Firearm assault injuries by residence and injury occurrence location

Brianna Mills,[1,2,3] