THE ASSOCIATION BETWEEN PEDIATRIC FALL INJURY AND PROPERTY TYPE IN A FIRE DISTRICT OF CLACKAMAS COUNTY

By

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CERTIFICATE OF APPROVAL

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Abstract

Context: Falls account for a disproportionate number of nonfatal injuries in the pediatric population. In 2005, 2.6 million fall injuries in children ages 0-19 were reported to emergency departments, with an associated medical cost of over $6 billion. Research of fall injuries has traditionally focused on individual factors. Recent research into injury has shown associations with environmental factors such as higher rates of poverty and smaller household size.

Objective: To identify characteristics of the environment associated with pediatric fall injury within a fire district of Oregon.

Study Population: Children ages 0-17 years utilizing the emergency medical services (EMS) system within Clackamas County Fire District #1 (CCFD1), Oregon, for 2009 – 2012.

Methods: This case-control study included 562 children age 17 and under who used EMS to report either a fall injury or medical illness. Predictor variables were selected from individual and census tract-level characteristics, with location of injury as the predictor of interest. Location of injury was categorized as either residential or non-residential. A multivariate logistic model was used to characterize the association between fall injuries and location of injury.

Results: Pediatric fall injuries had a significantly decreased odds of occurring at residential locations (OR = 0.26, 95% CI: 0.17 – 0.39) compared to non-residential locations. Census tracts with higher percentages of single mother families and those located further eastward were associated with increased rates of pediatric fall injury.

Conclusions: The results of this study suggest that environmental factors may have an effect on the likelihood of pediatric falls. Non-residential locations, single mother families and eastward location within CCFD1 are all associated with pediatric falls. From these data, targeted interventions may be developed to reduce the risk and degree of pediatric fall injuries.

Background

Public Health Impact of Fall Injuries in the U.S.

Injury, both intentional and unintentional, is a major public health issue for children. The Center for Disease Control (CDC) estimates that in 2010, unintentional injury was the leading cause of death for ages 1-17 years.[1] In 2010, there were over 2 million unintentional fall injuries for children 14 years old and younger that were treated by emergency departments across the U.S., making unintentional falls the leading cause of nonfatal visits to an emergency department (ED) for children ages 0-14. In 2005, fall injuries in children ages 0-19 accounted for a total medical cost of over $6 billion for ED visits alone.[1] Thus, falls represent a large proportion of injury in the pediatric population[2], at a significant cost and efforts should be made to develop effective forms of prevention. Developing interventions to reduce pediatric fall injuries is valuable to reduce the injury sustained by this population as well as reducing the cost for treatment.

The US Public Health Service estimates that two thirds of all falls, both pediatric and adult, could be prevented.[3] To develop successful preventions, it is necessary to understand the factors that lead up to fall injuries. Many previous studies have focused on individual-level factors that may contribute to adverse outcomes, such as drug treatment,[4] disease status[5] and behavior.[6] Preventions targeting behavioral changes, such as prescription drug-use or sleeping behavior are common, as well as preventions focusing on immediate environmental factors such as the presence of carpets, rugs, furniture or handrails.[7] These prevention strategies typically target older individuals, who experience greater levels of mortality due to falling injuries.[8] There is a dearth of interventions in the pediatric population, even though falling injuries is one of the leading cause of nonfatal injuries for younger children.

Fall Prevention in the Pediatric Population

Historically, injury prevention in children has received less attention than injury in the older population, despite the high levels of injury experienced in the U.S.[9] There may be some reasons injuries are less likely to be investigated in the pediatric population, such as the different types of causes for fall injuries or lower rates of mortality as compared to geriatric populations. However, pediatric fall injury places a large financial burden on the population and can lead to serious complications such as traumatic brain injury.[10-12] In 1993, the annual cost of trauma admissions related to pediatric fall injuries in Washington State was $4.5 million;[2] further adding motivation to better understand factors associated with pediatric fall injuries.

Individual-level causes of fatal falls in the pediatric population has been well-studied,[13-17] however the causes in nonfatal falls have not been as well investigated. Different age groups within the pediatric population experience different causes and outcomes of falls;[18-21] for example younger children are more likely to suffer serious head injuries when falling because they do not have the ability to shield themselves and their relatively large head causes it to strike first during a fall.[10] On the other hand, older children are more likely to suffer from lacerations and fractures to their extremities due to shielding their faces when falling and improved coordination.[22]

Given the variation within the cause of falls in the pediatric population, there are several different preventive strategies that target a wide range of forms of injury and causal pathways. Of the few interventions that target the pediatric population, the most successful have focused on fatal falls.[3,23] Window falls have received the most attention[24] starting in the early 70's with the “Children Can’t Fly” program in New York City.[23] Many of these studies took place in controlled environments such as hospitals and apartment buildings, where decisions around fall interventions were applied at the individual or household-levels. In the “Children Can’t Fly” program, window guards provided to families in apartments with children less than 10 years old significantly reduced the number of falls.[23] A previous study has shown that children in Chicago are more likely to fall out of 2nd or 3rd floor windows of apartment buildings,[25] which tend to be nonfatal as compared to falls from higher floors. Unfortunately, despite the overwhelming number of nonfatal falls and their substantial contribution to morbidity and health care costs, targeted interventions have not been implemented.

One reason for the lack of prevention strategies for nonfatal pediatric falls may be the potential for these falls to occur at a variety of different locations, such as the home, other residential locations, commercial locations, schools or even outside locations such as parks and playgrounds. Due to the variety of places at which pediatric falls can occur, it is difficult to research risk factors at specific locations without better understanding where falls most often occur. Conversely, without targeted research around risk factors at locations of fall injuries, it is not feasible to implement successful interventions. One study in the early 1990’s found that among children reporting to emergency departments in New York, the majority of pediatric falls occurred at or near the child’s home.[26] No other studies focus on nonfatal pediatric fall injuries.

A better understanding of the factors that are associated with pediatric fall injuries in non-residential areas would allow for improved interventions. In addition to tailoring interventions around the location of injury, it is important to understand the environments characteristics of the context in which these injuries occur. One study found an association between risk of severe pediatric injury, including unintentional injuries such as falls, and low-income neighborhoods.[27] These results suggest that factors outside of individual-level demographics or home environments may be associated with injury in the pediatric population. Residing in a low-income neighborhood is linked with unsafe play areas outside of the home, and could also imply that children in these areas do not have access to organized extracurricular activities.

A better understanding of the ecological-level risks children face in geographic areas would allow improvements in targeted interventions and population-wide prevention strategies. One technique that has been used to study location-specific risk factors is geographic information systems (GIS). Neighborhood-level information, coupled with person-level data, may provide more clues to prevalence of falls than either piece of information alone.

Several studies have used GIS to better understand epidemiological factors of disease incidence. [28] A study in Stockholm used GIS to match a retrospective emission databases for NO_x/NO_2 and SO_2 as markers of air pollution to residential addresses for a group of men with lung cancer to determine if there was an association.[29] A more recent study utilized GIS to determine communities that were at elevated-risk for out-of-hospital cardiac arrests.[30] There is also precedence for using GIS to associate street-level environment characteristics, such as alcohol outlet availability with intentional injury.[31] In terms of pediatric injury, the majority of recent research has focused mainly on the interaction between pedestrians and motor vehicles.[9,32] In addition to understanding the physical environment influencing the risk of pediatric falls, previous research studies have shown that injury (intentional or unintentional) is more likely to affect children that are part of minority racial, ethnic and low socioeconomic groups.[33]

A recent population-based cohort study done in 9 diverse cities in both the U. S. and Canada has utilized GIS to better understand the association between major trauma events and certain population characteristics. The results of this study indicate that major trauma events are more likely to cluster in areas with higher rates of poverty, higher rates of unemployment, larger percentages of non-White residents, smaller household size and geographical areas with younger individuals.[34] This study focused on all ages within the population; however, similar techniques can be applied to a pediatric population to explore associations between neighborhood-level factors and falls. With a better understanding of the population-level factors that influence risk of fall injury in children, targeted interventions can be developed to help populations most at-risk. Information concerning these environment-level factors may provide clues about prevalence of fall injuries that may not be explained by person-related factors.

Fall Injuries in Oregon

The prevalence of morbidity and mortality due to falls across all age groups is on the rise in Oregon.[35] The prevalence of fall injury in the pediatric population at risk in Oregon mirrors prevalence at the national level. A report published in 2009 indicates that the cost of hospitalization for unintentional injury in Oregon exceeded $348 million in the year 2007, with the leading cause of hospitalization in Oregon being falls.[35] Similar to the national scale, unintentional injury is a huge financial burden to Oregon. Likewise, pediatric falls are one of the top causes of EMS calls in Clackamas County Fire District #1 (CCFD1). CCFD1 represents a large portion of the population within Clackamas County and includes five cities; Milwaukie, Oregon City, Happy Valley, Johnson City and a portion of Damascus. Clackamas County is located to the south and east of the city of Portland, Oregon and includes several cities and major highways as well as parts of two national forests. CCFD1 is on the northwestern corner of Clackamas County and has a mix of regions, including urban, suburban, rural and territorial.

The regional diversity of CCFD1 provides a good representation of many different environmental characteristics as well as a variety of individual-level characteristics. Roughly 70% of the all the 9-1-1 calls made in Clackamas County originate in CCFD1, indicating a potentially large sample size.

Research Questions and Specific Aims:

This study examined the association between the locations of pediatric fall injuries as responded to by emergency management services (EMS). Medical illness calls were selected to provide a comparable control group for this analysis.

In addition, the spatial relationship of pediatric fall injuries by census tract was explored in this analysis. The results from this study guided the understanding of the relationship between the location of injury and the prevalence of pediatric fall injuries within CCFD1. The resulting association can help guide how future interventions, city-planning and behavioral awareness programs can be better implemented to reduce pediatric falls.

1. Is there an association between the type of property and reported pediatric fall injuries in CCFD1?

> *Specific Aim 1*: Describe the individual-level characteristics of children who experience fall injuries and compare them to the individual-level characteristics of children who have medical emergencies using the 2009-2012 EMS data from CCFD1.
>
> *Specific Aim 2:* Determine whether non-residential locations are more likely to be sites of pediatric fall injuries than residential locations. The hypothesis is that non-residential locations are more likely to be areas of pediatric fall injuries as compared to pediatric medical illness calls.

2. Are there census tracts that exhibit a higher-than-average number of pediatric fall injuries within CCFD1?

Specific Aim 3: Identify and describe spatial patterns using ArcGIS, such as clusters of both pediatric fall injuries and pediatric medical illness calls, while controlling for census tract predictors. Utilize regression analysis to determine census tract-level predictors for pediatric fall rates.

Significance

This work provides one of the first analyses to test whether pediatric falls occur more often in non-residential areas. A secondary goal is to understand whether pediatric fall injuries occur in clusters by census tract within CCFD1. Cluster analysis may help to detect areas with increased risk factors, improving the use of resources in targeted interventions for pediatric fall prevention. While many studies have utilized EMS call data, very few have tested if pediatric falls are related to environmental and census tract-level factors. Results from this study will help to guide future research, such as development of more targeted interventions based on location of incident and using individual characteristics like race to predict increased risk of injury due to falling. This research is also important to determine the significance of environmental factors in predicting potential pediatric falls, which in turn can be used to help target at-risk populations. Given that pediatric injury is a major concern, developing non-traditional interventions that do not focus on complicated behavioral change may help to reduce overall injury and reduce income and race/ethnic inequities in injury risk and severity. This type of analysis will provide valuable insight into community factors that might be targeted in pediatric fall prevention strategies.

Rationale: The prevalence of injury due to falls across all age groups is on the rise in Oregon. Interventions have focused mainly on geriatric populations; however falls are one of the top causes of EMS calls among children in CCFD1. This correlates with historical data which indicates that unintentional falls are one of the leading causes of morbidity and mortality in the pediatric population. Little is known about the effect of environmental factors and the type of location on the prevalence of pediatric falls, though fall hazards are more likely to be different between different types of locations. Using EMS call data for pediatric individuals from CCFD1 collected 2009-2012, this case-control study assessed the relationship between fall injuries and the location at which they occur.

