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RESEARCH ARTICLE

Impact of Community Socioeconomic Characteristics on Emergency Medical Service Delays in Responding to Fatal Vehicle Crashes

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Introduction: This study aimed to determine the impact of community socioeconomic status on emergency medical services' response time for fatal vehicle crashes.

Methods: Authors used the 2019 National Highway Traffic Safety Administration Fatality Analysis Reporting System and 2019−2020 Area Health Resource Files to obtain emergency medical services' time intervals and county socioeconomic characteristics (e.g., median household income, availability of trauma centers, and rurality), generating a study sample of 18,540 individuals involved in fatal vehicle crashes between January and December 2019. Generalized linear models with log-link and Gamma-family were used to obtain estimates, and other variables were adjusted in the model.

Results: Both the mean time of the emergency medical service arrival to the site of the crash and the mean transport time from the crash site to hospital varied by county SES. Counties with a higher mean household income had 12% shorter emergency medical services' arrival times and up to 7% shorter emergency medical services' hospital transport times than counties with lower SES. The emergency medical services' hospital transport times by emergency medical services also varied by proximity to trauma centers and were 15% shorter in counties that had ≥2 trauma centers than in counties without trauma centers.

Conclusions: This study shows socioeconomic disparities in emergency medical service rescue time for fatal vehicle crashes. Community characteristics play a major role in emergency medical services' arrival time intervals. Prior research demonstrated a strong link between the timeliness of emergency medical service response and the likelihood of survival in fatal motor vehicle accidents. These findings showing that socioeconomically disadvantaged areas and those lacking trauma facilities had slower emergency medical service rescue times, suggest that socioeconomic status may be a predictor of mortality in fatal motor vehicle accidents. Effective emergency medical services are essential to reduce the morbidity and mortality among motor vehicle crash victims; however, disparities exist in the timeliness of these services by geographic and socioeconomic county characteristics. Further research is urgently needed to inform policy interventions.

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INTRODUCTION

Road traffic crashes are the leading cause of death and injuries for individuals aged ≤54 years in the U.S.[1] In 2019, individuals aged ≥15 years were involved in a total of 6.8 million police-reported crashes in the U.S., including 2.3 million resulting in injuries requiring emergency department visits and hospitalizations and 36,096 fatal motor vehicle accidents.[2,3] Furthermore, vehicle crashes often cause life-long physical disabilities, mental trauma, and financial hardship even if the crash victim survives. In 2018, traffic crash deaths led to $55 billion in medical costs to the victims and their families.[4]

Importantly, the literature suggests that emergency medical services (EMS) response time plays a critical role in rescuing and treating victims and improving their likelihood of survival. Furthermore, morbidity in trauma is crucially aggravated if a patient does not receive adequate trauma care within the first hour of the injury, also known as the golden hour.[5] The likelihood of severe injury complications and fatality increases considerably after 5 minutes of the trauma occurrence.[6] Rapid field triage—the process of identifying seriously injured patients in need of care in specialized trauma centers—is a critical component of EMS care.[6,7] *EMS response time* is defined as the time interval between EMS notification and arrival on the scene, which potentially determines the survival likelihood of an injured patient. The early arrival of EMS allows early stabilization of crash victims with severe injuries, timely triage, and transportation to a medical care facility.[6,8,9] Prior research indicates that shorter time intervals between the crash occurrence and EMS arrival at the hospital may result in improved survival rates. For example, according to Byrne et al., increased EMS response times were significantly associated with a higher rate of motor vehicle crash mortality (≥12 vs <7 minutes).[10] In addition, although trauma centers in the U.S. are growing in number, their varying geographic distribution across states and different regions within the states can result in inequitable access to timely trauma care.[11,9]

The association of SES and morbidity and mortality in fatal motor vehicle accidents has been less well studied.[12,13] Some studies have reported that differences in SES (income, poverty, and low education) either at the county level or state level, motor vehicle crash injuries, and fatalities are more prominent in poorer regions.[14–17] Non-Hispanic Blacks, particularly men, are at 1.48 times higher risk of dying than non-Hispanic Whites in motor vehicles.[12]

However, there is limited research on the association of county socioeconomic factors with the EMS rescue times after a crash occurs. This paper aims to address this evidence gap regarding the association between county sociodemographic characteristics and disparities in the timeliness and quality of EMS services. The authors used 2019 data from the National Highway Traffic Safety Administration Fatality Analysis Reporting System and the Health Resources and Services Administration Area Health Resources Files to compare (1) time interval between the vehicle crash and EMS arrival, (2) time interval between EMS notification and EMS arrival, (3) time interval between EMS arrival and hospital arrival, and (4) time interval between the crash and hospital arrival across different counties from 50 states and 2 territories of the U.S.

METHODS

The authors used the 2019 Fatality Analysis Reporting System (FARS)[18] and 2019−2020 Area Health Resource Files (AHRF) data.[9] FARS is a national-level database collected by the National Highway Traffic Safety Administration, which includes data of all the fatal traffic crashes occurring in the 50 states, the District of Columbia, and Puerto Rico. The National Highway Traffic Safety Administration defines *fatal traffic crashes* as cases involving the death of either the vehicle occupant or a non-occupant within 30 days of the crash, which were identified from multiple sources such as police crash reports, death certificates, and coroner/medical examiner reports.

The 2019 FARS data comprised 23 data files (e.g., accident, person, vehicle, drugs, and more) and 3 auxiliary files (e.g., person-, accident-, and vehicle-auxiliary) at crash-, vehicle-, person-, and event-levels, including 3 unique identifiers (state case, vehicle, and person number), allowing the authors to merge the files and construct individual-level analytic data files. The 2019 FARS accident data file consists of 33,244 fatal crashes involving 82,220 individuals. The authors used 3 data files: accident, person, and person auxiliary files. The accident file includes various information such as date and time of the accident, ambulance arrival times at the crash site, and the ambulance arrival times at the hospital. Person data files provide information such as victim age and sex, EMS transport used, seating position, use of seat belt, and others, and person auxiliary files include information such as race/ethnicity, age groups, alcohol testing, and more.

AHRF provides county-level data across 3,142 counties from various sources such as the U.S. Census, American Community Survey, American Hospital Association, and others, including demographics (e.g., age, sex, race/ethnicity), SES (e.g., education, employment, median household income, insurance status), medical providers (e.g., primary care physician, and hospital characteristics), urban−rural areas (e.g., metropolitan statistical areas [MSA]), and trauma center information, among others.

Study Population

The study population included all age groups whose fatal traffic crashes required any type of EMS to be transported to the hospital. For this study, the authors first merged the FARS accident, person, and person auxiliary data files using the state case unique identifier, generating a total of 82,220 individuals and 33,244 crashes from the 2019 FARS data. Then, the authors merged the person-level FARS file and county-level AHRF files using state and county Federal Information Processing Standards codes.

The study population included all the individuals who were involved in fatal traffic crashes requiring transportation to the hospital via EMS, excluding all motor vehicle crash victims who either died at the crash scene or en route to the hospital because EMS transporting times for these individuals were not documented within the FARS database (Appendix B, available online). However, other victims involved in the crash could have been transported to the hospital. The unit of analysis is each individual rather than an accident. Notably, each individual could be transported to different hospitals or with different priorities, depending on the severity of the injury and transportation capacity, although individuals were in the same vehicle crash. For some crashes, the different time points (accident occurred, EMS notified, EMS arrived at the crash scene, and EMS arrived at the hospital) were incorrectly recorded or were missing. After dropping missing values, the analytic population was 18,540 individuals, as shown in Appendix C (available online).

Measures

EMS response times. Using the FARS crash times, the authors constructed 4 outcomes measured in minutes to account for the following various time intervals related to a car crash: time interval between vehicle crash and EMS arrival (Time Interval 1 [T1]), time interval between EMS notification and EMS arrival (Time Interval 2 [T2]), time interval between EMS arrival and hospital arrival (Time Interval 3 [T3]), and time interval between crash and hospital arrival (Time Interval 4 [T4]) (Appendix A, available online). The authors differentiated T1 and T2 to account for delayed notification, if any, between when a crash occurred and EMS arrival. The time interval T1 was measured by the difference between the time when the EMS arrived at the crash scene and the time when the crash occurred. T2, T3, and T4 were generated similarly.

Independent variables. The primary independent variable was a categorical variable produced by 4 quartiles of median household income (bottom [<$42,000], second, third, and top [$57,616−$115,314] category), for 3,142 counties in the U.S. In multivariable regression analyses, the authors adjusted both victims' other independent variables, including the demographics of car accident victims and county-level demographics, and SES, where the car accident occurred. FARS provides the age in years for each crash victim. Using these data, age was categorized as 0−11, 12−18, 19−29, 30−39, 40−49, 50−64, and ≥65 years. Other victim demographics included sex (male versus female) and race/ethnicity (non-Hispanic White, non-Hispanic African American, Hispanic, and others, including multiracial, Native American, and Pacific Islander). The race/ethnicity information was only available for deceased crash victims, as it was obtained from the death certificates.

