Available online at www.sciencedirect.com

Public Health

journal homepage: www.elsevier.com/puhe

Original Research

Factors affecting ambulance utilization for asthma attack treatment: understanding where to target interventions

L.H. Raun [a,b,*], K.B. Ensor [a], L.A. Campos [a], D. Persse [c,d]

[a] Rice University, Department of Statistics, Houston, TX, USA
[b] City of Houston Health and Human Services Bureau of Pollution Control and Prevention, Houston, TX, USA
[c] City of Houston Emergency Medical Services, Houston, TX, USA
[d] Medicine and Surgery, Baylor College of Medicine, Houston, TX, USA

ARTICLE INFO

Article history:
Received 3 June 2014
Received in revised form
14 January 2015
Accepted 1 February 2015
Available online 7 March 2015

Keywords:
Asthma
Ambulance
Intervention

ABSTRACT

Objectives: Asthma is a serious, sometimes fatal condition, in which attacks vary in severity, potentially requiring emergency medical services (EMS) ambulance treatment. A portion of asthma attacks requiring EMS ambulance treatment may be prevented with improved education and access to care. The aim of this study was to identify areas of the city with high rates of utilization of EMS ambulance for treatment, and the demographics, socio-economic status, and time of day associated with these rates, to better target future interventions to prevent emergencies and reduce cost.

Study design: A cross-sectional study was conducted on individuals in Houston, TX (USA) requiring ambulance treatment for asthma attacks from 2004 to 2011.

Methods: 12,155 EMS ambulance-treated asthma attack cases were linked to census tracts. High rate treatment areas were identified with geospatial mapping. Census tract demographic characteristics of these high rate areas were compared with the remainder of the city using logistic regression. The association between case level demographics and the time of day of asthma attack within the high rate area was also assessed with logistic regression.

Results: EMS ambulance-treated high rate areas were identified and found to have a utilization incidence rate over six times higher per 100,000 people than the remainder of the city. There is an increased risk of location in this high rate area with a census tract level increase of percent of population: earning less than $10,000 yearly income (RR 1.21, 1.16–1.26), which is black (RR 1.08, 1.07–1.10), which is female (RR 1.34, 1.20–1.49) and have obtained less than a high school degree (RR 1.02, 1.01–1.03). Within the high rate area, case level data indicates an increased risk of requiring an ambulance after normal doctor office hours for men compared with women (RR 1.13, 1.03–1.22), for black compared with Hispanic ethnicity (RR 1.31, 1.08–1.59), or for adults (less than 41 and greater than 60) compared with children.

* *Corresponding author*. Rice University, Department of Statistics, PO Box 1892, MS 138, Houston, TX 77251-1892, USA. Tel.: +1 713 417 1896; fax: +1 713 348 5476.
E-mail address: raun@rice.edu (L.H. Raun).

http://dx.doi.org/10.1016/j.puhe.2015.02.009

Conclusions: Interventions to prevent asthma emergencies should be targeted in the high rate area and towards groups identified most at risk. Consideration should be given to improved access to care after normal doctor office hours in these locations. While ambulance treatment reflects the most urgent care needs, these interventions are also expected to reduce the need for emergency room visits.

Introduction

Asthma is a growing national concern, affecting more than 25 million Americans including an estimated seven million children.[1] In 2009, there were 1.9 million asthma related emergency department visits and 479,300 hospitalizations.[2] Moreover, in the last decade the number of people living with asthma rose by nearly 15%.[3] In 2010, there were 3404 deaths from asthma nationwide, and in 2007 there were 198 adult and 16 child deaths in the state of Texas alone.[4,5]

Asthma attacks vary in severity sometimes requiring emergency medical service (EMS) ambulance treatment. A recent review summarizing existing systematic reviews of asthma-related interventions (not medication) that could be carried out by community asthma control programs indicated two intervention methods had the strongest record of effectiveness: self-management education, and more general, comprehensive home-based multitrigger reduction interventions.[6] However, the uptake of these interventions is weak. Of people with asthma, only 12.2% report taking a management class and 49.3% receive counselling on reducing triggers at work or home.[3] Given that effective interventions have been identified but not fully implemented, researchers have emphasized the importance of future efforts geared towards communities suffering from a disparate asthma burden.[6] Additionally, preventing an asthma health emergency would preserve EMS resource availability for other urgent needs and potentially reduce health care costs. Each EMS response has a baseline cost of approximately 1400 dollars (Dr. David E. Persse, personal communication, August 1, 2013) in the study area.

Rates of asthma hospitalization are known to vary by and within states,[7] but spatial variation of asthma attack rates requiring EMS ambulance treatment within city has not been documented. Because cardiac arrest rates are known to vary across a city according to neighbourhood characteristics, it is expected that spatial variation of asthma attack rates requiring EMS intervention also exisits.[8–14] The location of this study is Houston, Texas. Houston is the fourth largest city in the United States. Houston EMS ambulance responded to 12,644 emergency calls for asthma from 2004 to 2011. The goal of this study was to evaluate if the rate of asthma attacks requiring EMS ambulance response varied across a large metropolitan city, and if so, provide this information to public health officials to target interventions toward high-rate areas. In addition to spatial information, understanding the demographics of those who have required EMS ambulance response for an asthma attack and when attacks are most likely to occur may further inform officials of how to target interventions. It has been hypothesized that a portion of asthma attacks requiring EMS ambulance treatment may be prevented with improved education and access to care. This is the first study to evaluate EMS ambulance-treated asthma attack cases by space, time, and demographic with the intent of targeting prevention.

Methods

Study design and setting

All cases in which an EMS ambulance team designated the working assessment in the field as asthma and the patient was treated with nebulized albuterol were considered in the study. In 2012, the asthma incidence data was obtained from Houston Fire Department calls spanning an eight-year period from 2004 to 2011. Due to missing variables such as age or time of incidence, 3.9% of the data was removed from the study. After removing the incomplete cases, the database consisted of $n = 12{,}155$ (9593 adults and 2562 children under 18) cases of EMS treated asthma. Both Rice University and Baylor College

Table 1 – EMS ambulance-treated asthma attacks in Houston, Texas from 2004 to 2011. Case level statistics.

Characteristic	Adult No. of events	Child No. of events
Total cases (%)	9593 (100)	2562 (100)
Sex (%)		
Female	5684 (59)	925 (36)
Male	3909 (41)	1637 (64)
Race/Ethnicity (%)		
Asian	148 (2)	28 (1)
African American	6639 (69)	1879 (73)
Hispanic	1033 (11)	509 (20)
Indian	52 (1)	13 (1)
Unknown	40 (0)	10 (0)
Caucasian	1681 (18)	123 (5)
Median age	46	8
Average age (SD)	47 (18)	8 (4)
Year (%)		
2004	1014 (11)	233 (9)
2005	1127 (12)	292 (11)
2006	1104 (12)	310 (12)
2007	1386 (14)	342 (13)
2008	1342 (14)	360 (14)
2009	1186 (12)	326 (13)
2010	1229 (13)	349 (14)
2011	1205 (13)	350 (14)