Methods

Overview

This study evaluated the characteristics of pediatric fall injuries within CCFD1, a subset of Clackamas County. Pediatric individuals are defined as those individuals less than 18 years old at the time of the incident. This evaluation was accomplished by analyzing EMS calls reported in CCFD1 from 2009-2012; specifically the proportion of EMS calls for pediatric fall injuries relative to pediatric medical calls. This study utilized a case-control study design to determine association between location of injury, specifically non-residential spaces, and pediatric fall injury. Cases were defined as pediatric fall injuries and controls were defined as medical calls responded to by EMS personnel. This study also evaluated characteristics at the census tract level, which are listed in Table 1, to determine the correlation between these factors and pediatric falls. The final step in this analysis was to test the hypothesis that pediatric falls are associated with non-residential locations. A secondary aim of this study was to determine if pediatric fall injuries cluster within census tracts after controlling for census tract-level factors.

Table 1: List of variables and predictors for analysis

Measure	Source
Injury Type (Main outcome)	CCFD1[1] EMS Data
Property Type (Main predictor)	CCFD1 EMS Data
Tranportation to Hospital	CCFD1 EMS Data
Age	CCFD1 EMS Data
Sex	CCFD1 EMS Data
High school level education	2007-2011 ACS[2]
Family size	2007-2011 ACS
Martial status within families	2007-2011 ACS
Single Mother family	2007-2011 ACS
Single Father family	2007-2011 ACS
Grandparents responsible for children	2007-2011 ACS
English language spoken at home	2007-2011 ACS
Family poverty status	2007-2011 ACS

[1]Clackamas County Fire District 1

[2]American Community Survey by census tract

Original Data

EMS call data from Clackamas County was continuously collected via the 9-1-1 emergency system. This data was automatically documented via computer aided dispatch and included information such as latitude and longitude coordinates of the emergency and by responding EMS crews. The incident and patient-level data were used to monitor the EMS system and provide quality assurances, such as reduced response time. CCFD1 encompasses the northwest region of Clackamas County, including the cities of Happy Valley, Oregon City and Milwaukie. There are fifteen fire stations within CCFD1 that respond to 9-1-1 calls that are located both within and outside CCFD1. Figure 1 illustrates CCFD1 with major arteries, waterways and census tracts are outlines on the map.

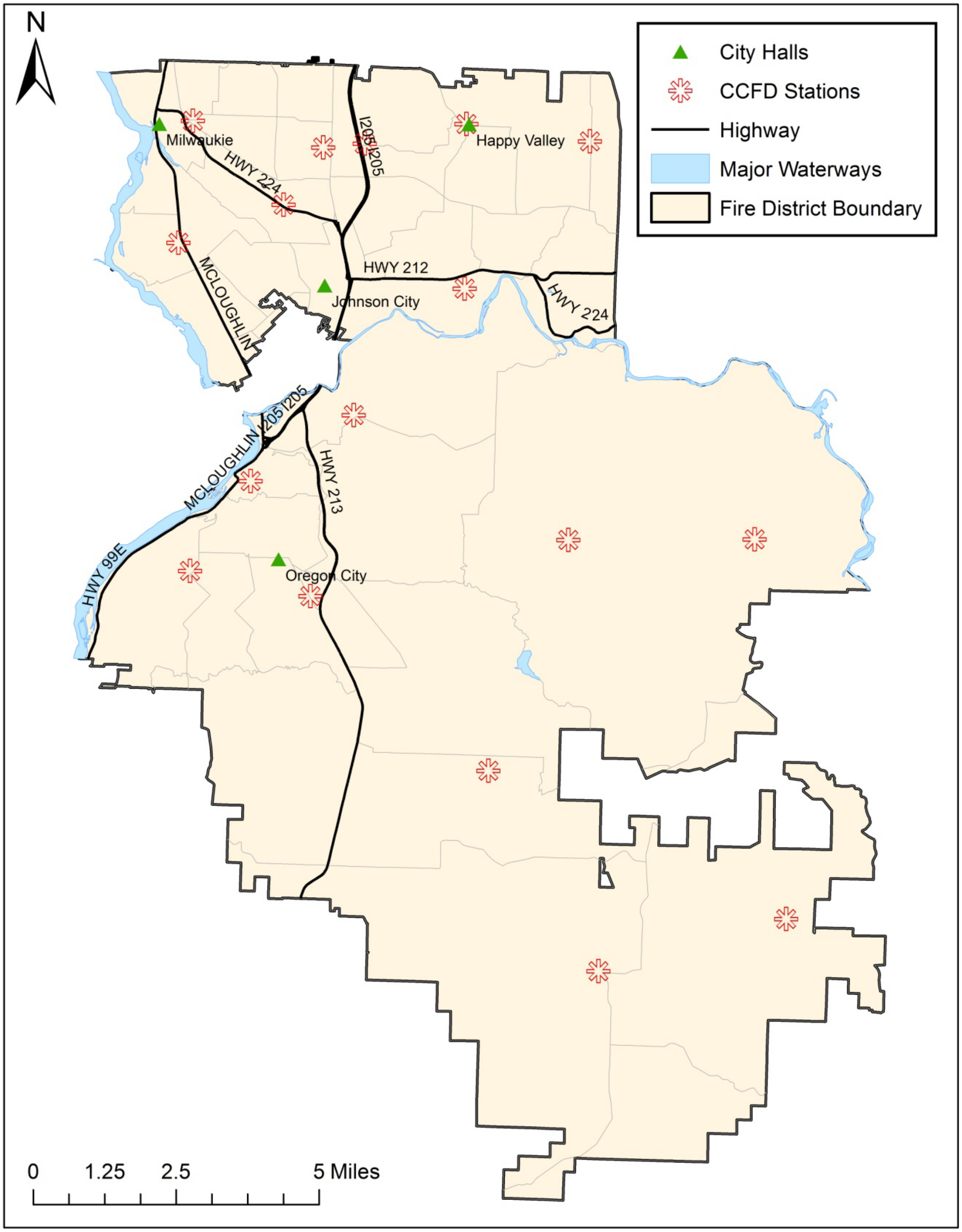

Figure 1: Map of Clackamas County Fire District #1

The database included detailed information about the emergency, such as the number of individuals involved, their ages, type of emergency, and description of locale. It is mandatory for EMS personnel to document this information during the course of an emergency response. If multiple patients were involved in an emergency, there was one incident reported which could have contained multiple patient care charts. Since falls and medical cases occur with single patients, individuals with missing data were censored from the proposed secondary analysis, since it is unknown whether the individual-specific information matched the other members of the incident report or not. This data was collected in the same manner regardless of the type of incident, which reduced any potential bias in data collection.

Selection Criteria

This retrospective case-control study used data from the EMS patient care database and the incident reporting database of Clackamas County was collected 2009-2012. Children who suffered a fall injury were classified as cases; controls were selected from the population of children who EMS responded to common medical illness reasons. The study period began in January 2009 and continued through the end of the year for 2012. Data on all EMS calls were merged with the incident database, based on an incident identification number. During this time period there were 29,276 EMS calls from which the selection criteria were applied to find appropriate cases and controls. This process is outlined in Figure 2.

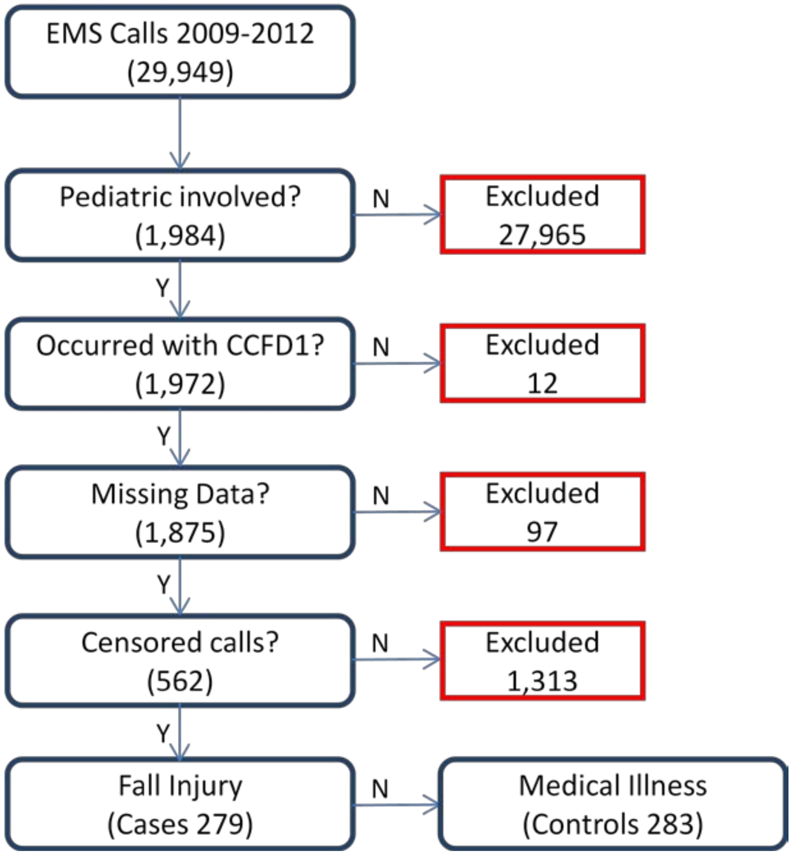

Figure 2: Algorithm for selecting cases and controls in this study

For this analysis, any event that occurred outside of CCFD1 was excluded, even though emergency responders provide aid for events outside of CCFD1. This provided a stable area of interest to investigate, as well as ensure that all potential calls were captured by the department. Some 9-1-1 calls located within CCFD1 that were responded to by outside agencies were also not captured in this analysis.

Control Selection

Controls were selected from the same EMS database as cases and were selected to represent medical illnesses/events requiring EMS support. The decision to use certain medical illness calls as controls was based on controlling for unknown confounders and differences between individuals who utilize the 9-1-1 system, and those individuals who do not. These controls are likely to use EMS to report injury and therefore provide good representation of the outcome of interest in this study. Medical illness calls were also used since these incidents would most likely not experience a fall injury as a secondary aspect of their emergency. Utilizing medical illness calls as a control group allowed for an estimate of the background frequency of exposure in children who do not necessarily suffer from falls. The controls also allow for a population to be defined from which cases can arise, providing a population denominator for this analysis.

Medical illness calls were coded mainly from the EMS assessment or comments documented in the data collected at the time of the incident, similarly to a previous study.[36] Those calls used in this study included respiratory illness, abdominal pain, and general illness. These types of calls were most like pediatric fall injuries in terms of potential for severity, likeliness of transportation to a hospital and commonality within the pediatric population. Calls that related to other forms of injury, such as trauma, assault, motor vehicle accidents or environmental “injuries” (poisoning, hypothermia, venomous bites/stings or burns) were excluded from this analysis.

Excluding non-fall injuries, including the classification “hemorrhaging/bleeding” that were not clearly resultant of fall injuries, from this analysis helped to reduce potential misclassification of the outcome. The decision to exclude the EMS assessment “hemorrhaging/bleeding” from the analysis is based on the concern that if the origin of the hemorrhage could not be determined, it is too ambiguous to categorize as either a fall or a medical illness call. In addition, seizure calls were censored from the analysis, since these may cause falls, but may have vastly different underlying mechanisms with respect to the cause of the fall.

Measurement of Variables

Primary Outcome Variable

The outcome variable, pediatric fall, indicated whether an EMS call for a child (0-17 years) was coded as a fall during the original data collection. Whether an EMS call is documented as a fall or other type was based on three different field entries in the EMS data set. The first two places where a call can be coded as a fall is by the EMS personnel if the cause of the call is a fall, or if the assessment of the event was documented as a fall. This codes the call as a fall in one data field. The EMS personnel at the scene also have the option to add comments to each patient indicating type of injury or cause of injury. These comments were reviewed for fall indicators such as “GLF” or “ground level fall”. Incidents in which the EMS personnel indicated a fall in the comments section were re-coded as a fall, even if they had been categorized as a different type of call. Common categories of calls that were re-categorized to falls are “trauma”, “unknown” and “other”. The exceptions to this were cases that involve either bicycle or motor vehicle accidents, or events documented as assault or physical abuse. These cases were left as they were originally coded, even if there was a fall component to the incident. This is due to the difference in the mechanism of falls that occur during a bicycle or motor-vehicle event, or an assault.

