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Emergency Medical Services Demand: An Analysis of County-Level Social Determinants

Jackson D Déziel PhD MPA NRP

School of Health Sciences, Western Carolina University, Cullowhee, NC, USA

Original Research

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Corresponding author:
Jackson Déziel,
Email: jddeziel@wcu.edu.

Abstract

Objectives: Variations in the demand for Emergency Medical Services (EMS) exist when observed at a local level. This unspecified heterogeneity leads to an investigation of social factors contributing to EMS demand.

Methods: Data for this study were collected from publicly available EMS reports from Florida and Oklahoma for 2009 - 2015. Health and social data were gathered from County health rankings and roadmap reports. Data were combined into a single dataset, and pooled ordinary-least-squares models with time-fixed effects were utilized for tests of inference. EMS call volume was log-transformed to derive a semi-elasticity function.

Results: A total of 874 county-year observations were analyzed. Increases in poor/fair health (95% CI: 0.6% - 3.9%), binge drinking (95% CI: 1.6% - 3.5%), teen birth rate (95% CI: 1.1% - 5.2%), unemployment rate (95% CI: 0.5% - 3.9%), and violent crime rate (95% CI: 1.0% - 3.0%) were associated with an increase in the EMS demand rate.

Conclusion: The data supports the notion that some community measures have an effect on EMS demand as counties with higher levels of poor health, binge drinking, teen births, unemployment, and violent crime saw higher EMS demand. These factors may have been treated as spurious, or overlooked by policy makers and EMS leadership.

Introduction

The demand for Emergency Medical Services (EMS) is an ever-present reality in communities throughout the United States. In the late 1960s, researchers began to develop simple mathematical demand models to better design newly established emergency medical response systems and account for variable demand.[1–3] While EMS prediction models have since moved from stochastic endeavors to the deterministic realm (while incorporating Geographic Information System visualizations and forecasting), they have often been limited to a singular geographic area with efficient ambulance deployment/placement as the emphasized deliverable.[4–6] Although individual community needs are of great import for designers and managers of EMS systems, factors may exist that transcend geopolitical boundaries and can be bookmarked as universal predictors of demand.

Drawing from social determinants of health theory, this research seeks to explore broad socioeconomic and health behavior elements among disparate U.S. counties and their association with EMS demand.[7–9] In doing so, a shift of the unit of analysis is proposed from the individual to the locale, also, broad community and environmental factors have remained largely unexplored when studying EMS demand. Expanding on older research that has focused solely on singular urban population centers and individual-level explanatory mechanisms, this analysis highlights the impact of the greater community and expands our understanding of EMS demand variations.

As demand for EMS increases much faster than can be explained by population increase, social factors merit a close inspection.[10] Although individual health status decreases with progressively lower socioeconomic conditions, one's state of health is inexorably tied to the community.[11–13] Research has repeatedly pointed to socioeconomic conditions as contributors to individual health status.[11–15] Generally, one's health state has shown to be connected to the community's socioeconomic status above and beyond the socioeconomic status of the individual,[14] and that simply living in a poor community may be bad for one's health.[15]

Methods

For this retrospective analysis of panel data, EMS demand data were collected from publicly available ambulance call volume reports from the Florida EMS Section and Oklahoma EMS Division.[16,17] Each state reported total annual requests for service per county in all counties. All 77 Oklahoma counties publicly reported through the years 2009 to 2015 (OK State Dept. of Health), while all 67 Florida counties reported through the years 2010 to 2014 (FL Dept. of Health). These ambulance data were not completely exclusive to 9-1-1 emergency activations and may have included a small number of non-emergent medical transport requests. The call

volume reports did not include the transport decision. Florida and Oklahoma represent distinct regions of the United States and have both urban and rural areas.

County-level health and social data were gathered by the Robert Wood Johnson Foundation (RWJF) and are publicly available in their annual County health rankings and roadmaps reports. The County health rankings data is comprised of multiple factors concerning population health and is conducted each year in each county across the United States.[18] These data are frequently used by public health researchers and have been widely validated.[18] Ambulance data are publicly available through each state's respective department of health and verified by state officials.