From AHRF, county-level independent variables for SES included education (percentages of individuals aged ≥25 years with a high school diploma or college degree, generated by quartiles) and employment status (percentage of employed persons aged ≥16 years, generated by quartiles). For these percentages, the authors created quartiles for each county. Other county-level independent variables included insurance status (persons aged <65 years with any health insurance, generated by quartiles), availability of trauma centers with no specific trauma level designation (no trauma center, 1 trauma center, and ≥2 trauma centers available), and MSA (categories: rural [urban cluster <10,000 population], micro [urban cluster >10,000 but <50,000 population], and metropolitan [urban cluster of >50,000 population]). To measure the true impact of counties' racial/ethnic composition on outcomes, the authors adjusted majority of race/ethnicity in each county (non-Hispanic White, non-Hispanic African American, Hispanic, and others).

Statistical Analysis

The authors presented the descriptive summary statistics of each dependent and independent/explanatory variables. Pairwise correlations were conducted to check multicollinearity between explanatory variables. Bivariate analysis used ANOVA to examine the differences in each variable with median household income categories (Appendix F, available online).

A generalized linear model with a log-link function and a Gamma-family (GLM-LG) was used because the continuous outcome variables were skewed to the right and had outliers. To improve interpretability of the GLM-LG model, estimates were interpreted as semi elasticity, by converting the raw coefficients reported in Table 1 to coefficients multiplied by 100. Semielasticity measures the percentage change of outcome with respect to unit change of explanatory variable. The authors performed sensitivity analyses to obtain categorical

Table 1. Generalized Linear Model Adjusted Coefficients Between Crash Time Intervals, Crash Victim's Characteristics, and Community Characteristics Using the FARS, 2019 and AHRF, 2019–2020

Variables	Coefficient (95% CI)			
	Time Interval 1 (T1) - Crash and EMS arrival at scene	Time Interval 2 (T2) - EMS notification and EMS arrival at the scene	Time Interval 3 (T3) - EMS arrival at the scene and EMS arrival at the hospital	Time Interval 4 (T4) - Crash and EMS arrival at hospital
Age category, years				
0–11	−0.054 (−0.130, 0.023)	0.005 (−0.047, 0.056)	−0.012 (−0.050, 0.027)	−0.028 (−0.068, 0.011)
12–18	0.130 (0.037, 0.223)	0.068 (0.020, 0.116)	0.025 (−0.014, 0.065)	0.053 (0.008, 0.098)
19–29	−0.005 (−0.076, 0.066)	−0.003 (−0.039, 0.033)	−0.010 (−0.040, 0.021)	−0.009 (−0.043, 0.026)
30–39 (ref)	ref	ref	ref	ref
40–49	−0.063 (−0.131, 0.004)	0.003 (−0.040, 0.045)	0.008 (−0.027, 0.043)	−0.016 (−0.052, 0.020)
50–64	−0.005 (−0.085, 0.075)	0.020 (−0.018, 0.057)	−0.012 (−0.043, 0.019)	−0.011 (−0.048, 0.027)
≥65	−0.110 (−0.181, −0.039)	−0.090 (−0.129, −0.051)	−0.026 (−0.058, 0.006)	−0.053 (−0.088, −0.018)
Race/ethnicity				
Non-Hispanic White (ref)	ref	ref	ref	ref
Black/African American	−0.117 (−0.191, −0.043)	−0.039 (−0.089, 0.012)	−0.076 (−0.116, −0.037)	−0.092 (−0.132, −0.053)
Hispanic	−0.093 (−0.201, 0.014)	−0.005 (−0.072, 0.062)	0.003 (−0.048, 0.054)	−0.031 (−0.086, 0.023)
Others	−0.015 (−0.106, 0.076)	0.078 (0.018, 0.139)	−0.002 (−0.045, 0.041)	−0.012 (−0.059, 0.035)
Not a fatality[a]	−0.033 (−0.093, 0.026)	0.034 (0.008, 0.061)	0.005 (−0.017, 0.028)	−0.009 (−0.038, 0.019)
Race unknown	−0.142 (−0.240, −0.045)	−0.047 (−0.117, 0.022)	0.091 (0.016, 0.166)	0.029 (−0.035, 0.093)
Hospital transfer				
EMS ground (ref)	ref	ref	ref	ref
EMS air	0.509 (0.424, 0.594)	0.458 (0.414, 0.502)	0.223 (0.184, 0.262)	0.318 (0.275, 0.361)
Law enforcement	−0.048 (−0.215, 0.118)	0.047 (−0.117, 0.211)	0.078 (−0.066, 0.223)	0.040 (−0.079, 0.159)
EMS mode unknown	0.164 (−0.031, 0.358)	0.139 (0.039, 0.240)	0.002 (−0.063, 0.066)	0.055 (−0.033, 0.144)
Transported unknown source	−0.018 (−0.318, 0.282)	0.080 (−0.208, 0.369)	−0.374 (−0.550, −0.199)	−0.268 (−0.432, −0.103)
Other	0.070 (−0.048, 0.188)	0.238 (0.114, 0.362)	0.036 (−0.049, 0.121)	0.048 (−0.030, 0.126)
Not transported	0.035 (−0.006, 0.075)	0.016 (−0.008, 0.039)	−0.003 (−0.022, 0.016)	0.009 (−0.011, 0.030)
Community race/ethnicity majority[b]				
Non-Hispanic White (ref)	ref	ref	ref	ref
Black/African American	0.010 (−0.049, 0.069)	0.037 (−0.014, 0.087)	−0.012 (−0.048, 0.024)	−0.003 (−0.035, 0.029)
Hispanic	0.013 (−0.061, 0.087)	−0.033 (−0.085, 0.020)	−0.171 (−0.213, −0.129)	−0.113 (−0.154, −0.073)
Others	0.072 (−0.036, 0.179)	0.007 (−0.067, 0.080)	−0.119 (−0.188, −0.050)	−0.072 (−0.128, −0.015)
Community median household income[b]				
Bottom quartile (ref)	ref	ref	ref	ref
Second quartile	0.019 (−0.057, 0.095)	0.042 (−0.005, 0.088)	0.066 (0.029, 0.103)	0.055 (0.016, 0.094)
Third quartile	−0.115 (−0.203, −0.027)	−0.064 (−0.114, −0.014)	0.109 (0.066, 0.151)	0.046 (0.002, 0.091)
Top quartile	−0.118 (−0.226, −0.009)	−0.088 (−0.143, −0.033)	0.137 (0.091, 0.184)	0.071 (0.015, 0.126)

