Spatial and Spatio-temporal Epidemiology 12 (2015) 19–25

Contents lists available at ScienceDirect

Spatial and Spatio-temporal Epidemiology

journal homepage: www.elsevier.com/locate/sste

Original Research

# Maternal anemia associated with walkable distance to healthy food sources in Bronx, New York

Danielle M. Bottalico [a], Glen D. Johnson [b], Cynthia Chazotte [a,c], Chavi Eve Karkowsky [a,c,*]

[a] Albert Einstein College of Medicine, Bronx, NY, USA
[b] City University of New York, Lehman College, Department of Health Sciences, Bronx, NY, USA
[c] Department of Obstetrics & Gynecology and Women's Health, Montefiore Medical Center, Bronx, NY, USA

ARTICLE INFO

*Article history:*
Received 8 January 2014
Revised 7 November 2014
Accepted 19 December 2014
Available online 30 December 2014

*Keywords:*
Maternal health
Urban health
Anemia
Walkable food access
Built environment
Street network analysis

ABSTRACT

The relationship between walkable access to healthy food sources and risk of anemia in pregnancy was evaluated for a cohort of 4678 women who initiated prenatal care in the year 2010 at an academic medical center in Bronx, New York. After geocoding patient residences, street network distances were obtained for the closest healthy food sources, which were identified from multiple databases. For lower-income patients, as indicated by Medicaid or lack of health insurance, those who lived less than 0.25 miles from a healthy food source were less likely to be anemic when compared to those who lived farther (adjusted OR = 0.65, 95% CI 0.48, 0.88). Patients with commercial insurance showed no effect. These results help to understand how a nutritionally-mediated condition such as anemia during pregnancy can be affected by one's built environment, while also highlighting the importance of conditioning on socioeconomic status for these types of studies.



## 1. Introduction

Anemia during pregnancy, as evidenced by low hemoglobin or hematocrit levels, has long been linked with adverse pregnancy outcomes such as preterm birth and small for gestational age (SGA) neonates (Scholl, 2005, 1992; Perry et al., 1995; Scanlon et al., 2000; Kozuki et al., 2012; Alwan et al., 2011; Scholl, 2011; Zhang et al., 2009; Milman, 2011). Mild anemia in pregnancy is very common, and can be considered part of the physiologic adaptation of pregnancy as the dilutional effects of volume expansion outpace increased blood cell production (Creasy, 2009). However, according to the Center for Disease Control and Prevention, more than half of pregnant women have inadequate iron stores to fulfill physiologic gestational needs and suffer from clinically significant anemia during pregnancy (Perry et al., 1995). In addition to ramifications for maternal health, maternal iron stores are essential for fetal brain development and prenatal exposure to a low-iron environment can have long-standing effects on the fetus and neonate (Lozoff and Georgieff, 2006).

While there are many established etiologies of anemia, dietary iron deficiency is the most common cause (Scholl, 2011). Therefore, the prevention and treatment of anemia during gestation has been linked to nutritional access and behaviors as well as iron supplementation (Scholl, 2005, 2011). Evidence strongly suggests that the local food environment is associated with individual dietary behavior (Morland et al., 2002; Moore, 2008; Morland and Wing, 2002). Several studies have used spatial analysis techniques to demonstrate a relationship between the geographic availability of healthy food and nutritionally-related conditions, such as obesity and hypercholesterolemia (Morland, 2006; Rundle et al., 2009). However, there

* Corresponding author at: Montefiore Medical Center, 1825 Eastchester Road, Room 703, Bronx, NY 10461, USA. Tel.: +1 718 904 2767; fax: +1 718 904 2799.
*E-mail address:* ekarkows@montefiore.org (C.E. Karkowsky).

http://dx.doi.org/10.1016/j.sste.2014.12.001
1877-5845/

is currently little literature using these techniques to better understand the relationship between pregnancy-related anemia and healthy food access. This study was designed to evaluate the association between walkable access to a healthy food source (HFS) and risk of anemia in pregnancy in a large urban center.

