utilized demographic variables previously (Duncan et al. 2016), including age (high/low; 18–19 years versus 13–17 years), gender (male, female), and race/ethnicity (White, Black/Hispanic, Asian/Other). A younger-white-female represents one of 12 categories. We conducted clustering tests with and without covariate adjustments. If the significant cluster disappeared after the models adjusting for covariates, it indicates that the geographic distribution of the covariates explained the cluster.[24] Respondents with missing SSB intake and covariate data were removed from the analyses, resulting in a final sample of 1,108 students for soda intake and 1,109 students for other sugary beverage intake.

In both unadjusted and adjusted models, SaTScan™ uses a maximum likelihood ratio test statistic to determine the p-value of each cluster (Kulldorff 2005). The program performs random data simulations under the null hypothesis and compares the maximum likelihood for each simulation to that calculated from observed data. If $\alpha = 0.05$, the null hypothesis is rejected when the observed maximum likelihood is larger than 95% of the maximum likelihood estimates from the random replications. A significant p-value indicates that individuals inside the cluster differ significantly from ones outside the cluster. We report the number of observed and expected cases, relative risk (RR), and p-value for each cluster identified in the unadjusted models. Once clusters are adjusted for covariates, we only report the associated p-value. We used ArcGIS (ESRI, Redlands, CA) to map these results from the analyses.

Results

The mean age of the participants was 16.3 years (SD ± 1.3 years). These students were predominantly Black (43%) and Hispanic (32%), and U.S. born (74%) (Table 1). The majority of the students had a normal weight-status (63%) and approximately 33% of them were at least overweight. About 77% and 81% of the students reported any consumption of soda and other sugary drinks in the past 7 days, respectively.

Geospatial clusters of high self-reported SSB consumption were detected in Boston. For soda consumption, we identified four unadjusted clusters in middle, western and southern Boston, but none of them was statistically significant (Table 2), meaning the maximum likelihood calculated from the observed data was not greater than the 95th percentile of the maximum likelihoods calculated from the random data. Two spatial clusters of other sugary drinks were identified in middle and south Boston in the unadjusted model (Fig. 1). Respondents inside Cluster 1 (location: the middle of Boston, RR=1.20, p=0.005) had a 20% higher probability of reporting other sugary drink consumption than outside the cluster.

No significant clusters were found for the adjusted model indicating that the geographic distribution of covariates explained the cluster.

Discussion

Our study employed a binary Bernoulli spatial scan statistic to detect high rates of self-reported SSB intake among a population-based sample over 1,000 Boston youth in Massachusetts. We identified one statistically significant cluster of other sugary drink consumption in the unadjusted model. After adjusting for age, gender, and race/ethnicity, we did not find statistically significant high rates of other sugary drinks, indicating that the geographic distribution of covariates accounted for the unusually elevated cases of reporting other sugary drink intake among Boston adolescents.

Our study of SSB clusters among adolescents in Boston is not comparable to other studies because no other study has examined localized clusters of SSB intake among adolescents in a small geographic urban area, such as Boston. Only a few studies examined geographic patterns of SSB consumption among adults and found that SSB consumption differed at the larger scale such as region- and state-level (Park et al. 2014a, Park et al. 2014b, Kumar et al. 2014, Park et al. 2015). One recent study using the 2012 BRFSS on the prevalence of SSB intake among adults across 18 states in the U.S. showed that they assessed the state-specific prevalence by age groups, gender, and race/ethnicity. The authors found that younger adults (18–34 versus 35–54, ≥ 55 years), men (versus women), and Hispanic (versus White, non-Hispanic) had a higher prevalence of regular soda consumption ≥ 1 times/day (Kumar et al. 2014). As the differences in the prevalence of SSB consumption differed by age, gender, and race/ethnicity among adults across the 18 states, demographic characteristics may play a role in SSB consumption among younger age groups, such as our study.

To our knowledge, the present study is the first to test for geospatial clustering of SSB consumption among adolescents. The statistically significant cluster of other sugary drink intake from the unadjusted model indicates that respondents within cluster 1 (middle of Boston) had higher consumption of other sugary drinks than respondents in cluster 2 and outside the cluster (Prevalence: 95% versus 87% and 76%, respectively, chi-square test $p<.0001$). However, once we adjusted for demographic covariates, cluster 1 was no longer statistically significant; suggesting the spatial variation that we observed in self-reported SSB consumption was driven by demographic differences. In particular, although age and gender of respondents were similar inside and outside the cluster, the distribution of race/ethnicity (White, Black, Hispanic, Asian, and other students) differed significantly (chi-square test $p<.0001$), with pre-dominantly Black (n=68) and Hispanic (n=43) respondents reporting any consumption of other sugary drinks in cluster 1. This was confirmed by one covariate adjustment at a time (i.e., race/ethnicity), as opposed to multiple covariate adjustments. However, further investigation for the high rates of other sugary drink consumption among these students is needed. For example, it would be valuable to assess the food environments within cluster 1 and outside the cluster to determine whether food environmental exposures differ within and outside cluster. In addition, consumption of other sugary drinks, especially energy drinks among adolescents increased significantly between 1999 and 2008 (Han and Powell 2013), in part due to targeted advertisement to teen TV audiences (Emond et al. 2015). Public awareness of detrimental health consequences linked to energy drinks may also need to be increased, specifically to Black and Hispanic students due to high consumption of SSBs, compared to White students (Harris et al. 2011).