(continued on next page)

Table 1. Generalized Linear Model Adjusted Coefficients Between Crash Time Intervals, Crash Victim's Characteristics, and Community Characteristics Using the FARS, 2019 and AHRF, 2019−2020 (*continued*)

	Coefficient (95% CI)			
Variables	**Time Interval 1 (T1) - Crash and EMS arrival at scene**	**Time Interval 2 (T2) - EMS notification and EMS arrival at the scene**	**Time Interval 3 (T3) - EMS arrival at the scene and EMS arrival at the hospital**	**Time Interval 4 (T4) - Crash and EMS arrival at hospital**
Community high school diploma or more[b]				
Bottom quartile (ref)	ref	ref	ref	ref
Second quartile	0.028 (−0.037, 0.094)	−0.044 (−0.085, −0.003)	−0.037 (−0.070, −0.004)	−0.008 (−0.044, 0.027)
Third quartile	0.097 (0.028, 0.167)	0.082 (0.035, 0.130)	−0.042 (−0.080, −0.003)	0.008 (−0.029, 0.045)
Top quartile	0.110 (0.035, 0.185)	0.129 (0.075, 0.183)	−0.003 (−0.044, 0.039)	0.035 (−0.005, 0.075)
Community employment[b]				
Bottom quartile (ref)	ref	ref	ref	ref
Second quartile	−0.049 (−0.108, 0.010)	−0.106 (−0.149, −0.064)	−0.168 (−0.209, −0.126)	−0.133 (−0.170, −0.096)
Third quartile	−0.053 (−0.118, 0.011)	−0.140 (−0.189, −0.091)	−0.234 (−0.282, −0.186)	−0.178 (−0.220, −0.137)
Top quartile	−0.048 (−0.128, 0.032)	−0.164 (−0.215, −0.112)	−0.323 (−0.374, −0.272)	−0.240 (−0.288, −0.192)
Community insurance coverage[b]				
Bottom quartile (ref)	ref	ref	ref	ref
Second quartile	−0.214 (−0.278, −0.151)	−0.063 (−0.096, −0.029)	−0.135 (−0.160, −0.110)	−0.166 (−0.198, −0.134)
Third quartile	−0.171 (−0.237, −0.105)	−0.102 (−0.138, −0.066)	−0.153 (−0.180, −0.125)	−0.166 (−0.200, −0.133)
Top quartile	−0.326 (−0.392, −0.259)	−0.228 (−0.267, −0.189)	−0.096 (−0.126, −0.065)	−0.172 (−0.207, −0.137)
Community trauma center[b]				
No trauma center (ref)	ref	ref	ref	ref
1 trauma center available	−0.026 (−0.078, 0.026)	−0.088 (−0.116, −0.059)	−0.152 (−0.175, −0.130)	−0.108 (−0.135, −0.080)
≥2 trauma centers available	−0.247 (−0.290, −0.204)	−0.253 (−0.282, −0.224)	−0.246 (−0.271, −0.221)	−0.245 (−0.269, −0.221)
Metropolitan statistical area[b]				
Rural (ref)	ref	ref	ref	ref
Micro	−0.152 (−0.250, −0.053)	−0.050 (−0.094, −0.007)	−0.061 (−0.098, −0.025)	−0.097 (−0.146, −0.048)
Metro	−0.337 (−0.446, −0.228)	−0.249 (−0.286, −0.212)	−0.119 (−0.151, −0.087)	−0.201 (−0.256, −0.147)