Selected individual health behavior and socioeconomic measures were analyzed as a function of county-level EMS demand (Table 1). Through the RWJF County health rankings, the health behavior variables included in this analysis are self-reported by the respondent. For the socioeconomic status variables in this analysis, data and proportions are generally available via official reports from various governmental agencies.

The included RWJF variables were chosen on completeness across all years (2009 – 2015) and were representative of the 5 key areas within the social determinants of health (SDOH) framework. Akaike and Bayesian information criteria tests were utilized to determine final model specifications.[19] Information criteria tests established a combined semi-elasticity model the most appropriate, with 11 independent variables across health behavior and socioeconomic areas (Table 1). Variance Inflation Factors (VIF) and tolerance levels were calculated to identify potential multicollinearity within the final model.[20]

Stata statistical software (Version 13; College Station, TX) was used for data analysis. EMS call volume (per 10000 persons) was log-transformed (natural log) to derive a semi-elasticity function of demand. Within the panel data, there were some empty data cells resulting in an unbalanced panel. Due to the unbalanced nature of the panel data, pooled ordinary least squares models with time (year) fixed-effects were utilized for tests of inference. Control variables included county-level race, age, and sex proportions along with population density, median household income, and metropolitan statistical area (MSA) status.

Results

A total of 874 county - year observations were analyzed. The metropolitan statistical area (MSA) breakdown included 304 urban county-years (34.8%), 495 rural county - years (56.6%), and 75 frontier county - years (8.6%). After Variance Inflation Factors (VIF) and tolerance levels were calculated, no statistically significant collinearity was found among the independent variables.

The mean county area was 858 square-miles with a mean population of 140583. EMS annual call volume averaged 23505 over all county - years. Mean population density was 173 per square - mile with an average EMS call rate of 1281 per 10000 residents. Proportionally, those older than 65 years comprised 17.3% of the population, females 49.3%, and African Americans 8.3%. Median household income across all county-years was $41614 (Table 2).

Over the core analyzed years (2010 – 2014), average county population increased 5.1% and county population density increased 4.2%. Correspondingly, average EMS call volume increased 7.1% while EMS calls per 10000 increased 6.9% (Table 3).

Across all county-year observations, 19.4% of residents reported their health as poor or fair and experienced 4 poor mental health days per year. Among adults, 23.5% were regular smokers, 31.3% were obese, and 13.2% reported binge drinking (Table 4).

The average teen birth rate was 56.8 per 1000 (aged 15 – 19 years) and the average high school graduation rate was 77.3%. Among adults, 23.7% were not covered by health insurance and 7% were unemployed. On the average of all county - years, 25.7% of children fell below the federal poverty level. And the average violent crime rate was 369 per 100000 residents (Table 4).

EMS demand rate was positively associated with increases in county - level poor health, binge drinking, teen birth rate, unemployment, and the violent crime rate (Table 5). A 1% point increase in poor/fair health was correlated with a 2.3% increase in the EMS demand rate (95% CI: 0.6% - 3.9%). A 1% point increase in binge drinking was correlated with a 2.5% increase in the EMS demand rate (95% CI: 1.6% - 3.5%). An additional 10 teen births per 1000 was correlated with a 3.2% increase in the EMS demand rate (95% CI: 1.1% - 5.2%). A 1% point increase in the unemployment rate was correlated with a 2.3% increase in the EMS demand rate (95% CI: 0.5% - 3.9%). And an increase of 100 violent crimes per 100000 was correlated with a 2.0% increase in the EMS demand rate (95% CI: 1.0% - 3.0%) (Table 5).

EMS demand rate was negatively associated with obesity and the child poverty rate (Table 5). A 1% point increase in obesity was correlated with a 1.2% decrease in the EMS demand rate (95% CI: -2.2% - -0.2%). A 1% point increase in the child poverty rate was correlated with a 1.1% decrease in the EMS demand rate (95% CI: -1.9% - -0.2%). The remaining health behavior and socioeconomic measures did not yield statistically significant findings (Table 5).