These specific measures have not been validated, yet previous studies have demonstrated the validity of EMS data.[37-39] One study has shown that EMS measures that are quantitative in nature, are more likely to have a higher error rate, than measures such as sex and age.[40] EMS data has been used to accurately report different issues, such as injuries,[34,36] as well as the to improve the utilization of EMS services by the elderly.[41] Several studies validated EMS dispatch codes to identify patients with low-acuity illness to better manage resources.[42,43] Furthermore, EMS providers track aspects of the service to improve the quality and timeliness of services.

These considerations indicate that while the use of EMS data for reporting fall outcomes or property type has not been validated, EMS data are reliable for identifying specific types of emergency calls and documenting property types.

Primary Predictor Variables

The independent variable of interest is the type of property at which the injury occurred. This information was previously documented by EMS personnel when they are dispatched to an event. In total, there were close to 60 different options for this variable, making it necessary to create several broad categories of this variable for analysis. Location was dichotomized into either residential or non-residential areas. Residential areas included single and multifamily dwellings as well as residential streets or driveways. Non-residential areas included commercial buildings, public buildings, school, daycare, playgrounds or parks, highways or streets in commercial areas, as well as both indoors or outdoors recreational areas. Similar categories have been used in a previous study to investigate spatial clustering of pediatric injuries.[36]

Predictors

Most predictors describe census tract-level factors and can be seen in Table 1. The individual-level predictors include sex, age, year of the incident, level of care administered by EMS, whether the individual was transported to a hospital or not, time of the incident and the type of property that EMS responders reported to. Age was considered the strongest predictor of fall injuries based on biological and behavioral differences based on previous findings.[22,44,45] Children's age determines their mobility, which dictates behavioral aspects such as playground use. This affects the propensity of a child to fall given their opportunities. The biological difference in children's age is seen in the increased ratio of head mass to the rest of the body for younger children. Younger children may be more likely to fall due to increased head mass proportionate to their bodies, as compared to older children.[10] All of the predictors were standard demographic data collected by EMS personnel at the time of the incident.

Additional factors that were considered potential predictors were assessed by census tract and are also listed in Table 1. These data were gathered from the American Community Survey (ACS) for the years 2007-2011. Briefly, the ACS is annual survey conducted by the US Census Bureau and designed to provide population estimates between each decennial census. The ACS randomly samples the population of each census tract for demographic data such as age, sex and race to veteran status, health insurances and disabilities. Data is compiled at several different levels, including census tract, and is used by state and local communities to help determine how federal and state funds are distributed each year. This data is available to the public via the ACS website.[46]

Steps for calculating rates of EMS calls (fall and total) per 10,000 pediatric residents (<18 y/o) by census tract

1. A map of all census tracts (2010) in Clackamas County was the starting point.

2. Intersect: Using a second map of the outline of CCFD1, a new map was cut from the original map of Clackamas County. This map is the shape of CCFD1 and has census tracts from 2010 within it.

3. Exact method was repeated for a 2000 census tract map of Clackamas County.

4. Join: 2000 census data for population was joined, by census tract, to the 2000 CCFD1 map.

5: Spatial Join: 2000 CCFD1 map with population data was spatially joined to the 2010 CCFD1 map. This populates the proportion of each census tract of 2000 population into the corresponding 2010 census tracts.

6: Data was exported to Excel. The population, by census tract, was calculated for each year (2009-2012) using linear interpolation.

7. Join: Utilizing the CCFD1 2010 map, annual population data and average (2009-2012) population data was joined by census tract.

8. Spatial Join: All eligible incident data with XY coordinates was spatially joined to correlating CCFD1 maps. The sum feature was used to sum the counts of incidents (total events, medical calls and falls) in each census tract. Maps were created for each year as well as the overall effect.

9. Calculations:

Total EMS calls by taking the sum of total events / population in that census tract.

Fall EMS calls by taking the sum of fall events / population in that census tract.

Medical EMS calls by taking the sum of medical events / population in that census tract.

Statistical Analysis

Statistical analyses were performed with the software packages ArcGIS version 10 (Esri, Redlands, CA), Stata 12 (StataCorp, College Station, TX) and Pass (v.11).

Specific Aim 1: Describe the individual-level characteristics of pediatric fall injuries and compare them to the individual-level characteristics of pediatric medical calls.

Descriptive analyses of the individual-level characteristics for both the pediatric fall injuries and pediatric medical illness calls were performed. This included assessing the following characteristics: age, sex, level of care, whether or not the individual was transported to the hospital, time of incident and year of incident. The main predictor variable, location of incidence, was also examined. Continuous variables were described using mean and standard deviation. Frequencies and percentages were calculated for categorical variables. Descriptive analyses of the following census tract-level characteristics were performed: average family size, percentage of families that only speak the English language at home, percentage of children in families for whom poverty status has been determined in the last 12 months, percentage of single mother households, percentage of single father households, percentage of high school level education status and percentage of grandparents responsible for children in the household. Bivariate analysis using chi-squared statistics was performed to determine if there was a relationship between potential confounding variables and pediatric fall injuries, or medical illness calls. Correlation testing was done to determine if any collinearity is present between the independent variables.

Specific Aim 2: Determine if non-residential locations are more likely to be sites of pediatric fall injuries than residential locations.

Multiple logistic regression analysis determined if there is an association between non-residential locations and pediatric fall injuries. Backwards stepwise selection procedure was used to narrow the list of potential independent variables. All variables were originally included in the model. A significance level > 0.10 resulted in elimination from the model. Since location of injury was the exposure of interest it was forced into the model. The independent variables that remained after the backward stepwise selection procedure were then assessed in the overall model by manually removing the variable with the highest p-value and comparing this model using a likelihood ratio test. This process was repeated iteratively until the likelihood ratio test indicated that all the independent variables in the model were significant at the 0.05 level. The resulting model was then analyzed for the interaction between age and location.

Predictor variables were tested for normality using the Shapiro-Wilkes method prior to analysis. It was determined that a dichotomous split at the median of CCFD1 for English spoken at home, married families and average family size provided an acceptable distribution and an easier interpretation. No other transformations were needed for the other predictor variables. Model diagnostics, such as pseudo R^2, residual analysis and goodness of fit, were performed to assess the validity of the assumptions of logistic regression. The goodness of fit for the final model was assessed using the Hosmer and Lemeshow test.

Specific Aim 3: Identify and describe spatial patterns using ArcGIS, such as clusters of both pediatric fall injuries and pediatric medical illness calls. Utilize regression analysis to determine census tract-level predictors for pediatric fall rates.

Spatial analysis of both pediatric fall injuries and medical illness calls was performed using ArcGIS. Cases and controls were spatially matched to a map of CCFD1 and assigned to the appropriate census tract. Rates were then calculated based on 10,000 children per census tract. The local statistics for Moran's I and Getis-Ord Gi* testing were performed to examine clustering of injury type by census tract. Moran's I was mainly used to determine if any of the census tracts had outlying values of the outcome of interest (pediatric fall rate or medical illness call rate) with regards to neighboring census tracts. This analysis compared the differences between the census tract of interest and its immediate neighbors to that of the census tract of interest and all the other census tracts. If the differences between the neighbors and the census tract of interest were less than the differences of the census tract of interest and all the other census tracts, then a cluster was present. Depending on the values of the differences, this census tract could also be considered an outlier, or a census tract with a value that is different than its neighbors. Conversely, Getis-Ord Gi* compares the high values of either pediatric fall rate or medical illness call rate of the census tract of interest to all the other high or low values for all the census tracts to determine a concentration of the values. This statistic then maps these concentrations to show areas with high or low clusters, or rates of either pediatric fall injury or medical call illness. The Getis-Ord Gi* test can only provide information on whether census tracts are surrounded by like census tracts.

To control for the effect of census tract-level predictors on clusters of pediatric fall injuries and medical illness calls, residual analysis of the census tract-level negative binomial regression model was performed. The resulting values for the residuals for the pediatric fall model were analyzed in ArcGIS using Moran's I and Getis-Ord Gi*. Spatial clusters identified using this method take into account the effect of significant census tract-level independent variables. A final model was developed that looks at census tract-level predictors in determining pediatric fall injury, after accounting for medical illness calls. This model utilized negative binomial regression analysis while accounting for the correlation between census tracts for each pair of cases and controls.

Negative binomial regression analysis was done to determine if census tracts with higher rates of pediatric fall injuries per 10,000 children were associated with any census tract-level information. Negative binomial regression was used to reduce the likelihood of over-dispersion seen in a Poisson model when the variance of the pediatric fall rate is greater than the mean. The variance of the pediatric fall rate by census tract was over 30 times larger than the mean, indicating that a Poisson regression analysis was not appropriate. In addition to the census tract-level variables discussed previously; English spoken at home, married families, single mother or father families, poverty status and high school level education, two additional variables were introduced into this analysis. Longitude and latitude of the centroid of each census tract was calculated via ArcGIS. These two new variables represent the spatial relationship of the census tracts within CCFD1. Across CCFD1, more urban environments are located in the northwest, while the southeast census tracts are more rural. Latitude and longitude will help to account for the distribution of urban areas across CCFD1.

The over-dispersion parameter was also investigated to ensure that negative binomial regression was the correct method for analysis, as opposed to Poisson regression. The over-dispersion parameter alpha was tested via the likelihood ratio test to determine if the parameter was significantly different than zero. When the over-dispersion parameter is the same as zero, the negative binomial distribution is equivalent to the Poisson distribution.

Data matched to census tracts from ArcGIS were analyzed in the overall model by manually removing the variable with the highest p-value and comparing this model using a likelihood ratio test. This process was repeated iteratively until all the independent variables in the model were significant at the 0.05 level. Due to the exploratory nature of this analysis, none of the census tract-level variables were forced into the model for the analyses that looked at pediatric fall injuries or medical illness calls. However, case/control status was forced into the model during analysis of the final model to predict pediatric fall rate when case/control status was accounted for.

Sample Size and Power

Data for this analysis has already been collected passively via the EMS response system in CCFD1. Of the 29,276 EMS calls reported from 2009-2012, 562 calls were still eligible after applying selection criteria. Of these total calls, 50% originated from a residential dwelling and 50% of the calls originated from a non-residential dwelling, such as a commercial venue, a recreational venue, a school/church/daycare, or a car-accessible area. These two categories (residential vs. non-residential) were utilized for the power calculation for the main analysis. Using PASS 2008 software, v 11, a sample size of 562 was used to calculate the minimum detectable odds ratio at a significance level of 0.05, using a logistic regression analysis with a binary predictor variable (residential vs. non-residential). This study has an 82% power to detect with a significance level of 0.05 an odds ratio of 0.56 in the logistic regression analysis with a binary predictor variable. The crude odds ratio was calculated to be 0.4, which indicates that this study was sufficiently powered to detect a meaningful difference. The baseline probability of falls in this study for non-residential areas was assumed to be 40%, while the assumed R^2 of other predictors in the analysis is 0.25.

Human Subjects Protections

Due to the nature of emergency services, individuals were not consented prior to treatment. Concerns around location of the incident were discussed with the Oregon Health & Science University (OHSU) Internal Review Board (IRB), which concluded that there is no assurance that the coordinate location corresponds with the individual's home location. Therefore location information was not considered a personal identifier for this study. The only personal health information available in the EMS data set is the individual's birth date, which was used to verify age. To ensure that the privacy of study participants was protected for this secondary analysis, birth date was removed from the data set prior to reviewing it for secondary analysis. The OHSU IRB considered this secondary data analysis exempt from review.

Results

Specific Aim 1: Describe the individual-level characteristics of pediatric fall injuries and compare them to the individual-level characteristics of pediatric medical calls using the 2009-2012 EMS data from CCFD1.