Limitations

There are several limitations in the present study. Our sample may be biased because the response rate was relatively low (68.9%) and the students who responded to the survey could be more health conscious compared to those who did not. Self-reported SSB measures are one limitation that may facilitate potential recall and social desirability biases related to how many cans or what amount respondents consume SSBs each day. This may result in over- and under-estimation of SSB intake.[13] The findings from this study may not be applicable to low socio-economic adolescents in other U.S. cities, especially non-dense cities. A limitation related to covariate adjustment is that SaTScan only allows classifications up to 12. This limited our analyses to further understand how racial/ethnic groups may be linked to the development of SSB clusters. A limitation related to scanning windows is that the actual cluster may not emerge as a circular cluster. An alternative approach could be the Flexible Scan Statistics (FleXScan) software that allows users to detect irregularly shaped cluster of a specific outcome of interest (Tango and Takahashi 2005), which can be conducted in future research.

Conclusion

Our findings from this study add to the limited research on geospatial clustering of SSB consumption among adolescents. We found one statistically significant geospatial clustering of “other sugary drinks” consumption among adolescents, which was characterized by a greater number of racial/ethnic minority students inside the cluster. Further investigation of the identified clusters is needed to better understand why specific demographic groups have higher rates of SSB consumption which might be linked to their neighborhood food environment such as proximity and density of fast-food outlets and grocery stores. This line of research may serve to inform public health officials and practitioners by identifying exact locations where environmental policy interventions are needed. In doing so, we should examine relationships between food environmental factors (e.g., fast-food restaurants) and SSB intake by applying a spatial regression model, such as a geographically weighted regression model.

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Research Involving Human Participants

The original study protocols were approved by the Institutional Review Board at the Harvard School of Public Health and all procedures were in accordance with the Helsinki Declaration of 1975, as revised in 2000.

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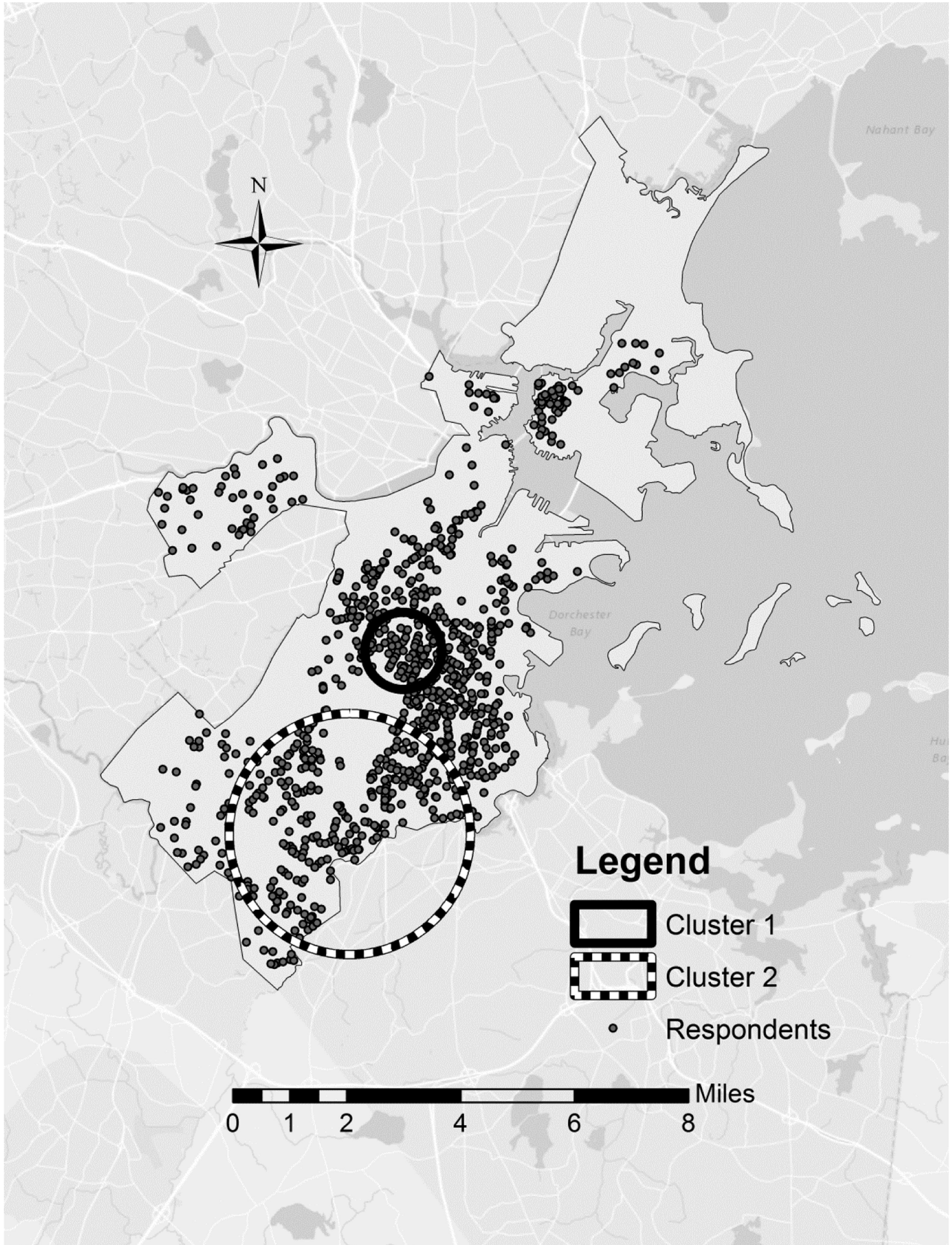