Although used as control variables, county-level demographic measures also produced statistically significant results. The proportion of African Americans, proportion of females, and population density were positively correlated with EMS demand rate (Table 6). A 1% point increase in African Americans was correlated with a 0.6% increase in the EMS demand rate (95% CI: 0.2% - 1.1%). A 1% point increase in the females was correlated with a 3.4% increase in the EMS demand rate (95% CI: 1.3% - 4.6%). A 10 person per square mile increase was correlated with a 0.3% increase in the EMS demand rate (95% CI: 0.2% - 0.3%) (Table 6).

Median household income was negatively associated with the EMS demand rate (95% CI: -0.01% – 0.01%). The proportion of those over 65 years old was positively related to the demand rate, but statistical significance was minimal (95% CI: -0.04% - 12.8%) (Table 6).

Discussion

The social determinant of health framework has been a previously unexplored theoretical mechanism through which to analyze EMS demand. As our understanding of population-level health has grown, the onus has progressively shifted from the individual to the greater community.[11,12] When considering health as a community asset,[21] a "health in all policies" approach must incorporate EMS stakeholders.[9,21]

Any approach to understanding ambulance utilization may prove futile if the greater environment is not considered. Health care systems (including EMS systems) operate within the societal bounds of the community, not free or separate from them.[9,21,22] After examination, the data in this study support the notion that some community measures and behaviors have a statistically significant association with EMS demand. Policy makers and EMS leadership can use these findings to more appropriately predict the needs of their community.

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Table 1. Definition of health behaviors and socioeconomic measures

Variable Category	Robert Wood Johnson Foundation Definition
Health Behaviors	
% Poor/Fair Health	Percent of adults that report fair or poor health
Poor Mental Health Days	Average number of reported mentally unhealthy days per month
% Smoker	Percent of adults that reported currently smoking
% Obese	Percent of adults that report BMI >= 30
% Binge Drink	Percent of adults that report excessive drinking
Socioeconomic Status	
Teen Birth Rate	Teen births/ / females ages 15 - 19 per 1000
% Uninsured Adults	Percent of population < 65 without insurance
High School Grad Rate	Graduation rate (Cohort or Averaged Freshman)
% Unemployed	Percent of population age 16+ unemployed and looking for work
% Child Poverty	Percent of children (under age 18) living in poverty
Violent Crime Rate	Violent crimes/population per 100000

Table 2. Descriptive analysis of demographic variables

Variable	Mean	Standard Deviation	Minimum	Maximum
Area	858.97	380.21	240	2251
EMS Calls	23505.65	63106.47	90	582507
Population	140583	319,202.9	2202	2675000
Persons/Sq Mile	173.08	374.26	1.2	3349.76
EMS Demand Rate	1281.46	587.25	153.69	11248.15
% Over 65	17.32	4.97	9.2	51.6
% African American	8.28	8.51	0	55.19
% Female	49.33	2.97	35.32	52.47
Median Household Income	$41614	$7449	$27771	$68421

Table 3. Descriptive analysis of change in mean population and EMS demand

	2010	2014	% Change
Population	156298	164276	5.10
Persons/Sq Mile	191	199	4.19
EMS Demand	26066	27921	7.12
EMS Demand Rate	1245	1331	6.91

Previous study of individual urban population centers has shown that frequent users of EMS have been noted to have a disproportionately higher frequency of substance abuse and behavioral health incidents.[23] Similarly, employment rates,[24] household income,[25] and population density[26,27] have been shown to affect local EMS demand. Additionally, traumatic incidents occur more frequently in neighborhoods with higher unemployment rates, larger minority proportions, lower educational levels, and lower income levels.[28]