The individual-level characteristics of both pediatric fall injuries and medical call illnesses are presented in Table 2. For the factor of sex there was no significant difference between cases and controls. In addition, whether the individual was transported to a hospital and the level of care the EMS personnel provided were not significantly different between cases and controls. This result is expected since control selection was based on commonness in the pediatric population as well as similar levels of severity as cases. The results indicate that the location of where the incident occurred varied significantly between cases and controls ($p < 0.001$), with controls more likely to call 9-1-1 from residential locations. Cases were on average 7.96 years old and controls were on average 9.74 years old, which was significantly different between the two groups ($p = 0.0001$). There were higher percentages of falls and medical illnesses that were males (52.7% and 51.6%, respectively) than females (47.3% and 48.4%, respectively), though there was no difference between cases and controls. The majority of pediatric falls (73.5%) occurred between 6AM and 6PM, while medical illness calls were more evenly distributed over the 24-hour period of a day. Both pediatric fall injuries and medical illness calls exhibited a similar distribution over each year of the 4-year time span.

Table 2: Descriptive statistics of EMS individual-level factors and census tract covariates for fall injuries (cases) and medical illness (controls)

Parameter	Definition	Cases (n = 279)	Controls (n = 283)	p-value
		Mean (std) or Frequency	Mean (std) or Frequency	
Property Type	Non-residential Residential	0 = 50.2% 1 = 49.8%	0 = 29.0% 1 = 71.0%	p < 0.0001
Age	Continuous value	7.96 (5.25)	9.74 (5.74)	p = 0.0001
Sex	Female Male	0 = 47.3% 1 = 52.7%	0 = 48.4% 1 = 51.6%	p = 0.7944
Time of Day	Midnight to 6AM 6AM to Noon Noon to 6PM 6PM to Midnight	0 = 1.4% 1 = 30.8% 2 = 42.7% 3 = 25.1%	0 = 16.3% 1 = 30.7% 2 = 27.6% 3 = 25.4%	p < 0.0001
Transport	No Tranport Tranport to hospital	0 = 38.0% 1 = 62.0%	0 = 37.1% 1 = 62.9%	p = 0.8275
Care	Not paramedic Paramedic	0 = 41.2% 1 = 58.8%	0 = 43.5% 1 = 56.5%	p = 0.5903
Year	2009 - 2012	2009 = 27.6% 2010 = 24.0% 2011 = 24.7% 2012 = 23.7%	2009 = 24.7% 2010 = 22.6% 2011 = 25.0% 2012 = 27.6%	p = 0.705
Married Families	Median of Census Tract	20.30 (9.53)	21.63 (11.01)	p = 0.1266
Families with Grandparents Responsible for Children	Percentage within Census Tract	39.02 (28.69)	36.57 (29.18)	p = 0.3161
Families with Children below the Poverty Level	Percentage within Census Tract	14.08 (8.90)	14.43 (9.4)	p = 0.6514
Families with Single Mothers	Percentage within Census Tract	7.42 (3.42)	7.60 (4.15)	p = 0.5674
Families with Single Fathers	Percentage within Census Tract	2.19 (1.73)	2.21 (1.71)	p = 0.8989
Average Family Size	Median of Census Tract	2.92 (0.45)	2.93 (0.44)	p = 0.9063
Highschool Level Education	Percentage within Census Tract	86.43 (12.61)	85.89 (12.55)	p = 0.6107
English Language Only Spoken at Home	Median of Census Tract	83.08 (14.00)	81.28 (13.84)	p = 0.1278

Appendix A shows both the pediatric fall injury average rate as well as the overall injury average rate for 2009-2012 by census tract. The pediatric fall injury rates per census tract ranged from 0 to 149.6 per 10,000 children per year, while the overall injury rate per census tract ranged from 0 to 153.8 per 10,000 children per year. Appendix B shows these results in a spatial context with Figure 9, which is of CCFD1 illustrating the average rate of pediatric fall injuries for the years 2009 – 2012 by census tract. It should be noted that darker areas indicate higher rates while lighter areas indicate lower rates. Census tracts with higher rates are located in the more northern area of CCFD1, though there are a few census tracts with higher rates of pediatric fall injuries in central and southern CCFD1. There are also several census tracts with low rates of pediatric fall injury dispersed across CCFD1. Figure 10 is a similar map that shows the average medical illness call rate for the years 2009 – 2012. Upon observation, there are several census tracts with high rates of medical illness calls. These census tracts appear to be evenly dispersed across CCFD1. There are also fewer census tracts with the lowest quintile of medical illness call rate. Overall, the rate of medical illness calls appears more evenly distributed across CCFD1 then the pediatric fall rate.

Specific Aim 2: Determine whether non-residential locations are more likely to be sites of pediatric fall injuries than residential locations.

The backwards stepwise selection procedure indicated a model that included both individual-level predictors such as age, time of day of injury, as well as the main predictor of interest, location of injury. The significant census-tract level predictors that the stepwise selection procedure selected were English spoken at home and percentage of single mother families.

The interaction between age and location of injury was then assessed using the likelihood ratio test. The results indicated that the addition of an interaction term between age and location of injury did not significantly improve the fit of the model. To ensure the dichotomous transformations of English spoken at home was appropriate, a model comparing this variable as a continuous variable to dichotomous variable was analyzed. In addition, the Akaike information criterion (AIC) value for the dichotomized English spoken at home variable was lower than that of the continuous variable, 707.4 vs. 710.1. Similarly, the Bayesian information criterion (BIC) value for the dichotomized variable was less than that of the continuous variable, 733.5 vs. 736.1. This indicates that the model with the dichotomized English spoken at home variable was the better fit. Finally, the fit of the model was evaluated using the Hosmer and Lemeshow goodness-of-fit statistic. The results indicate that the model fits the data well (χ^2_{481} = 501, p-value = 0.25).

Table 3: Univariate and multivariate analyses of EMS individual-level factors and census tract covariates for fall injuries (cases, n=279) and medical illness (controls, n=283)

Parameter	Definition	p-value	Univariate OR (95% CI)	Multivariate OR (95% CI)
Property Type	Non-residential Residential	p < 0.0001	*Reference* 0.41 (0.28 - 0.58)	*Reference* 0.26 (0.17 - 0.39)
Age	Continuous value	p = 0.0001	0.94 (0.92 - 0.97)	0.91 (0.88 - 0.94)
Sex	Female Male	p = 0.7944	*Reference* 1.04 0.75 - 1.46)	*NS**
Time of Day	Midnight to 6AM 6AM to Noon Noon to 6PM 6PM to Midnight	p < 0.0001	11.37 (3.92 - 32.95) 17.54 (6.07 - 50.68) 11.18 (3.82 - 32.71) *Reference*	8.56 (2.84 - 25.53) 15.26 (5.14 - 45.31) 11.95 (3.99 - 35.77) *Reference*
Transport	No Tranport Tranport to hospital	p = 0.8275	0.96 (0.68 - 1.35)	*NS*
Care	Not paramedic Paramedic	p = 0.5903	1.02 (0.94 - 1.11)	*NS*
Year	2009 - 2012	p = 0.705	0.92 (0.79 - 1.06)	*NS*
Married Families	Median of Census Tract	p = 0.1266	0.73 (0.52 - 1.03)	*NS*
Families with Grandparents Responsible for Children	Percentage within Census Tract	p = 0.3161	1.00 (0.99 - 1.01)	*NS*
Families with Children below the Poverty Level	Percentage within Census Tract	p = 0.6514	0.99 (0.98 - 1.01)	*NS*
Families with Single Mothers	Percentage within Census Tract	p = 0.5674	0.99 (0.95 - 1.03)	0.95 (0.90 - 0.99)
Families with Single Fathers	Percentage within Census Tract	p = 0.8989	0.99 (0.90 - 1.09)	*NS*
Average Family Size	Median of Census Tract	p = 0.9063	1.22 (0.69 - 2.18)	*NS*
Highschool Level Education	Percentage within Census Tract	p = 0.6107	1.00 (0.99 - 1.02)	*NS*
English Language Only Spoken at Home	Median of Census Tract	p = 0.1278	1.50 (1.07 - 2.10)	1.66 (1.14 - 2.41)

*Not significant in the multivariate model, and therefore omitted.

Specific Aim 3: Identify and describe spatial patterns using ArcGIS, such as clusters of both pediatric fall injuries and pediatric medical illness calls. Utilize regression analysis to determine census tract-level predictors for pediatric fall rates.

In negative binomial regression analysis, all of the census-tract predictor variables were tested iteratively to determine removal of the most non-significant variable. Due to the exploratory nature of this analysis, none of the variables were forced into the model. After the backward elimination stepwise procedure, the remaining predictor variables in the model were all significant at the <0.05 level (Table 4).

The results of the negative binomial regression analysis show that the rate of pediatric fall injury increases with the variables latitude, percentage of families with single moms and percentage of high school level education. All three of these predictors have confidence intervals close to the null value, which may be related to the small sample size for census tracts. Average family size as compared to the median of average family size within CCFD1 was the only variable found to be significantly associated with lower rates of pediatric fall injury. When compared to the similar Poisson model, the results indicate that negative binomial regression analysis is significantly different than zero and therefore the correct method to use in this analysis (alpha = 0.99, χ^2_1=861.3, $p < 0.0001$). The AIC and BIC values, 463.41 and 474.38, respectively, for the negative binomial regression model were much lower than those for the Poisson regression model, 1322.75 and 1331.89, respectively. This analysis does not take into account the effect of medical illness calls however.

Table 4: Multivariate negative binomial regression analysis of census tract covariates for fall injuries (cases) by census tract (n=46)

Parameter	Definition	p-value	Incidenct Rate Ratio (95% CI)
Latitude by 10,000 feet	Centroid of Census Tract	0.007	1.22 (1.05 - 1.40)
Families with Single Mothers	Percentage within Census Tract	0.037	1.11 (1.01 - 1.22)
High school level Education	Percentage within Census Tract	0.014	1.03 (1.00 - 1.05)
Average Family Size	Dichotomized by median of CCFD1	0.036	0.18 (0.04 - 0.89)

A comparable model was tested to look at the association between medical illness rate and census tract-level factors. The results shown in Table 5 indicated that similar variables such families with single mothers, high school level education and average family size, are associated with medical illness rate within census tract. Longitude by 10,000 feet is significantly associated with increased rate of pediatric medical illness rate, as compared to latitude by 10,000 feet, which was associated with an increased rate of pediatric falls. Similarly, average family size as compared to the median average family size of CCFD1 is associated with lower rates of medical illness rates. When compared to the Poisson distribution using the likelihood ratio test, the results indicate that negative binomial regression analysis is significantly different than zero and therefore the correct method to use in this analysis (alpha = 0.60, χ^2_1=551.65, p < 0.0001). The AIC and BIC values, 559.33 and 570.30, respectively, for the negative binomial regression model were much lower than those for the Poisson regression model, 3285.62 and 3294.77, respectively.

Table 5: Multivariate negative binomial regression analysis of Census tract covariates for medical illness (controls) by census tract (n=46)

Parameter	Definition	p-value	Incidenct Rate Ratio (95% CI)
Longitude by 10,000 feet	Centroid of Census Tract	< 0.001	1.49 (1.22 - 1.83)
Families with Single Mothers	Percentage within Census Tract	0.002	1.16 (1.06 - 1.28)
High school level Education	Percentage within Census Tract	< 0.001	1.07 (1.04 - 1.11)
Average Family Size	Dichotomized by median of CCFD1	0.002	0.05 (0.01 - 0.32)

A final negative binomial regression model was created, taking into account the status of outcome (pediatric fall injury versus medical illness call) and testing all census tract-level predictors. Table 6 shows the results. Census tracts with a higher percentage of single mother families are associated with increased rates of pediatric fall injury after taking medical illness call rate into account. The other significant predictor is longitude; for roughly every 2 miles eastward across CCFD1, the rate of pediatric falls increases by 11% after controlling for the affect of medical illness rate. Using the likelihood ratio test, the results indicate that negative binomial regression analysis is significantly different than zero and therefore the correct method to use in this analysis (alpha = 0.07, χ^2_1=7.43, p < 0.003).

Table 6: Multivariate negative binomial regression analysis of census tract covariates for fall injuries (cases) after controlling for medical illness by census tract (n=46)

Parameter	Definition	p-value	Incidenct Rate Ratio (95% CI)
Longitude by 10,000 feet	Centroid of Census Tract	0.028	1.11 (1.01 - 1.23)
Single Mother Families	Percentage within Census Tract	< 0.001	1.06 (1.03 - 1.09)

Spatial analysis of both pediatric fall injuries and medical illness calls was performed using ArcGIS. Cases and controls were spatially matched to a map of CCFD1 and assigned to the census tract that corresponded to the physical location of the event. Moran's I and Getis-Ord Gi* testing was performed to examine clustering of injury type, pediatric fall injuries and medical illness, by census tract.