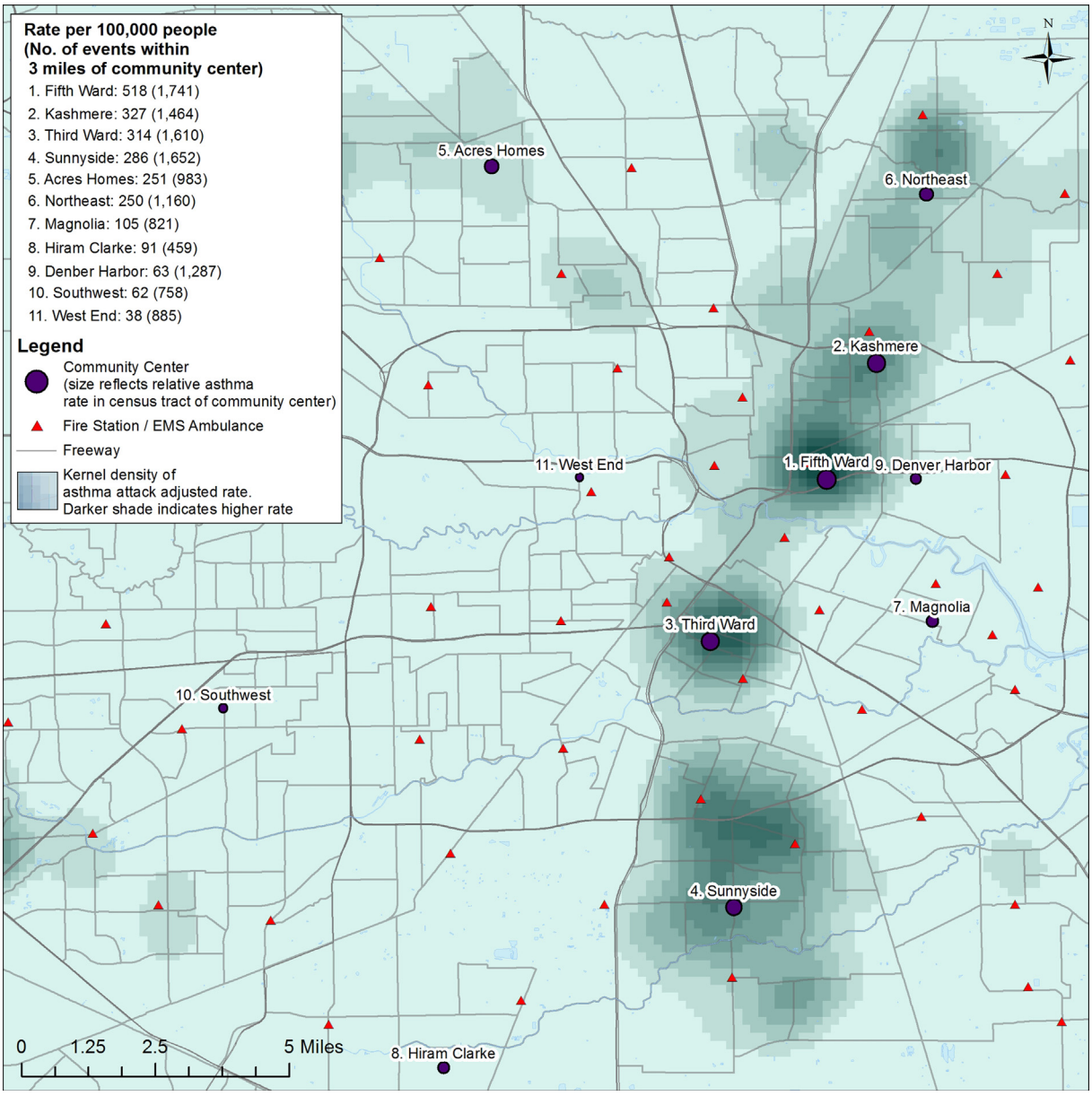

Fig. 1 – Kernel density map of adult EMS ambulance-treated asthma attack rate for 2004–2011, eleven community centers identified as potential intervention locations priority ranked by Bayesian adjusted rate of EMS ambulance-treated asthma attack.

of Medicine IRBs approved all data-collecting procedures for human subjects.

Selection of participants

All patients two years of age and older were included in this study. Patients less than two years of age were excluded from the study because the diagnosis is less reliable.

Measurement

EMS dispatch begins a case record that is updated with patient information by the responding EMS personnel. This record is transferred electronically to a database where the information is kept to create a patient care record. EMS data included the latitude and longitude of the event, the physical address, and whether albuterol was administered. In addition to the time and location of the incidence, other information regarding age, sex, and race/ethnicity was recorded electronically. The EMS database consists of data collected according to National EMS Information Systems guidelines.[15] If the location was missing, the geocoded location was identified using ArcGIS version 10.1 (ArcGIS, version 10.1). Locations were complete for 99% of cases. ArcGIS was used to match event locations to census tracts. Census tract demographic data was obtained using the 2010 Census Summary File 1 and the 2006–2010 ACS 5-year estimates.[16,17] All census tracts were retained within the EMS Service Area.

Table 2 – Census tract characteristics for child and adult: city-wide, and in vs out of high-rate area.

Characteristic	City-wide	Adult In high-rate area	Adult Outside high-rate area	Child In high-rate area	Child Outside high-rate area
Number of tracts (%)	592 (100)	115 (19)	477 (81)	103 (17)	489 (83)
Population (%)	2,949,582 (100)	461,416 (16)	2,488,166 (84)	422,252 (14)	2,540,370 (86)
Sex (%)					
Female	1,477,485 (50)	234,760 (51)	1,242,725 (50)	216,960 (51)	1,267,196 (50)
Male	1,472,097 (50)	226,656 (49)	1,245,441 (50)	205,292 (49)	1,273,174 (50)
Race (%)					
Caucasian	1,541,914 (52)	132,777 (29)	1,409,137 (57)	104,804 (25)	1,443,644 (57)
African American	644,672 (22)	234,645 (51)	410,027 (16)	233,574 (55)	413,692 (16)
Other	762,996 (26)	93,994 (20)	669,002 (27)	83,874 (20)	683,034 (27)
Hispanic origin (%)[a]					
Yes	1,251,088 (42)	188,282 (41)	1,062,806 (43)	132,078 (31)	1,124,184 (44)
No	1,698,494 (58)	273,134 (59)	1,425,360 (57)	290,174 (69)	1,416,186 (56)
Mean (SD)					
Bayesian rate of EMS treated asthma attack per 100,000[b]	66 (90)	207 (108)	32 (36)	162 (121)	28 (45)
Median age	33 (6)	34 (5)	33 (6)	33 (5)	33 (6)
Percent of people w/less than High School Degree	26 (19)	35 (14)	24 (19)	30 (13)	25 (19)
Median household income	53,589 (34,464)	31,038 (11,310)	59,025 (35,939)	31,870 (12,444)	58,112 (35,849)
Percent of people earningless than 20,000/year	6 (5)	9 (4)	6 (4)	8 (4)	6 (5)
Percent of people earningless than 10,000/year	8 (7)	15 (9)	6 (5)	16 (9)	7 (5)

[a] Based on adult data from the American Community Survey Data: People who identify their origin as Hispanic may be of any race/ethnicity. Thus, the percent Hispanic should not be added to percentages for racial categories.
[b] Child rate based on child population within tract.

Data analysis

Statistical analyses were conducted using SAS, version 9.3. The annual rate of incidence for each census tract was calculated from the census tract EMS treated asthma attack annual count average divided by the census tract child or adult population size. An empirical Bayes method was employed to stabilize unadjusted incidence rates that may be subject to overestimation in small census tract populations.[18]

The census tracts in the highest quartile for the adjusted EMS treated asthma attack rate were identified as high-rate tracts. Spatial mapping was used to determine if the high-rate census tracts existed as contiguous areas. This method for identification of high-rate areas was duplicated with Kernel analysis and found to be consistent. Stability of rates within census tracts and contiguous regions was assessed by calculating the Spearman correlation of adjusted rates over the eight-year period.

Census tract demographic information was used to identify the demographic characteristics (e.g., race/ethnicity, income, education, age, gender) of the high-rate census tracts compared with that of the remainder of the city. Logistic regression was used to calculate the relative risk of a census tract identified as high-rate with a percent increase in a census tract demographic characteristic.

The case level demographic information collected by the EMS (i.e., race/ethnicity, age, and gender) was evaluated to identify those cases within the high-rate area calling after normal doctor office hours (before 9 a.m. and after 4 p.m.). The authors posit that a portion of those calling after hours revert to ambulance use because of limited access to care after hours. In addition to adding to the intervention and prevention education target audience information, this information can be used to identify areas in need of affordable care alternatives with flexible hours.

Finally, EMS ambulance treated asthma attack rates were calculated by three mile buffer distance from fire stations and potential city intervention points (e.g., community center, and public school). These locations were priority ranked in terms of census tract EMS treated asthma attack rate.

Results

The study case level population information is given in Table 1. The total number of events in the study is 12,155 of which 9593 were adults and 2562 were children. Adult cases averaged 47 years old (SD 18 years) and children cases averaged 8 years old (SD four years). More female adults than male (59%–41%, respectively) and more male children than female (64%–36%, respectively) required EMS ambulance treatment. African American ethnicity dominated the study (69% of adult cases and 73% of children cases) followed by Caucasian adults (18%) and Hispanic children (20%). Note that these ethnicity percentiles are not in parallel with the makeup of the city. For e.g., African Americans make up only 22% of the city yet approximately 70% of the cases of EMS treated asthma attacks. Of the total adult cases in the study period, the percent found in each year remained fairly constant ranging from 11% in 2004 to 14% in 2007 and 2008. For children, the