Table 4. Descriptive analysis of independent variables

Variable	Mean	Standard Deviation	Minimum	Maximum
Health Behaviors				
% Poor/Fair Health	19.39	4.37	9.6	35.8
Poor Mental Health Days	4.04	0.88	0.74	9.6
% Smoker	23.45	4.93	10.4	40.2
% Obese	31.27	3.92	18.9	41.4
% Binge Drink	13.16	3.67	0	28.1
Socioeconomic Status				
Teen Birth Rate	56.84	17.26	16.99	103.3
% Uninsured Adults	23.68	4.09	14.61	45
High School Grad Rate	77.32	10.89	26.67	100
% Unemployed	7.03	2.78	2.1	15.6
% Child Poverty	25.71	6.86	10	46.5
Violent Crime Rate	369.36	234.73	17.97	1323.19

Table 5. Semi-elasticity of health behavior and socioeconomic measures on EMS demand rate

Variable	Coefficient	95% Confidence Interval	*P* - Value
% Poor/Fair Health	0.0225	0.0063 – 0.0386	0.006
Poor Mental Health Days	0.0278	- 0.0118 – 0.0674	0.169
% Smoker	- 0.0017	- 0.0121 – 0.0086	0.742
% Obese	- 0.0115	- 0.0215 – - 0.0015	0.024
% Binge Drink	0.0253	0.0162 – 0.0345	< 0.000
Teen Birth Rate	0.0032	0.0011 – 0.0052	0.002
% Uninsured Adults	- 0.0056	- 0.0149 – 0.0034	0.217
High School Grad Rate	0.0028	0.0001 – 0.0055	0.044
% Unemployed	0.0222	0.0053 – 0.0392	0.010
% Child Poverty	- 0.0107	- 0.0196 – - 0.0019	0.017
Violent Crime Rate	0.0002	0.0001 – 0.0003	0.006

*Controls for demographics, MSA status, population density, and time fixed-effects

Table 6. Semi-elasticity of demographic measures on EMS demand rate

Variable	Coefficient	95% Confidence Interval	*P* - Value
Median Income	- 0.0001	- 0.0001 – - 0.0001	0.007
% Over 65	0.0062	- 0.0004 – 0.1281	0.066
% African American	0.0061	0.0015 – 0.0106	0.009
% Female	0.0339	0.0127 – 0.0462	< 0.000
Population Density	0.0003	0.0002 – 0.0003	< 0.000

*Controls for health behaviors and socioeconomic variables

It has been shown that the lower a person's overall socioeconomic status, the higher the likelihood of ambulance utilization.[25,29,30] Although areas of lower socioeconomic status yield a higher EMS utilization rate, these areas also produce a higher

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concentration of high-acuity calls.[30,31] Additionally, the incidence of cardiac arrest has been shown to be 30% to 80% higher in the lowest compared to the highest socioeconomic status quartiles.[31]

As a retrospective endeavor, there are limitations to this study. Social determinants of health are best analyzed at the neighborhood, ZIP code, or census tract level. Further research could highlight a more granular picture of EMS demand by examining these data at an increasingly micro level with additional race and ethnicity proportions. Additionally, county reports of EMS call volume did not distinguish between emergent and non-emergent requests, thus a small portion of call volume may have included non-emergent requests. Patient acuity was also unknown.

Conclusion

County-level analysis of EMS call volume has shown a positive correlation with many community health behaviors and socioeconomic measures. Counties with higher levels of poor health, binge drinking, teen births, unemployment, and violent crime were seen to have higher EMS demands per 10000 people. As anticipated and supported by previous research,[24–27] demographic variables such as median income, percentage, ages 65 years or older, and population density were also correlated with EMS demand rates. The theoretical mechanism behind the negative correlation between EMS demand and obesity rates and child poverty rates is unknown but may speak to the broader community resource landscape (e.g., food deserts, social services funding, etc.) and deserves some extra scrutiny.

This study highlights an opportunity for policy makers and EMS leadership to proactively explore the social conditions of the community. As EMS agencies across the nation begin to take on additional public health activities, it must be established whether these practices will yield definitive results in terms of emergency ambulance utilization. Community paramedicine and other wrap-around services may serve to mitigate negative effects within the social determinants of health framework and could decrease unnecessary ambulance utilization while allocating EMS resources in a more efficient manner. Further investigation is needed in this area in order to gain a greater understanding of variations in EMS demand.

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