## 2. Methods

### 2.1. Data

This study was reviewed and granted approval by the Montefiore Medical Center Institutional Review Board. A retrospective cohort of all patients who presented for prenatal care during the calendar year of 2010 to Montefiore Medical Center in Bronx, NY was created from the interactive software program, Clinical Looking Glass (CLG). This is a user-friendly interactive software application developed at Montefiore Medical Center to evaluate health care quality, effectiveness and efficiency. The system integrates clinical and administrative datasets, allowing production of epidemiologically cogent, self-documenting reports that globally assess care quality while identifying the specific patients in need of clinical remediation. The Birth Report, a tool of this interactive software, was used to match mothers with infants born in Montefiore, and to gather infant information such as birth weight, gestational age, and Apgar scores. In addition, ASObGyn and EPF Web, two electronic medical record systems, provided demographic characteristics and the prenatal course of patients as well as other relevant maternal and neonatal inpatient characteristics.

Anemia was defined according to the World Health Organization as hemoglobin below 11 g/dL (Health Organization, 2011).

Residential locations of this outpatient cohort, based on the patient's address recorded at first obstetric appointment, were identified as granular longitude and latitude coordinates through a geocoding tool that is built into the Clinical Looking Glass software.

To develop a complete healthy food source dataset for Bronx, NY, we defined healthy food sources as supermarkets and fruit and vegetable markets, similar to the methods in other published literature, and utilized their respective North American Industry Classification System or North American Industry Classification System code (Table 1, Morland and Wing, 2002). We then employed two commercial databases, Dun & Bradstreet® and ReferenceUSA®, to locate longitude and latitude coordinates for all healthy food sources in Bronx, NY during our study period. All supermarkets, as defined by North American Industry Classification System codes, were further refined by name recognition to include only chain supermarkets, as previously described (Morland and Wing, 2002; Morland, 2006). These stores were subsequently cross-validated using the store locator function provided by the respective chain websites.

**Table 1**
Healthy food sources definitions.

| Healthy food sources | North American Industry Classification System code | Example |
|---|---|---|
| Supermarkets | 445110 | A&P, Stop & Shop, Pathmark, Foodtown, C-Town |
| Fruit and vegetable markets | 445230 | Garden Market, Kim's Fruit Market, Modern Fruit, New Era Produce |

All healthy food sources were then verified by Google Maps street-view application or by store phone number provided by the databases. Stores that failed to be verified by either method were excluded from the dataset and were assumed to no longer exist. Our final healthy food sources dataset included 142 supermarkets and 99 fruit and vegetable markets for a total of 241 healthy food sources in Bronx, NY. These data are available as a kml file in the supplemental material associated with this paper.

### 2.2. Geospatial network distance calculation

Using ArcGIS™ v10.2 software, patient and HFS longitude and latitude ($x/y$) coordinates were plotted and exported into two separate layers. A street network dataset was obtained from the New York City Department of City Planning LION Road Network and clipped to only include road segments in Bronx, NY. All geo-referenced data were brought into a common geodatabase for further mapping and analysis. Fig. 1 displays the street network data overlaid with HFS locations; however, patient residence coordinates are not displayed in order to protect medical privacy.

The Network Analyst tool was activated in ArcMap™ v10.2 and set to model turns in street segments, but not elevation. Network analysis was performed to determine the closest healthy food source to each patient in our cohort. According to previous studies, walkable access to a healthy food source was defined as living 0.25 miles or less to a supermarket or fruit and vegetable market (Tester et al., 2010; Lukar et al., 2012). Fig. 2 illustrates examples of residences for pregnant women in our cohort who live within 0.25 street network miles of an HFS.

### 2.3. Statistical analysis

The effect of distance and other covariables were quantified through logistic regression (Hosmer and Lemeshow, 2000) using SAS™ 9.2 (Institute Inc, 2012) to obtain the odds of a pregnant woman being anemic for any level of a categorical covariable, relative to a reference level, after adjusting for the effect of other covariables in the model. Odds ratios were calculated along with their Wald 95% confidence limits.

Model fit was summarized by the percent concordance, which also estimates the area under the receiver operating characteristic (ROC) curve (Hanley and McNeil, 1982) and increases proportionally to the model's ability to discriminate between anemic and non-anemic patients. Model specification was evaluated by the deviance statistic to assess over/under dispersion and by residual spatial