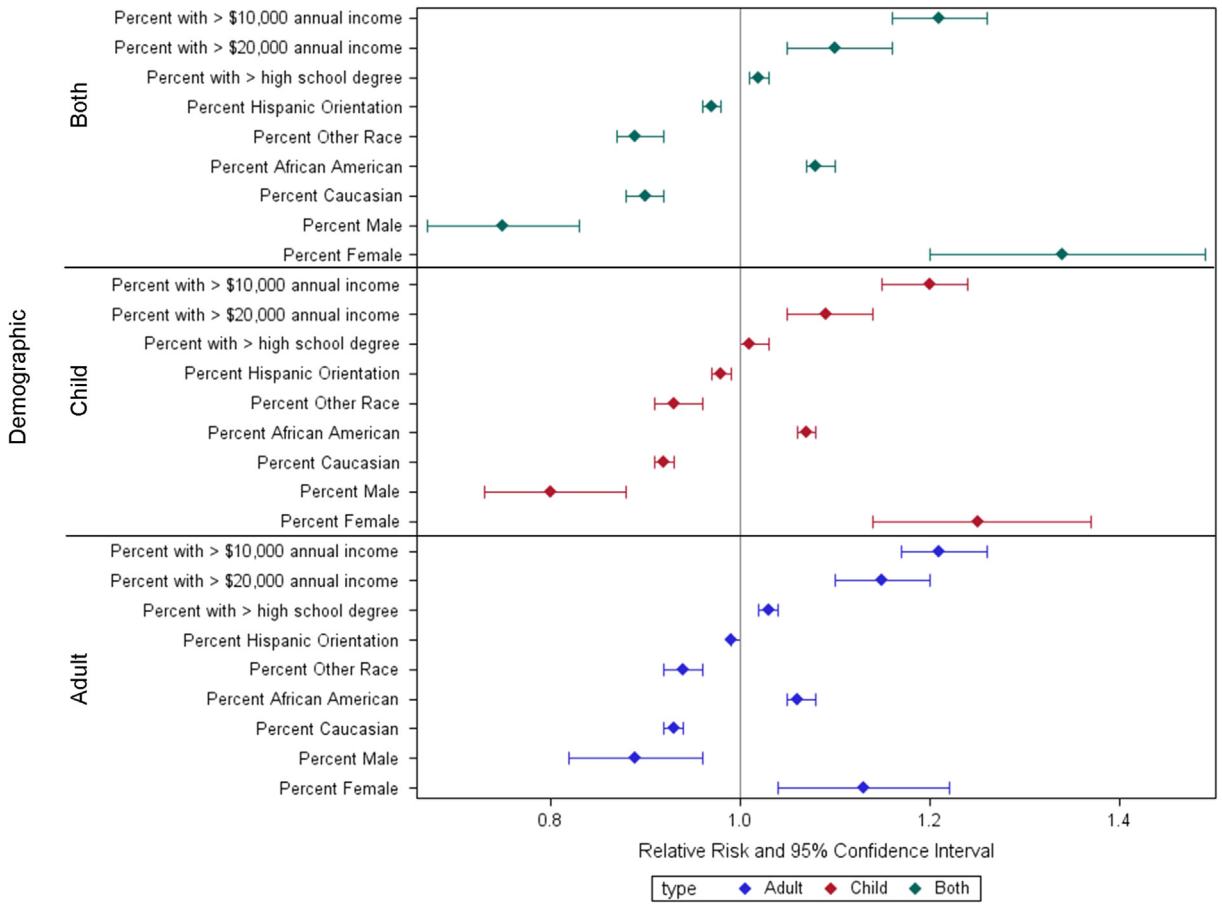

Fig. 2 – Relative Risk (With 95% Confidence Intervals) of EMS ambulance-treated asthma attacks in vs out of high-rate area with percent increase in census tract characteristics.

annual percent of total cases ranged from 9% in 2004 to 14% in 2008, 2010 and 2011.

Identification of high-rate area

The census tracts identified as high uncertainty areas based on comparisons between adjusted and unadjusted rates and low population were found to be airports and the main business district. These tracts were flagged and removed from this analysis because the objective of this research is directed toward identification of neighbourhood intervention locations. The flagged census number, location and rate per 100,000 people were: 9800, airport, 7292; 9801, airport, 2208; 5320.02, wastewater plant, 16; 4544, park, 57; and 1000, downtown, 61. Without these tracts, the average annual rate of incidence across census tracts was 66 per 100,000 people (SD 90) and 51 per 100,000 people (SD 82) for children.

Seventy-eight percent of the upper quartile rate census tracts were found to be contiguous for adults, and 75 percent of the upper quartile rate census tracts were found to be contiguous for children. This area was designated as a high-rate area. There is only a slight spatial difference between the adult and child high-rate area. The adult rate within the high-rate area is 207 cases per 100,000 people (SD 108) compared with 32 cases per 100,000 (SD 36) outside the high-rate area. For children, the rate within the high-rate area is 162 cases per 100,000 people (SD 121) compared with 28 cases per 100,000 (SD 45) outside the high-rate area. Fig. 1 indicates the high-rate area for adults and children identified by the Kernel analysis. Rates and the high-rate area were found to be stable across the study years with a year-to-year census tract rate correlation coefficient $r = 0.84$ to 0.94 ($P < 0.001$).