Figure 1.

Geospatial clustering of other sugary drink intake among Boston adolescents from the unadjusted model. Cluster 1 represents a statistically significant clustering, while Cluster 2 represents non-significant clustering.

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Table 1.

Student's characteristics, 2008 Boston Youth Survey Geospatial Dataset (N=1,096)

	Overall	Sugar-sweetened beverage intake					
		Soda			Other sugary drinks		
	n (%)	Never: n=253 (23.1%)	Any: n=843 (76.9%)	*p*	Never: n=205 (18.7%)	Any: n=891 (81.3%)	*p*
Age in years				0.115			0.009
≤ 14	86 (7.85)	14 (5.53)	72 (8.54)		15 (7.32)	71 (7.97)	
15	220 (20.07)	54 (21.34)	166 (19.69)		29 (14.15)	191 (21.44)	
16	292 (26.64)	57 (22.53)	235 (27.88)		45 (21.95)	247 (27.72)	
17	306 (27.92)	83 (32.81)	223 (26.45)		70 (34.15)	236 (26.49)	
≥18	192 (17.52)	45 (17.79)	147 (17.44)		46 (22.44)	146 (16.39)	
Gender				0.560			0.277
Female	615 (56.11)	146 (57.71)	469 (55.63)		122 (59.51)	493 (55.33)	
Male	481 (43.89)	107 (42.29)	374 (44.37)		83 (40.49)	398 (44.67)	
Race/Ethnicity				<0.001			<0.001
White	114 (10.40)	36 (14.23)	78 (9.25)		45 (21.95)	69 (7.74)	
Black	467 (42.61)	103 (40.71)	364 (43.18)		60 (29.27)	407 (45.68)	
Hispanic	355 (32.39)	60 (23.72)	295 (34.99)		53 (25.85)	302 (33.89)	
Asian	83 (7.57)	33 (13.04)	50 (5.93)		35 (17.07)	48 (5.39)	
Other	77 (7.03)	21 (8.30)	56 (6.64)		12 (5.85)	65 (7.30)	
Nativity status *				0.011			0.001
US Born	803 (73.87)	167 (67.61)	636 (75.71)		131 (64.85)	672 (75.93)	
Foreign Born	284 (26.13)	80 (32.39)	204 (24.29)		71 (35.15)	213 (24.07)	
Weight-status *				0.292			0.739
Underweight	46 (4.54)	11 (4.72)	35 (4.48)		9 (4.66)	37 (4.51)	
Normal	634 (62.52)	157 (67.38)	477 (61.08)		123 (63.73)	511 (62.24)	
Overweight	179 (17.65)	33 (14.16)	146 (18.69)		29 (15.03)	150 (18.27)	
Obese	155 (15.29)	32 (13.73)	123 (15.75)		32 (16.58)	123 (14.98)	

Note: Total sample is based on when SSB items, age, gender, and race/ethnicity are no missing.

* Nativity status and weight-status are missing with 9 and 82 students, respectively. P-values are based on chi-square test.

Table 2.

Cluster characteristics of sugar sweetened beverage consumption based on unadjusted and adjusted models

Cluster ID	Observed cases	Expected cases	Relative risk	p-value
Soda - unadjusted model				
1	38	29.99	1.28	0.34
2	23	17.69	1.31	0.65
3	19	14.61	1.31	0.93
4	18	13.84	1.31	0.97
Other sugary drinks - unadjusted model				
1	119	101.67	1.20	0.01
2	299	278.98	1.11	0.61
Other sugary drinks - adjusted model *				
1	-	-	-	0.48
2	-	-	-	0.79

Note:

*Models adjusted for age, gender, and race/ethnicity.