Note: Semielasticity, Coefficient x 100 (semielasticity measures the percentage change of outcome with respect to unit change of explanatory variable).
[a]Not a fatality—the authors do not have the race/ethnicity of individuals who were not fatally injured as the race/ethnicity information is only recorded from death certificates.
[b]County variables depict county-level socioeconomic characteristics derived from AHRF 2019−2020.
AHRF, Area Health Resource Files; EMS, emergency medical service; FARS, Fatality Analysis Reporting System.

variables from FARS and AHRF and to confirm the estimation results.

The University of Nebraska Medical Center IRB exempted the study as the data sources were deidentified and publicly available. Data management and analyses were conducted using Stata/MP version 16.1 (StataCorp LLC, College Station, TX).

RESULTS

Descriptive Summary Statistics

Demographic characteristics of individuals involved in fatal motor vehicle crashes. The descriptive summary statistics for demographics are depicted for the total population of 18,540 road traffic crash victims (Table 2). Mean age was 41 years, and 63.2% of the total population were males. Across age group categories, 22.2% of the victims were aged between 19 and 29 years and 19.1% were between 50 and 64 years. Non-Hispanic Whites accounted for 22.5% of the total population of traffic crash mortalities.

Median household income was < ~$42,000 in the bottom quartile and $57,616–$115,314 in the top quartile; 41.6% of the county population where the crash occurred were included in the top (fourth) median household income quartile ranging from $57,616 to $115,314, followed by the third quartile contributing to 26.1% ranging from $49,889 to $57,611.

Nearly 38% of counties where an accident occurred had no trauma center, 26.5% of the counties had 1 trauma center, and 35.7% of the counties had ≥2 trauma centers. The mean time between crash occurrence and EMS arrival at the scene (T1) was 15.6 minutes. The mean time between when the crash occurred and EMS arrival at the hospital was 50.1 minutes (T4) (Table 3).

Multivariable Regression Analyses. The estimation results show that, compared with crashes that occurred in the lowest-income counties (median household income < ~$42,000), EMS arrival time after the crash was faster by 11.8% for the fourth quartile ($57,616–$115,314) (Table 1). For age of crash victims, EMS arrived faster by 5.4% for victims aged 0–11 years than for victims aged 30–39 years. For transportation facility used during the crash, EMS was 51% slower to arrive at the crash site for air ambulances when compared with ground ambulances. However, only 5.6% of all EMS dispatches in these data were by air ambulance. When compared with rural areas, T1 was faster by 15% (mean time, 20 minutes) for micro and 34% (mean time, 13 minutes) for metropolitian areas.

In addition, the authors found that, compared with crashes occurring in the lowest-income counties, EMS arrival time after notification was reduced by 9% for

Table 2. Summary Statistics Showing Demographics and SES for Individuals Involved in Fatal Crashes Using FARS, 2019 and AHRF, 2019–2020