The results of the spatial analysis are shown in the figures below. Figures 3 and 4 are maps of CCFD1 using Anselin Local Moran's I for cluster analysis of pediatric fall incidence and medical illness incidence, respectively. This analysis identifies areas of high value and low value clusters, by analyzing the value of variable of interest of the surrounding census tracts. This analysis does not take the census tract being analyzed into account, just the neighboring census tracts. The results from Figure 3 indicate that the northwestern part of CCFD1 has several census tracts with neighbors that have higher rates of pediatric fall injuries, as well as one census tract towards the middle of CCFD1 that has a lower rate, but is surrounded by census tracts with a higher rate. Figure 4 shows the same analysis for medical illness incidence. Similarly to the results of the pediatric fall incidence, there is an area of several census tracts in the northwestern part of CCFD1 that have higher rates of medical illness calls. This is consistent with the results of the analyses performed by census tract previously. Results from the analysis looking at pediatric fall injury rate by census tract show that as latitude increases, so does rate of pediatric falls. The same trend was observed in the analysis for medical illness call rate. The location of the clusters of pediatric fall injuries and medical illness calls are located within the same area of CCFD1, which is consistent with the previous analyses. It is interesting to note that when medical illness calls are accounted for, latitude is no longer a significant predictor for pediatric fall injuries; however longitude still is a significant predictor. This is not presented in a figure due to the limitation in ArcGIS for spatial analyses.

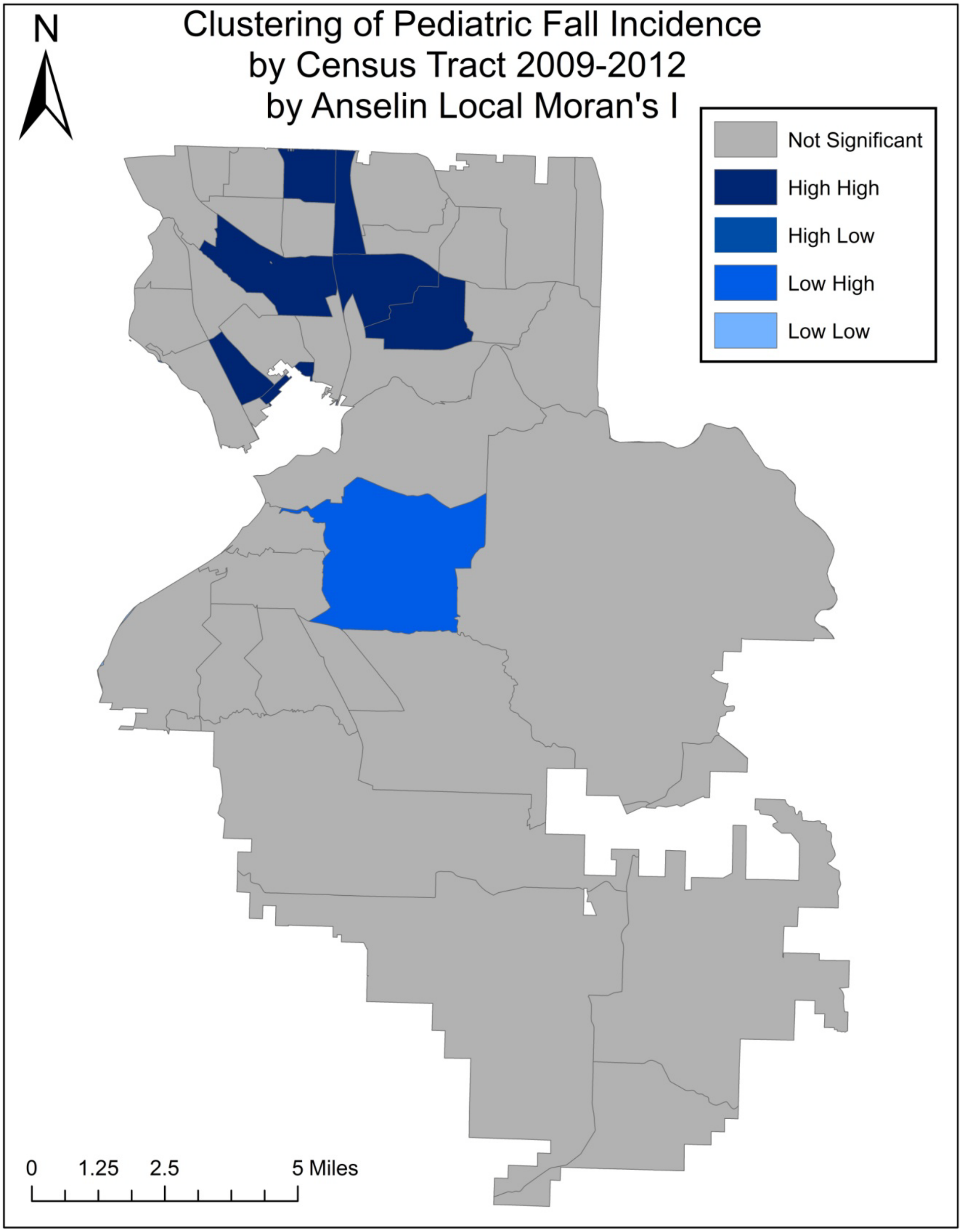

Figure 3: Cluster analysis using Local Moran's I of pediatric fall incidence (per 10,000 pediatric-years)

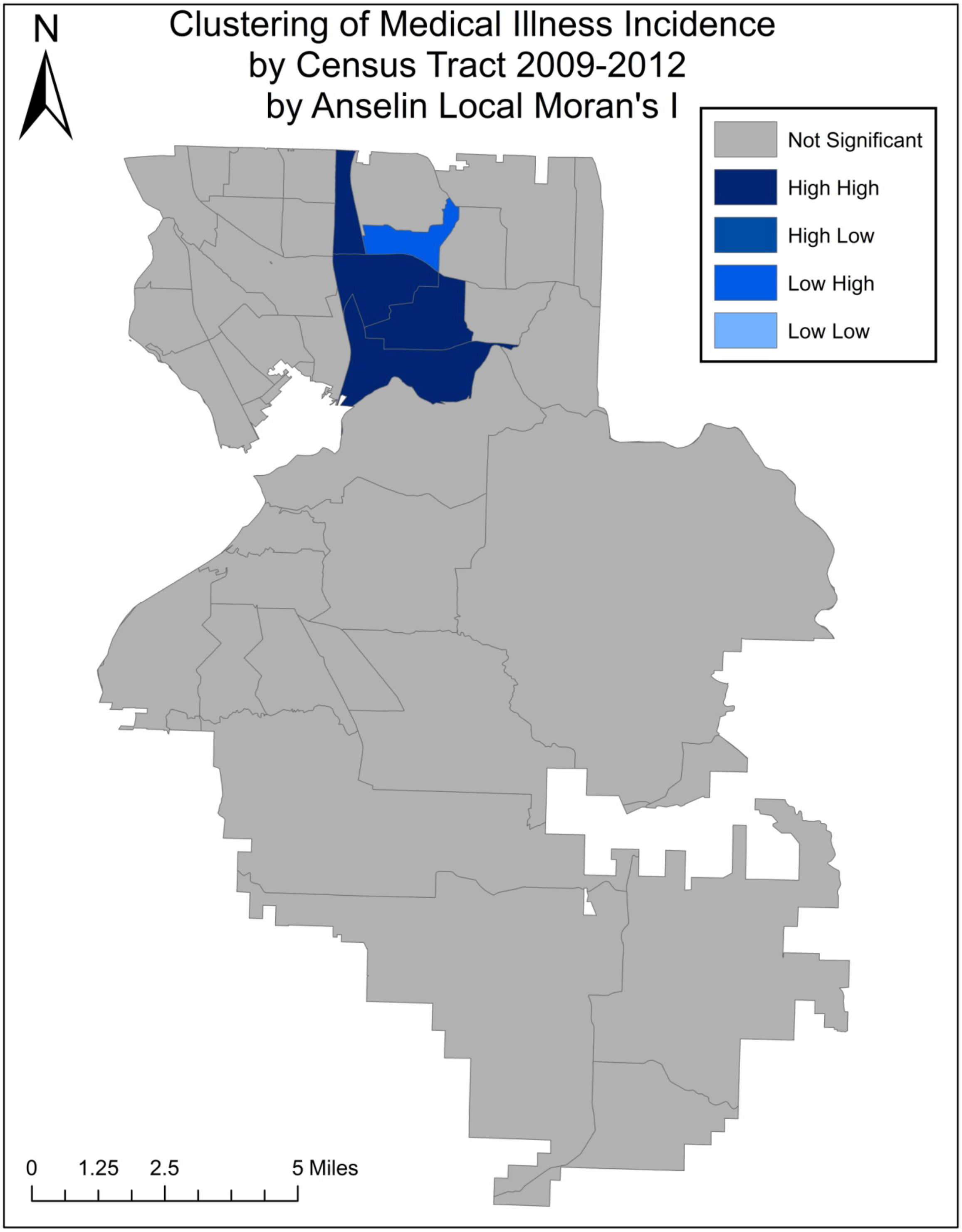

Figure 4: Cluster analysis using Local Moran's I of medical illness incidence (per 10,000 pediatric-years)

The second set of maps (Figures 5 and 6) illustrates the presence of hotspots, or clusters of high values, via Getis-Ord Gi* analysis for both pediatric fall rate and medical illness call rate. The location of the hotspots appears similar to the location of clusters in Figures 3 and 4. In Figure 5, the northwestern area of CCFD1 displays several census tracts that have high rates based on their surrounding census tracts. This is a more intense clustering of high values of pediatric fall rate. Of interest, there is also one census tract that is a “coldspot” at the southern edge of CCFD1. This coldspot indicates a clustering of lower pediatric fall rate. The standard deviation is minimally different from the average and this single census tract should not be considered very different than its surrounding neighbors. The results indicate that while both pediatric fall rate and medical illness call rate exhibit hotspots in the north-northwestern area of CCFD1, the pediatric fall rate hotspot is much more pronounced. There are more census tracts with higher-than-normal standard deviations for pediatric fall rates as well as the standard deviation values being more extreme than those for medical illness calls. There is a higher level of pediatric fall rate in the surrounding area in the northwest of CCFD1 as compared to medical illness call rate.