Census tract characteristics in and out of high-rate area

Table 2 provides census tract demographic information in the high-rate area and the remainder of the city for both the adult and child rate. The logistic regression of the demographic information in the high-rate area vs the remainder of the city (Fig. 2) indicates that there is an increased risk of being in this high rate area with a census tract level increase of percent of population: earning less than $10,000 yearly income (RR 1.21, 1.16–1.26), which is black (RR 1.08, 1.07–1.10), which is female (RR 1.34, 1.20–1.49), and have obtained less than a high school degree (RR 1.02, 1.01–1.03).

Case characteristics in high-rate area

The logistical regression of case level data within the high rate area indicates there is an increased risk of requiring an

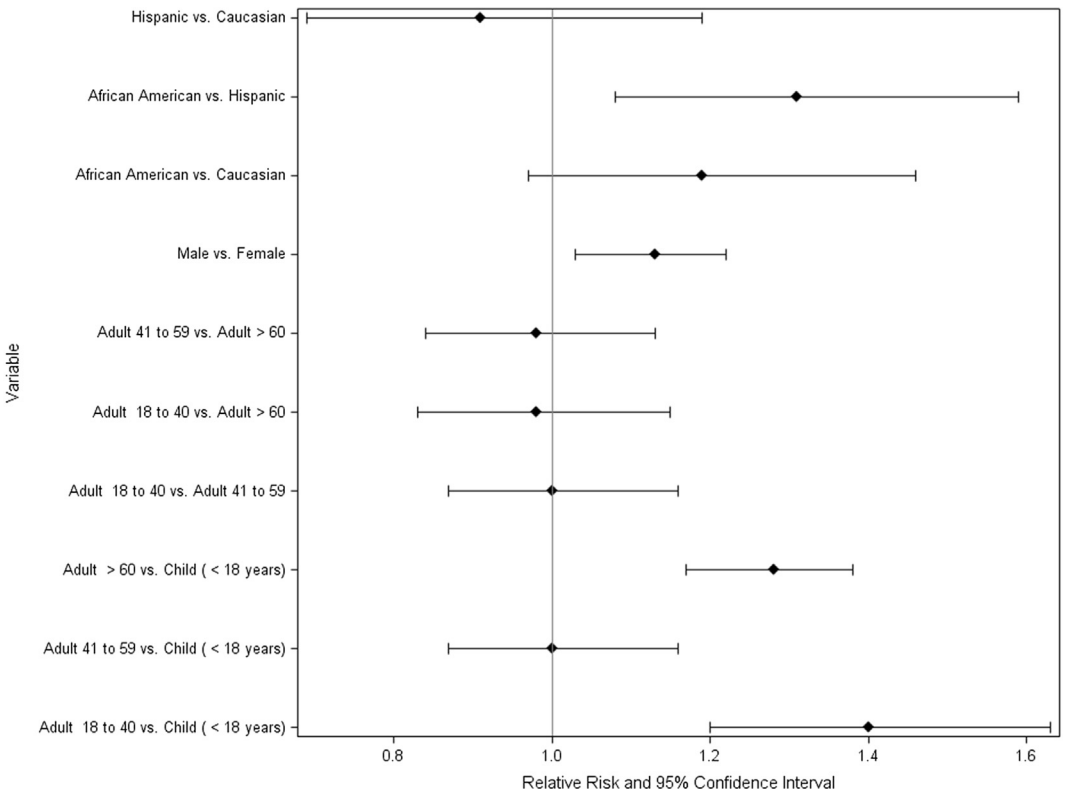

Fig. 3 – Relative Risk (With 95% Confidence Intervals) of EMS ambulance-treated asthma attacks after normal doctor office hours based on case level demographic characteristics within the high-rate area.

ambulance after normal doctor office hours for some demographics (9 a.m.–5 p.m.). The results are listed in Fig. 3. The highest risks were found for men compared with women (RR 1.13, 1.03–1.22), for African American compared with Hispanic ethnicity (RR 1.31, 1.08–1.59), and for adults (less than 41 and greater than 60) compared with children (RR 1.40, 1.20 to 1.63 and RR 1.28, 1.17 to 1.38, respectively).