Variables	*n* (%)
Age category, years	
0–11	1,235 (6.7)
12–18	1,490 (9.0)
19–29	4,119 (22.2)
30–39	2,845 (15.4)
40–49	2,289 (12.4)
50–64	3,538 (19.1)
≥65	3,024 (16.3)
Sex	
Male	11,717 (63.2)
Female	6,823 (36.8)
Race/ethnicity	
Non-Hispanic White	4,167 (22.5)
Non-Hispanic Black	1,000 (5.4)
Hispanic	718 (3.87)
Others	862 (4.7)
Not a fatality[a]	11,256 (60.7)
Race unknown	537 (2.9)
Hospital transfer	
EMS ground	10,053 (54.2)
EMS air	1,036 (5.6)
Law enforcement	45 (0.2)
EMS mode unknown	270 (1.5)
Transported unknown source	35 (0.2)
Other	135 (0.7)
Not transported[b]	6,966 (37.6)
Community race/ethnicity majority[c]	
Non-Hispanic White	16,006 (86.3)
Non-Hispanic Black	1,048 (5.7)
Hispanic	1,216 (6.6)
Others	270 (1.5)
Community median household income[c]	
Bottom quartile	2,403 (13.0)
Second quartile	3,592 (19.4)
Third quartile	4,840 (26.1)
Top quartile	7,705 (41.6)
Community high school diploma or more[c]	
Bottom quartile	2,916 (15.7)
Second quartile	5,369 (29.0)
Third quartile	5,806 (31.3)
Top quartile	4,449 (24.0)
Community employment[c]	
Bottom quartile	2,311 (12.5)
Second quartile	3,537 (19.1)
Third quartile	5,964 (32.2)
Top quartile	6,728 (36.3)
Community insurance coverage[c]	
Bottom quartile	3,928 (21.2)
Second quartile	4,882 (26.3)

(*continued on next page*)

Table 2. Summary Statistics Showing Demographics and SES for Individuals Involved in Fatal Crashes Using FARS, 2019 and AHRF, 2019−2020 (*continued*)

Variables	*n* (%)
Third quartile	4,419 (23.8)
Top quartile	5,311 (28.7)
Community trauma center[c]	
No trauma center	7,014 (37.8)
1 trauma center available	4,913 (26.5)
≥2 trauma centers available	6,613 (35.7)
Metropolitan statistical area[c]	
Rural	2,397 (12.9)
Micro	2,515 (13.6)
Metro	13,628 (73.5)

Note: Community summary statistics were produced after merging FARS and AHRF, hence, the results are proportional to the FARS data.
[a]Not a fatality—the authors do not have the race/ethnicity of individuals who were not fatally injured as the race/ethnicity information is only recorded from death certificates.
[b]Motor vehicle victims were not transported to the nearest hospital because they were either declared dead on-site, en route, or had minor injuries that did not require hospitalization.
[c]Community variables depict county-level socioeconomic characteristics derived from AHRF 2019−2020.
AHRF, Area Health Resource Files; EMS, emergency medical service; FARS, Fatality Analysis Reporting System.

counties with income > ~$57,000. When looking at the transportation facility used during the crash, compared with ground EMS, victims who were transported by air EMS observed a 46% slower EMS arrival time. Compared with crashes that occurred in rural areas, EMS arrival times were faster by 25% for metropolitan areas.

Overall EMS response times (the time between a motor vehicle accident occurrence and EMS arrival to the scene, T1) for motor vehicle accidents that occurred in counties ranking within the lowest quartile of median household income were 11.8% slower than the EMS response times in counties ranking within the highest median household income quartile. T2 were also 9% lower for accidents occurring in counties that ranked within the lowest socioeconomic quartile than for counties that ranked within the highest quartile. T3 showed a similar trend, by being the longest in counties ranked in the lowest socioeconomic quartile (7%), and the shortest within counties ranked in the highest socioeconomic quartile (14%).

When compared with counties with a higher population of non-Hispanic White residents, counties with a higher population of Hispanic residents, saw 17% faster EMS arrival time to the hospital. When compared with counties with no trauma center, the authors observed that the EMS arrival times to the hospital were 24.6% faster for counties with ≥2 trauma centers. Sensitivity analyses were conducted to derive the categories of county socioeconomic (median household income, high school diploma or higher, employment, insurance coverage, trauma centers, MSA) and sociodemographic (race/ethnicity majority) variables, however, the results were not substantially different.

DISCUSSION

To the best of our knowledge, there is limited to no prior research on the association of county socioeconomic factors with EMS rescue times after a crash occurs. However, SES, particularly income, has been reported to be a strong indicator of mortality.[15] This study examines the effects of county-level socioeconomic characteristics on EMS arrival times, either to the crash site or hospital. The authors found that the average time between when the crash occurred and EMS arrived at the hospital/trauma center was about 50 minutes. This time includes crash identification, notification, EMS arrival at the crash time, EMS resuscitation and stabilizing efforts, and EMS transport to the nearest hospital/trauma center.[7] One of the key findings of this study showed that, when compared with crashes that occurred in the lowest-income counties (mean time, 21 minutes), the EMS arrival time was reduced by 11.8% (mean time, 13 minutes) for crashes that occurred in high-income counties. For example, in this study's data, EMS arrival time to fatal crashes averaged about 15 minutes. Thus, the decreased arrival time in high-income counties would translate into nearly 2 minutes faster response than that in the lowest-income counties. Studies show that shorter time intervals between crash occurrence and EMS arrival at the hospital result in significantly improved survival rates. According to Males,[10] longer EMS response times were significantly associated with higher rates of motor vehicle crash mortality (≥12 vs <7 minutes). This study