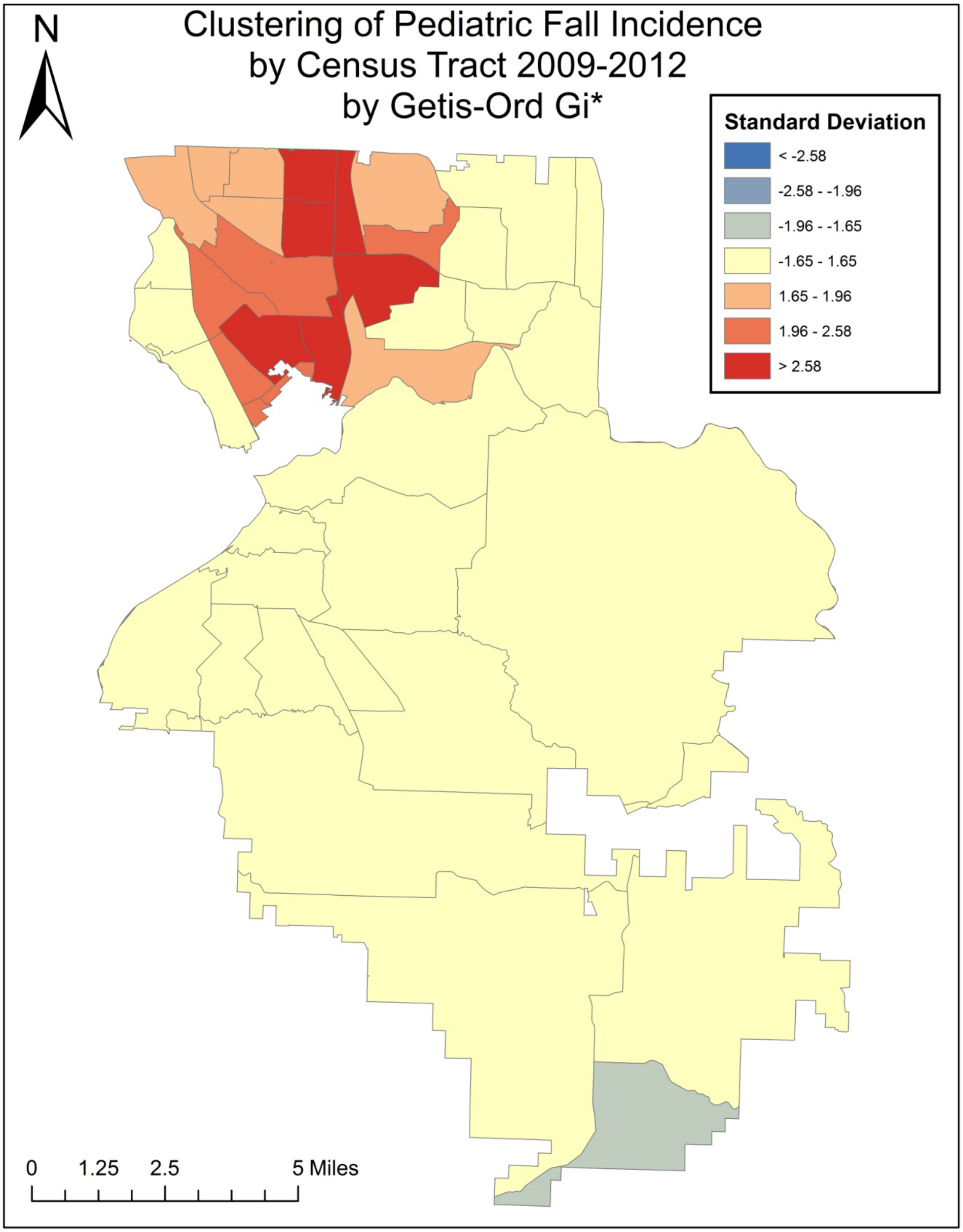

Figure 5: Hotspot analysis using Getis-Org Gi* of pediatric fall incidence (per 10,000 pediatric-years)

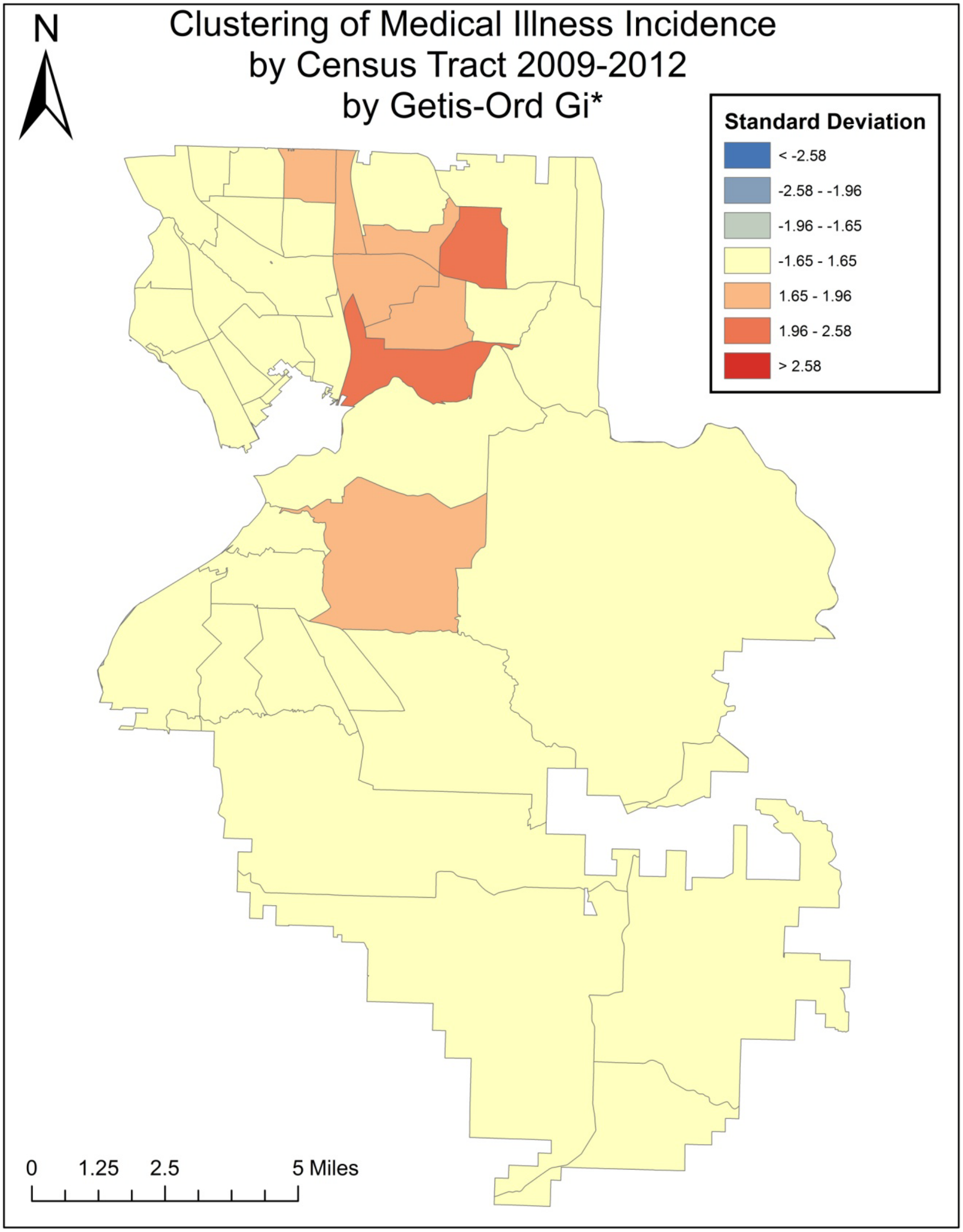

Figure 6: Cluster analysis using Getis-Ord Gi* of medical illness incidence (per 10,000 pediatric-years)

To control for the effect of census tract-level predictors on clusters of pediatric fall injuries and medical illness calls, residual analysis of the census tract-level negative binomial regression for pediatric fall rate was performed. The resulting values for the residuals were analyzed in ArcGIS using Anselin Local Moran's I (Figure 7) and Getis-Ord Gi* (Figure 8). Spatial clusters identified using this method take into account the effect of significant census tract-level independent variables. The results show that when the significant independent predictors; average family size, high school education, single mother families and latitude across CCFD1 are taken into account, both hotspots and clusters of pediatric fall rates disappear across CCFD1. It should be noted that this model does not take into account medical illness calls.

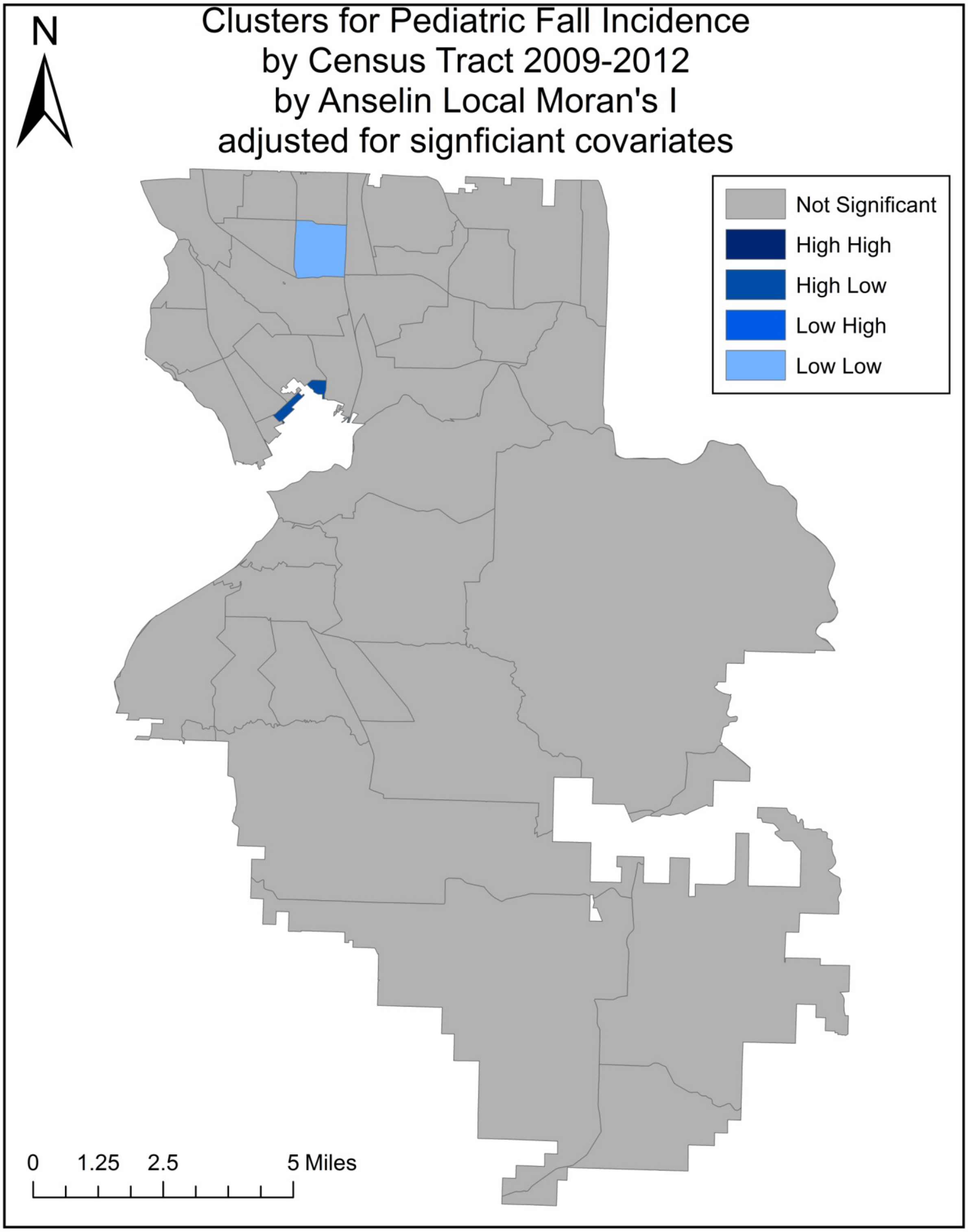

Figure 7: Cluster analysis of pediatric fall incidence (per 10,000 pediatric-years) after adjusting for significant covariates