Discussion

One route to improve public health and avert EMS ambulance treated asthma attack events is to focus intervention on those most at risk on the community level according to the historic record. While health department workers may be generally aware of the propensity for a given demographic or area of town to require EMS treatment for an asthma attack, the specific details and quantitative detection of elevated clusters of disease are needed for monitoring, aetiology, and early warning.[19]

In this study, systematic inspection of EMS data leads to identification of high-rate area of EMS treated asthma attack events, and the census tract demographics of those regions. Further, the individual age, race/ethnicity and gender to target spatially were identified using case level data.

The City of Houston Health Department took this information and identified three potential groups of physical locations for city directed intervention: community centers, schools, and EMS locations. To date, focus has been on the community centers. Cases in a three mile radius of each community center location were evaluated. The eleven city community centers were priority ranked by Bayesian adjusted rate of EMS treated asthma attack (Fig. 1) and the vicinity demographic characteristics (age, race/ethnicity and gender), the frequency of cases by time of day, day of week, and season of year were evaluated.

The analysis indicated that in and out of the high-rate area, certain seasons were more important than others. The city will schedule asthma education in these targeted community center locations especially during or before the relevant seasons identified in this study. The city will also raise awareness among the targeted community and primary and specialty care providers about the need for quality asthma self-management education. Quality asthma self-management education includes tailored education on how to handle signs and symptoms of worsening asthma, medication use and compliance, inhaler and spacer techniques, use of a written asthma action plan and education regarding potential environmental triggers for asthma.[20]

Day of week and time of day information indicate that cases occur throughout the week but more often than not after normal business hours assuming an eight hour workday. This information indicates that providing access to after-hours clinics, where needed, could also prevent the need for EMS ambulance treatment for asthma attacks. The city is raising awareness of the need for access to care and quality asthma self-management education services in these targeted locations.

The question of who, what, and when are more simply answered by statistics than why certain areas or

demographics require EMS treatment for asthma. At least part of the reason why a high-rate area is focused may be that the area is low-income. Because many of these individuals may not be able to afford their routine asthma medication, asthma is exacerbated until it requires EMS. Twenty-five percent of African American adults and 20% of Hispanic adults cannot afford their medications.[21] Therefore, when contemplating averting EMS treated asthma events by education and better physical access to care, affordability of treatment options should also be considered.

With a large number of cases contained in a highly diverse metropolitan area, this study is the first to the knowledge to evaluate the EMS ambulance treated asthma attack cases by space, time and demographic information to target prevention.

With the identification of high rate areas of EMS treated asthma attacks, it has been ensured that efforts used for prevention and management are applied where they are needed rather than where they are convenient.[22] The eleven community centers identified as potential intervention locations and priority ranked by Bayesian adjusted rate of EMS ambulance-treated asthma attack can serve as valuable guidance for the city to prioritize assignment of public health educators to community high-rate locations with special attention to engage identified demographics specific to that community center. Because asthma affects many individuals nationwide, this method can be used in cities across America with the intention of reducing EMS treated asthma cases and its associated financial burden.

Limitations

Calculation of rates by census tract assumes that the asthma incidence occurred near the home. The use of the EMS field diagnosis of asthma as the method to include a case may introduce error when asthma is not the correct diagnosis. Intervention through education and increased access to care are expected to reduce a portion of acute asthma attacks requiring ambulance treatment in the targeted areas. However, differences in the disease by demographic are not considered and may play a role in effectiveness.

Author statements

Acknowledgements

This work was supported by Houston Endowment and the City of Houston. The authors acknowledge Ally Bremer, Maitreyi Chintalapati, and Jiao Li for their work and dedication to this study. The authors would also like to thank Donna Travis, Aaron Cano, Arturo Blanco, Bobbie Harris and Jerry Corpening and the City of Houston Health and Human Services Department for their contributions.

Ethical approval

Both Rice University and Baylor College of Medicine IRBs approved all data-collecting procedures for human subjects.

Funding

City of Houston and a grant from Houston Endowment.

Competing interests

There are no competing financial interests.