Table 3. Descriptive Summary Statistics For Time Intervals (T1−T4) Using FARS, 2019

Time intervals	Mean (minutes)	SD	Median	IQR
Time Interval 1 (T1) - Crash and EMS arrival at scene	15.6	27.2	17.48	6.55−17.48
Time Interval 2 (T2) - EMS notification and EMS arrival at the scene	10.3	8.7	8.74	4.37−13.11
Time Interval 3 (T3) - EMS arrival at scene and EMS arrival at the hospital	34.5	23.6	28.40	19.66−41.50
Time Interval 4 (T4) - Crash and EMS arrival at hospital	50.1	38.1	41.51	28.40−58.98

EMS, emergency medical service; FARS, Fatality Analysis Reporting System.

also suggested that EMS may stay slightly longer at the crash scene after arriving in high-income counties than it did in low-income counties. The difference was small (1%−2%), but further research is needed to determine the reasons for this difference. For example, this may relate to differences in crash severity, systematic differences in EMS policies regarding stabilizing patients across these counties, or other factors.

County characteristics play a major role in EMS arrival time intervals. Prior research suggests that SES can be a predictor of overall mortality,[19] and some studies suggested that SES affects non-Hispanic Black and Hispanic populations the most.[20] This study also showed that, compared with counties with a larger non-Hispanic White population, counties with a larger Hispanic population observed a decrease in EMS arrival at the hospital (T3) by 17%. This difference is primarily because of EMS remaining on-scene at the crash site longer. This may relate to crash injury severity or other crash-related factors, but further research is needed to examine this. Studies have also found that hospitalization rates after a motor vehicle accident decreases as county-level SES increases, which could not be explained by place of residence or driving exposures, though other reasons for these differences were not explained.[21] In addition, these data indicated that high-income counties have nearly a 3-fold frequency of fatal crashes (41.6%) compared with counties at the bottom income quartile (13.0%). However, the authors also found that in counties with higher quartiles of median household income, their EMS arrival times after a crash occurrence decreased compared with those in lower quartiles. This may suggest that, despite the high frequency of crashes in high-income counties, there are sufficient EMS resources in place to result in low arrival times after a fatal crash.

It was also observed that education, employment, and insurance have a significant role in EMS arrival times.[22] Prior studies have reported education to be a strong determinant of motor vehicle crash mortality. Non-Hispanic Whites without high school diplomas had the highest death rates. The risk elevates among non-Hispanic Black men and women.[12] However, 22.5% of the motor vehicle crashes that resulted in death were non-Hispanic Whites in this study's data. In addition, the authors found that younger individuals (aged 19−29 years) and those aged >50 (50−64 and >65) years cumulatively accounted for more than half (57.6%) of all fatal motor vehicle crashes during the study period. This study found that, compared with counties included in the bottom quartile for a high school diploma or college, the time interval from car crash to EMS arrival at the crash scene was decreased by 11% for the top quartile.

EMS rescue time is also highly affected by the type of EMS used (i.e., ground versus air ambulance). It may be assumed that air ambulances should be faster than ground ambulances. However, studies suggest otherwise. The basic concept for introducing helicopter EMS (HEMS) was to improve EMS accessibility in remote locations by providing faster transportation and critical care for injured patients.[23] However, HEMS is also susceptible to weather interference, has limited cabin space, and tends to be more expensive. Studies have suggested that mortality increased in trauma patients transported by HEMS by 6% versus only 2.9% for ground ambulances. This is likely to occur because helicopters are used to travel a greater distance and transport severely injured patients.[24] The estimation results showed that, compared with a ground ambulance, the time interval 1 increased by 51% for an air ambulance.