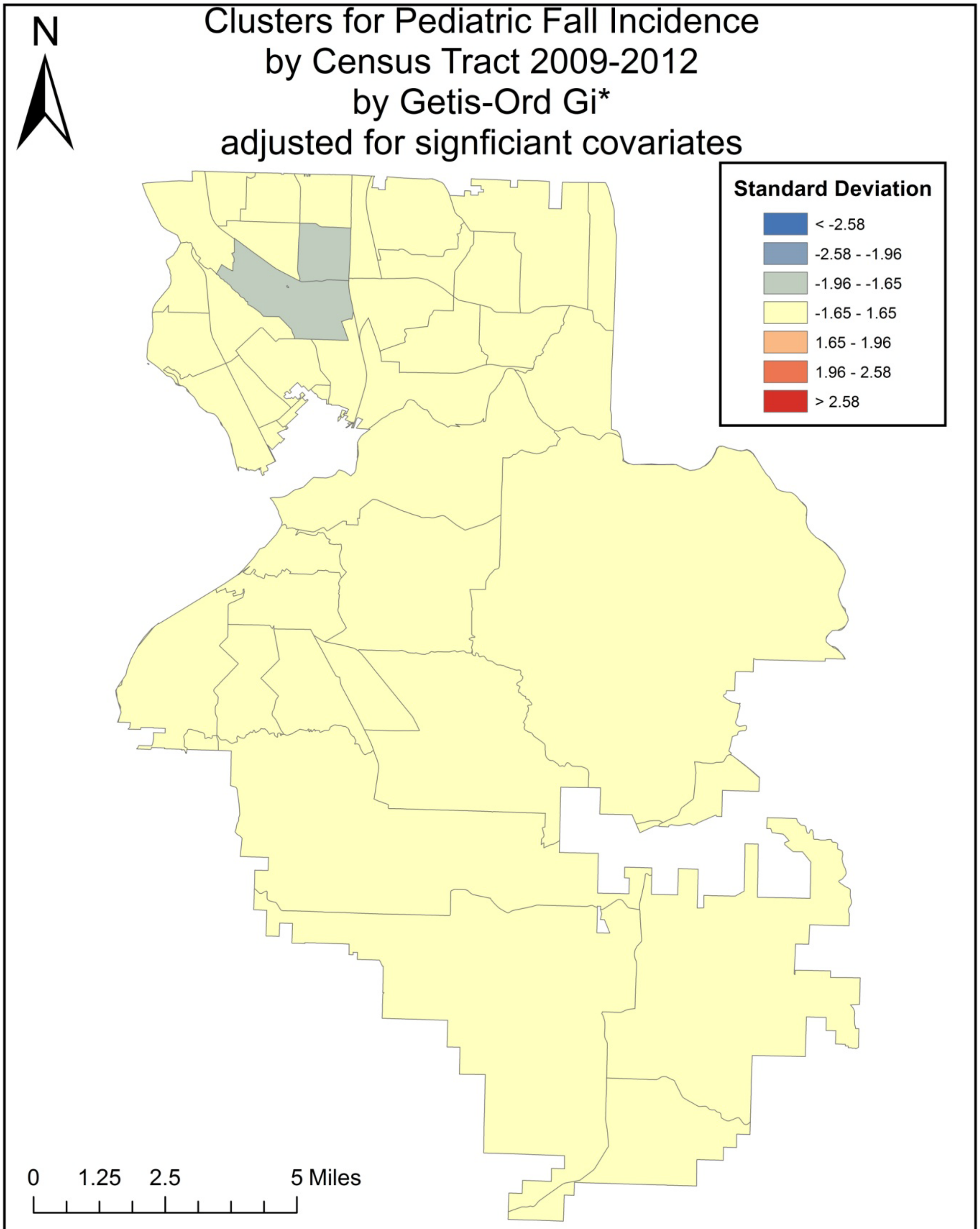

Figure 8: Cluster analysis of pediatric fall incidence (per 10,000 pediatric-years) after adjusting for significant covariates

Discussion

Specific Aims 1 and 2: Identifying Predictors of Pediatric Fall Injuries

Location of EMS call was a significant predictor for pediatric fall injury, with residential locations having lower odds of being a location for pediatric fall injuries (OR = 0.26, 95% CI: 0.17 – 0.39, $p < 0.0001$). This finding may be interpreted a number of ways. Since the comparison was made to medical illness calls, part of these results may be attributed to sick children being less likely to travel further from their homes before 9-1-1 is called. Conversely, non-residential locations may be more likely to induce pediatric falls due to lack of supervision or additional play equipment that may not be available at the home.

There were two individual-level characteristics that were predictive of pediatric fall injuries. For every year increase in age, there was a slight decrease in odds of pediatric falls (OR = 0.91, 95% CI: 0.88 – 0.94, $p = 0.0001$). Older children may have better coordination reducing their likelihood to suffer a fall injury than younger children. Time of day was also a significant predictor of pediatric falls, with the odds of pediatric falls increasing within midnight to 6am (OR = 8.56, 95% CI: 2.84 – 25.53), 6am to noon (OR = 15.26, 95% CI: 5.14 – 45.31) and noon to 6pm (OR = 11.95, 95% CI: 3.99 – 35.77) as compared to the 6pm to midnight time frame ($p < 0.0001$). This is expected, since pediatric falls would be more likely to occur while children are awake and mobile, while illness may be likely to occur randomly throughout the period of the day. There are a few studies that have described children falling out of bed or down stairs during the night; however this study captured the vast majority of pediatric fall injuries occurring during waking hours.

Perhaps expectedly, this analysis did not find any of the census tract-level variables significant for the prediction of individual fall injuries. While the initial analysis indicated that there was sufficient power to detect a significance association between pediatric fall injuries and property type, the addition of predictors may have reduced the power of the analysis. If there was a real association between some of the predictors and pediatric fall injury, this study was not able to detect it with its current sample size. Additionally, this study was only powered to see a difference of an odds ratio of 0.56, which may not have been a large enough change to detect. Another reason for the lack of significance of the predictors in the individual-level analysis may be due to the fact that census tract-level variables were being considered as proxies for true individual-level characteristics, instead of environmental-level factors. This illustrates the potential for children captured in the EMS reporting data to not be representative of the family environments documented in the census data.

Another issue to consider is that race was not controlled for in this analysis. The lack of power with additional predictors limited the ability to include all predictors of interest. Environmental-level predictors were selected based on their ability to develop a meaningful intervention for pediatric fall injuries. Percentage of high school education level attained, percentage of single parent families, average family size, percentage of grandparents being responsible for children and poverty status provide clues about the means and how families within specific census tracts are able to care for their children. Intentional injury, traumatic death and violent injuries as reported by EMS providers have been associated with a greater number of non-White residents per census tract.[34] These findings indicate that race may not play a large role in unintentional injuries, such as falls.

Specific Aim 3: Identify and describe spatial patterns using ArcGIS, such as clusters of both pediatric fall injuries and medical illness calls. Utilize regression analysis to determine census tract-level predictors for pediatric fall rates.

Without EMS data that is linked to individual demographic characteristics, it is unknown if the demographic data collected by census tract could be interpreted as contextual characteristics that may function independently of true independent-level variables. To reduce this effect, census tracts are used in this analysis. Several studies have shown that similar effects exist across arbitrary units of location, such as census tracts and block groups.[37,40] The negative binomial regression found several census-tract predictors that were significantly associated with higher rates of pediatric fall injuries. Census tracts with families with higher percentages of single mothers have 1.11 (95% CI: 1.01 – 1.22, p = 0.037) times the number of pediatric fall injuries. The analysis for medical illness call rates produced similar results with census tracts with families with higher percentages of single mothers have 1.16 times the number of medical illness calls (95% CI: 1.06 – 1.28, p = 0.002). These results are not surprising, due to several studies linking single parenthood with risk of childhood injury.[47-50] The mechanism by which single mothers and childhood injuries are associated is not well-understood. Access to resources, social contacts, or potential for living in lower-income areas which may reduce access to safe or well-maintained playgrounds may contribute to this relationship. However, it is interesting to note that census tracts experiencing higher rates of medical illness calls are associated with higher percentages of single mother families. Additionally, children captured in EMS reporting might not be ones with single mothers, further confounding this relationship. While the underlying mechanism and a causal pathway may not be well-understood, initiation of intervention efforts does not need to wait until these analyses are complete.

Education level was also found to be a significant predictor for an increased pediatric fall rate. Census tracts with individuals with higher percentages of high school level education will have 1.03 times the number of pediatric fall injuries (95% CI: 1.00 – 1.05, p = 0.014). Comparably, for every percentage point increase in high school level education within census tracts, the rate of medical illness calls increases 1.07 (95% CI: 1.04 – 1.11, $p < 0.001$). This is a relatively small association for both outcomes and it is somewhat unexpected. It is difficult to hypothesize a mechanism for this association that does not rely on the census tract measurement of increasing percentage of high school level educated individuals being related directly to parents of children experiencing falls or medical illness. Since this predictor is significant for both pediatric fall injuries and medical illnesses, it is complicated to understand this relationship; the assumption would be that census tracts with higher percentages of individuals with high school level education would have access to certain resources, such as health care, and would not utilize the 9-1-1 system for medical illness calls. However, high school level education may indicate a difference in access to certain resources like clinics or primary care facilities. This would explain the increased medical illness calls, but not necessarily the increased pediatric falls. Further research comparing education level of parents of children who have experienced a fall injury would be necessary to better understand this association.

Census tracts with families that are over the median average family size for CCFD1 have 0.36 (95% CI: 0.04 – 0.89, $p = 0.036$) times the number of pediatric fall injuries. Similarly, census tracts with families that are over the median average family size of CCFD1 have 0.05 times (95% CI: 0.01 – 0.32, $p = 0.002$) the rate of medical illness calls. Larger families within a census tract are associated with a marked decrease in both the rate of pediatric fall injuries and the rate of medical illness calls. This association with pediatric fall injury could potentially be explained by several different factors. Having an increased number of children in a family may alter behaviors within the children, with older children acting as babysitters for the younger children. Conversely, larger families may be more likely to be located in areas with less access to non-residential locations. For medical illness calls, larger families may be less likely to call 9-1-1 due to previous experience with older children reducing anxiety associated with child care.

However, these proposed mechanisms assume that children experiencing the outcome come from larger families, which may not necessarily be the case.

Location within the census tract was also a significant predictor, for both rate of pediatric fall injuries and rate of medical illness calls. For every 2 miles northward across CCFD1, the rate of pediatric fall injury increases by 22% (95% CI: 1.05 – 1.40, $p = 0.007$). Conversely, for every 2 miles eastward across CCFD1, the rate of medical illness increases by 49% (95% CI: 1.22 – 1.83, $p < 0.001$). These changes could be explained by differences in environmental factors, such as access to non-emergency clinics the further from dense population-centers or greater number of trip hazards in a more urban environment. This analysis did not capture any of aspects of the built environment, which could contribute to the differences in direction between the rate of pediatric fall injury and the rate of medical illness.

The final analysis performed by the census tracts investigated pediatric fall injury rates while controlling for the status of case or control. The results show that longitude and single mother families are the only census tract-level predictors that were significantly associated with increased pediatric fall injury rate. Census tracts had a 6% (95% CI: 1.03 – 1.09, $p < 0.001$) increase in pediatric fall rate for every percentage that single mother families increased, after adjusting for medical illness calls. For roughly every 2 miles traveled eastward across CCFD1, the rate of pediatric falls increased by 11% (95% CI: 1.01 – 1.23, $p = 0.028$), once medical illness calls were controlled. Neither percentage of high school level education nor average family size compared to median average family size within CCFD1 were significant in this analysis. This could be due to the fact that these factors were associated with families or individuals that utilized 9-1-1, instead of being associated with pediatric fall injuries. One reason for this could be that access to primary care facilities may be different across census tracts, leading individuals to utilize EMS differently within different census tract of CCFD1.

From 2009-2012, 14% of 9-1-1 calls that EMS personnel responded to involving children within CCFD1 were pediatric fall injuries. The year-by-year percentage of fall injuries within children indicates a persistent trend in reported EMS events, which may be increasing. The fire prevention department hosts several annual public safety fairs, focusing on fire safety as well as injury prevention through demonstrations and education. This group is strategically poised to increase childhood fall awareness within CCFD1.

Strengths and Limitations

There are several strengths in this analysis. The selection of cases and controls from a large and relatively diverse geographical area reduced the potential for selection bias by minimizing judgment in the selection process. There is precedence of geographical selection of cases and controls, with this technique being used in a case-control study of breast cancer and oral contraceptive use.[51] Selection bias may occur differentially in the selection of the cases, the controls or both. To address this limitation, controls will be limited to medical illness that is considered to be similar in severity to fall injuries. Due to control classifications, selection bias is thought to be random and non-differential in this study.

Using EMS data is another strength of this analysis. The level of missing data for pediatric 9-1-1 calls occurring with CCFD1, as defined by this study, is minimal at ~5%. EMS providers have been found to provide reliable and valid impressions when responding to emergencies. [39,52,53] Measures that are quantitative in nature, such as blood pressure, pupil dilation or heart rate have a higher error rate than measures such as sex and age.[38] Classification of the exposure by EMS providers can be considered reliable due to the large number of fields they can select from. Any potential misclassification of the exposure would most likely be minimal owing to the categories that they were re-classified into; residential versus non-residential. Classification of the outcome should also be considered valid for this study and any misclassification would be non-differential with regards to exposure status.

The use of ecological data in comparison to specific individuals is concern in this study. Ecological fallacy is a concern since it is unknown whether the children captured in the EMS call data are representative of the children captured in the census data. Without EMS data that is linked to individual demographic characteristics, it is unknown if the demographic data collected by census tract could be interpreted as contextual characteristics that may function independently of true independent-level variables. To reduce this effect, census tracts are used in this analysis. Several studies have shown that similar effects exist across arbitrary units of location, such as census tracts and block groups.[37,40] In addition, studies have found that a higher percentage of injury, including falls[45], occurs at or near the home.[22,45] Thus, there is a high likelihood that EMS personnel are dispatched to areas that are nearby individuals' homes, minimizing the potential limitation caused by using ecological data.