REFERENCES

1. Environmental Protection Agency. *What is asthma*. Research Triangle Park, NC: U.S. EPA; 2013.
2. Centers for Disease Control and Prevention. *Mortality and life expectancy. mortality by underlying cause, ages 18+*. Hyattsville,MD: National Center for Health Statistics, Centers for Disease Control and Prevention. Available at: http://205.207.175.93/hdi/ReportFolders/ReportFolders.aspx; 2009.
3. Centers for Disease Control and Prevention. Vital signs: asthma prevalence, disease characteristics, and self management education—U.S., 2001–2009. *MMWR Morb Mortal Wkly Rep* 2011;**60**:547–52.
4. Centers for Disease Control and Prevention. *Asthma facts—CDC's National Asthma Control Program Grantees, 2013 National Asthma Control Program Grantees*. Atlanta, GA: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention; 2013.
5. Centers for Disease Control and Prevention. *Asthma in Texas*. Atlanta, GA: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention; 2008.
6. Labre MP, Herman EJ, Dumitru GG, Valenzuela KA, Cechman CL. Public health interventions for asthma: an umbrella review, 1990–2010. *Am J Prev Med* 2012;**42**:403–10.
7. Knudson A, Casey M, Burlew M, Davidson G. Disparities in pediatric asthma hospitalizations. *J Public Health Manag Pract* 2009;**15**:232–7.
8. Raun LH, Jefferson LS, Persse D, Ensor KB. Geospatial analysis for targeting out-of-hospital cardiac arrest intervention. *Am J Prev Med* 2013;**45**:137–42.
9. Lerner BE, Fairbanks RJ, Shah MN. Identification of out-of-hospital arrest clusters using a geographic information system. *Acad Emerg Med* 2005;**12**:81–4.
10. Reinier K, Thomas E, Andrusiek DL, Aufderheide TP, Brooks SC, Callaway CW, Pepe PE, Rea TD, Schmicker RH, Vaillancourt C, Chugh SS, Resuscitation Outcomes Consortium Investigators. Socioeconomic status and incidence of sudden cardiac arrest. *CMAJ* 2011;**183**:1705–12.
11. Sasson C, Keirns CC, Smith D, Sayre M, Macy M, Meurer W, McNally BF, Kellermann AL, Iwashyna TJ, CARES (Cardiac Arrest Registry to Enhance Survival) Study Group. Small area variation in out-of-hospital cardiac arrest: does the neighborhood matter? *Ann Intern Med* 2010;**153**:19–22.
12. Ong ME, Earnest A, Shahidah N, Ng WM, Foo C, Nott DJ. Spatial variation and geographic-demographic determinants of out-of-hospital cardiac arrests in the city-state of Singapore. *Ann Emerg Med* 2011;**58**:343–51.
13. Iwashyna TJ, Christakis NA, Becker LB. Neighborhoods matter: a population-based study of provision of cardiopulmonary resuscitation. *Ann Emerg Med* 1999;**34**:459–68.
14. Galea S, Blaney S, Nandi A, Silverman R, Vlahov D, Foltin G, Kusick M, Tunik M, Richmond N. Explaining racial disparities in incidence of and survival from out-of-hospital cardiac arrest. *Am J Epidemiol* 2007;**166**:534–43.
15. National Highway Traffic Safety Administration. *EMS data standard*. Office of Emergency Medical Services, National Highway Traffic Safety Administration. Available at: http://

www.nemsis.org/media/XSD_v3/_nemsis_v3.3.2/3.3.2.130520/DEMEMS/DataDictionary/NEMSISDataDictionary_v3.3.2.130520_Overview.pdf; 2013.
16. U.S. Census Bureau. *Census 2010 summary file 1, Houston, Texas Suitland*. MD: U.S. Census Bureau. Prepared by Social Explorer. http://www.socialexplorer.com.
17. U.S. Census Bureau. *2006–2010 American community survey Houston, Texas. Suitland*, MD: U.S. Census Bureau. Prepared by Social Explorer. www.socialexplorer.com.
18. Devine OJ, Luis TA, Halloran ME. Empirical Bayes method for stabilizing incidence rates before mapping. *Epidemiology* 1994;**5**:622–30.
19. Patil GP, Taillie C. Upper level set scan statistic for detecting arbitrarily shaped hotspots. *Environ Ecol Stat* 2004;**11**:183–97.
20. National Asthma Education and Prevention Program. *Expert Panel Report 3: guidelines for the diagnosis and management of asthma*. NIH pub no 07-4051. Bethesda, MD: National Heart, Lung, and Blood Institutes of Health. Available from:, http://www.nhlbi.nih.gov/guidelines/asthma/; 2007.
21. Center for Disease Control and Prevention. *Asthma's impact on the nation*. Atlanta, GA: National Center for Environmental Health, Center for Disease Control and Prevention; 2012.
22. Waller LA. Detecting disease clustering in time or space. In: Brookmeyer R, Stroup DF, editors. *Monitoring the health of populations: statistical principles and methods for public health surveillance*; 2003. Oxford Scholarship Online.