Trauma center accessibility is highly important in providing immediate necessary help to injured patients.[25] A study conducted by Branas and colleagues estimated that about 84.1% of all U.S. residents had access to a Level I and II trauma center which was almost within 60 minutes using either ground or air EMS.[26] However, many studies focused on where people lived and not where the accident occurred.[11,27] Through this study, the authors tried to fill the knowledge gap by focusing on location of the crash and not the residence of the crash victim. This study adjusted trauma center availability in the crash county and examined the effect on EMS rescue times. The authors found that when compared with a county with no trauma centers, counties that have ≥2 trauma centers observed a 25% decrease in T1, T2, and T3. Research has demonstrated that the mortality rate was significantly reduced for patients when care was provided at trauma centers than in nontrauma centers (7.6% vs 9.5% respectively).[28] This would suggest that increasing the number of trauma centers might improve access to trauma care. Truong et al. investigated this hypothesis and found that there is no significant relationship between an increased number of trauma centers geographically and reduced injury-related mortality. They suggest that rather than increasing the number of trauma centers geographically, distributing them based on county characteristics and needs might be an efficient way to improve the trauma care system in the U.S.[29]

This study suggests that the frequency of motor vehicle accidents within metropolitan areas is nearly 7 times greater than that in rural areas. Rurality plays a major role in the distribution of trauma centers. The population is scarce in a rural area and so are the healthcare facilities.[30] A trauma center is essential in any injury situation and, unfortunately, the number of trauma centers that are closing is increasing, and, over the past 2 to 3 decades (1990−2005), about 339 trauma centers have closed out of 1,125 existing centers in the U.S.[31,32] Studies have suggested that trauma center closure affects vulnerable populations, such as rural communities, racial and ethnic minorities, and socioeconomically disadvantaged populations.[35] The authors found that when motor vehicle crashes occurred in rural MSAs, the EMS arrived 15% faster for micro areas and 34% faster for metropolitan areas after the crash occurred (T1). This suggests that the geographic distribution of trauma centers has important implications for the survival of injured crash victims.

After conducting a thorough analysis, the authors found that income, education, employment, and insurance status significantly affect EMS response time. Furthermore, the availability of trauma centers and the mode of transportation used are critical in lowering response times to crashes. Geographic characteristics and racial/ethnic disparities have led to less accessibility of health services; however previous studies, as well as the findings of this study, suggest that there is no bias for EMS. Going forward, the authors would like to assess the reasons behind such disparities.

Limitations

FARS data are collected from various sources such as police reports, coroner's office, death certificates, and hospital data. Because the data only relates to fatal crashes, this study did not include any data on EMS response to nonfatal crashes. For some crashes, times may have been inaccurately recorded in FARS, such as EMS notification times recorded before the crash occurred leading to missing values. Race/ethnicity information in FARS is collected from death certificates, and, for victims who were not fatally injured, their racial/ethnic information was not available. Furthermore, the authors did not examine the driver's residence, and therefore some occupants may have been commuting through counties at the time of the fatal crash. Community characteristics are county-level from the AHRF and some counties can be large in population and geographic area. Controlling MSA may remove some of this strata bias. AHRF provides information on the number of trauma centers in a county; however, it does not report the level of the trauma centers. Most critical motor vehicle crash victims will have to be taken to a Level I or II trauma center for treatment. It is possible that EMS response varies systematically with the time of day or season. Further research is needed to examine this relationship. Finally, there may be other factors not included in the used database that may affect this analysis.

CONCLUSIONS

This study shows an overall impact of socioeconomic characteristics on EMS time intervals in response to fatal road crashes. Even though SES seems to be a powerful risk factor associated with the survival of motor vehicle crashes, few, if any, studies have examined EMS response with geographic variation in SES. The authors saw a significant association between SES and ambulance response time. Ideally, EMS rescue should not be affected by socioeconomic disparities, however, this study suggests otherwise. These findings highlight the need for additional research on the association between EMS response times and the socioeconomic characteristics of victims and of the communities in which crashes are occurring.

Little research exists on the association of county socioeconomic factors with EMS rescue times after a crash occurs. The findings of this study showed socioeconomic and sociodemographic disparities that led to delayed EMS response time. Where EMS should be available for everyone without any bias, the opposite has been observed time and again. The solution lies in conducting further studies on trauma center distribution according to not just population but the SES of the neighborhoods and geographic location. An in depth understanding of why such EMS disparities are observed is needed and once that is identified, working on the solutions can start.

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Sachi Verma: Conceptualization, Formal analysis, Investigation, Methodology, Software, Validation, Visualization, Writing - original draft, Writing - review & editing. Fernando Wilson: Conceptualization, Methodology, Supervision, Writing - original draft, Writing - review & editing, Validation. Hongmei Wang: Methodology, Reviewing. Lynette Smith: Methodology, Validation, Reviewing. Hyo Jung Tak: Conceptualization, Methodology, Software, Supervision.

SUPPLEMENTARY MATERIALS

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