Public Health Implications and Future Studies

Findings from this analysis indicate that more than individual-level factors are associated with pediatric fall injuries. The public health implications for this research are large and far-reaching. In terms of interventions, it is often more feasible to change factors in the environment than to modify an individual's behavior. This includes public health efforts that take into account both environmental- and individual-level characteristics to reduce pediatric fall injuries in high-risk areas. The results of this analysis show that children in CCFD1 are more likely to experience fall injuries away from their residences. This suggests that a public awareness campaign in high-risk census tracts could help to reduce pediatric fall injuries that are occurring outside of the home. A public awareness campaign could include education of local businesses or other areas identified as high-risk for pediatric fall injuries, to make them aware of potential fall hazards. These policy changes can target at-risk areas more efficiently, rather than implementing a broad-scale intervention. The results of this study can also influence the method that EMS deploys its resources. EMS providers can work to develop checklists for fall safety inspections in community areas, similarly to the current fire inspections that are done at apartment complexes. Knowing where pediatric falls are more likely to occur can also focus fall-prevention experts to work with local communities to develop tailored fall prevention strategies.

Future research should consider linking hospital admission information to EMS call data to reduce confounding. Linking EMS data sets to hospital data sets for individuals who are admitted would allow for collection of other variables, such as types of treatment, hospital stay and potential development of co-morbidities. This procedure would also allow for collection of personal data, which in turn can data such as frequency of hospital visits or history of falls, and could lead to improving individual-level risk factors.

Future studies utilizing EMS data could also incorporate more valuable information during the data collection process. This would involve a questionnaire for EMS responders to fill out addressing additional aspects of the environment, as well as questions about previous injuries and causal mechanism for the incident, such as stair fall, ground level fall, etc. Another technique would be to implement follow-up interviews of EMS responders to determine mechanism of the fall or other aspects that are not captured in standardized questionnaires. More informed decisions could be made around priorities in pediatric fall injuries with a better understanding of the causal mechanism. However, this must be balanced with the first priority of EMS personnel, which is to provide emergency response and ensure the individual is being treated as effectually and as efficiently as possible.

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Appendix A: Rates of Injury per Census Tract

Table 7: Incidence Rates for 2009 - 2012 per 10,000 by year by Census Tract

Census Tract	Fall Injuries	Medical Illness Calls	Overall	Census Tract	Fall Injuries	Medical Illness Calls	Overall
205.03	0.0	0.0	0.0	222.05	24.1	12.7	36.7
205.05	0.0	0.0	0.0	222.06	26.9	51.3	78.3
208	120.9	66.7	187.7	222.07	47.3	103.8	150.8
209	74.8	57.5	132.5	222.08	50.1	79.3	129.3
210	89.5	8.4	97.4	223.01	114.0	67.3	181.3
211	86.0	71.2	157.2	223.02	8.0	64.3	72.3
212	61.6	55.0	117.0	224	93.1	47.7	140.7
213	60.7	28.7	89.7	225	76.0	54.0	130.0
214	101.0	41.3	142.3	226.02	11.7	29.0	41.0
215	106.2	90.9	196.9	226.03	108.6	153.8	262.8
216.01	88.4	45.7	133.7	226.05	85.1	118.5	203.5
216.02	34.1	112.0	146.0	226.06	17.5	45.1	62.1
217	51.5	67.9	119.9	227.02	0.0	0.0	0.0
218.01	65.3	29.2	94.2	229.01	0.0	0.0	0.0
218.02	133.3	99.7	232.7	230.01	13.8	76.1	90.1
219	40.2	35.2	75.2	230.02	96.4	58.7	154.7
220	105.3	0.0	105.0	231	62.1	72.7	134.7
221.01	45.9	56.9	102.9	232.01	84.1	0.0	84.0
221.03	42.1	31.3	73.3	232.02	49.7	119.3	169.3
221.05	141.5	142.5	284.5	235	0.0	0.0	0.0
221.07	140.2	93.5	233.5	236	40.0	127.2	167.2
221.08	69.3	98.5	167.5	237	0.0	25.8	25.8
222.01	144.3	93.8	237.8	241	0.0	0.0	0

Appendix B: Maps of Injury Rates within Clackamas County Fire District #1

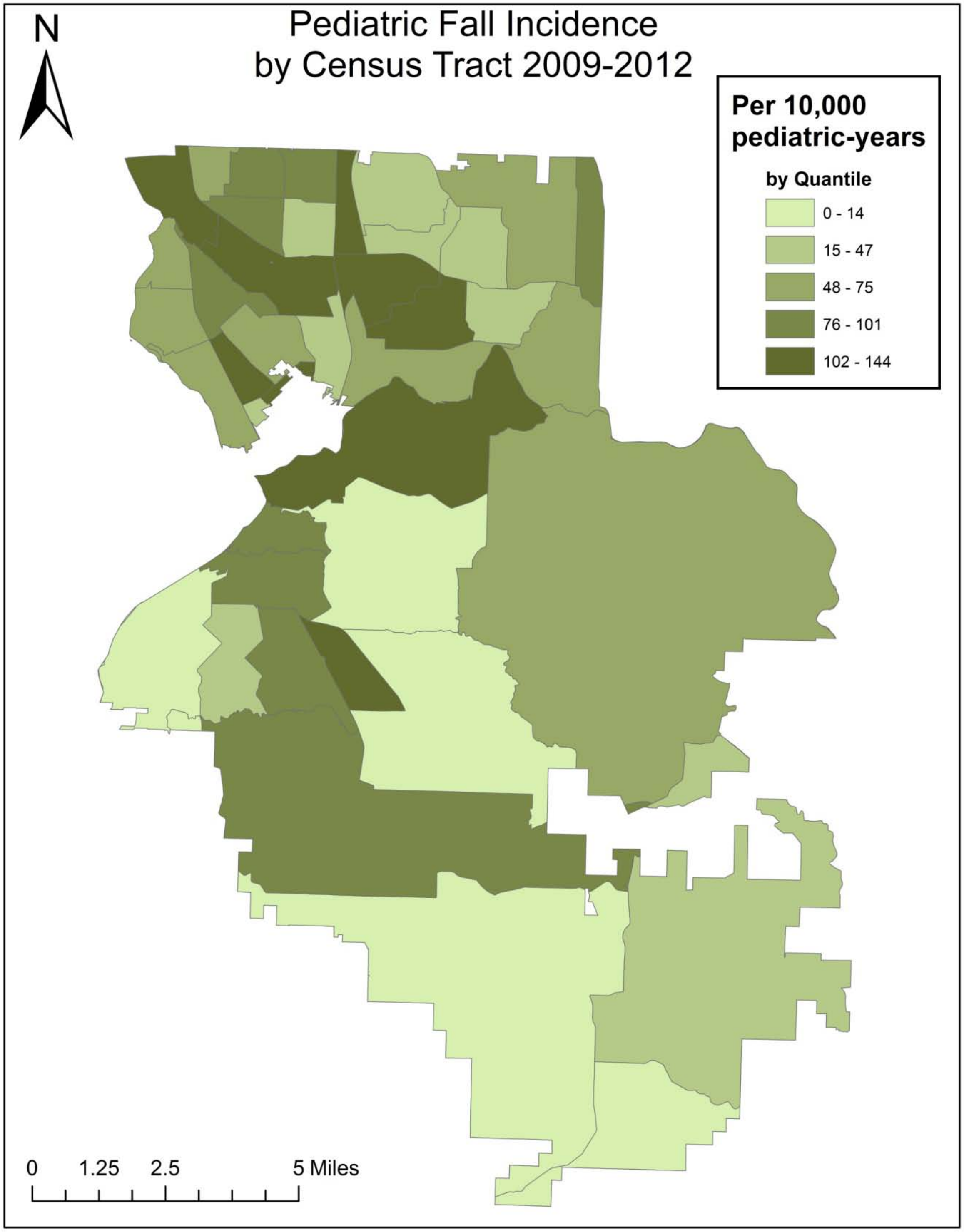

Figure 9: Pediatric fall incidence within CCFD1 from 2009-2012 (per 10,000 pediatric-years)

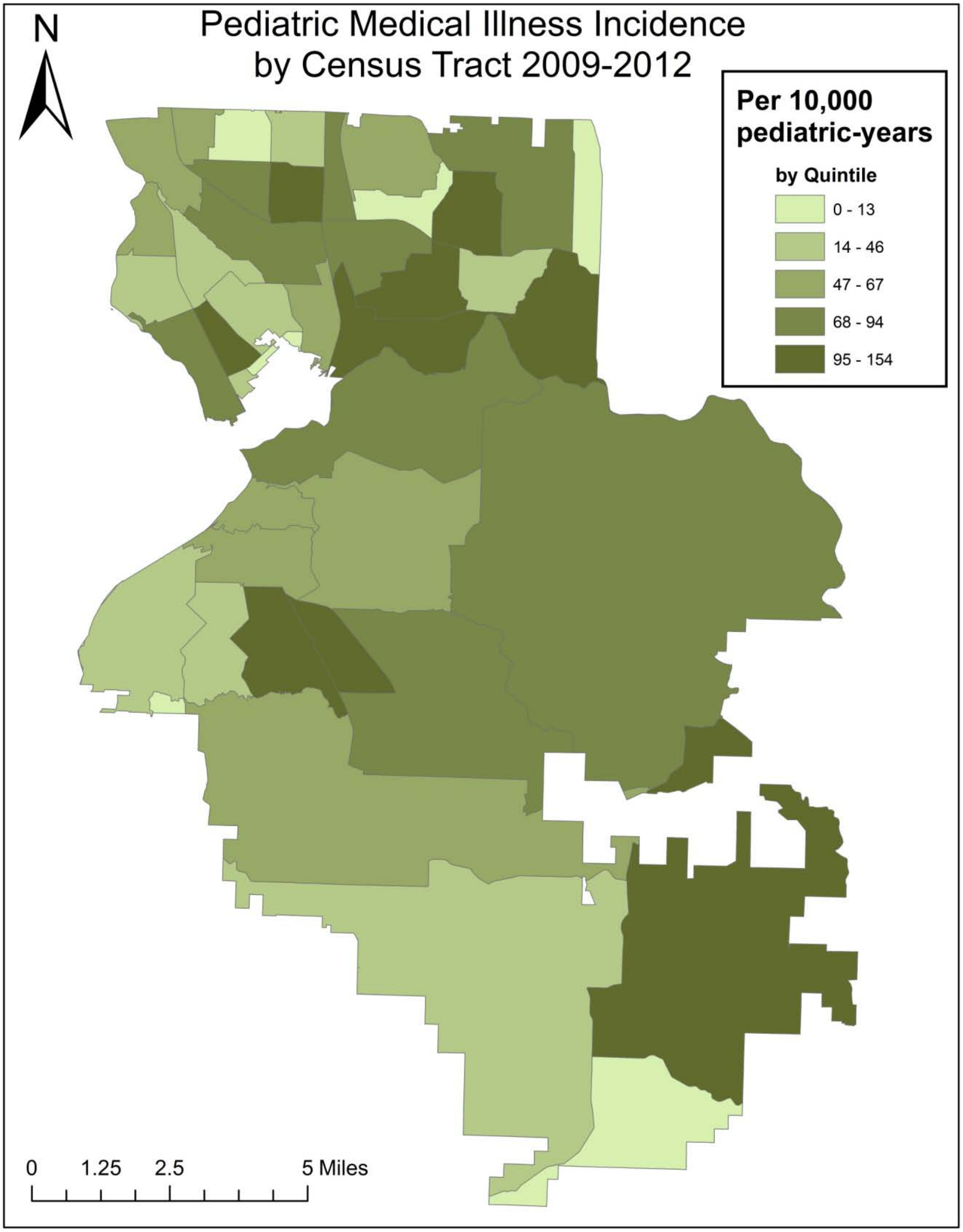

Figure 10: Medical illness incidence within CCFD1 from 2009-2012 (per 10,000 pediatric-years)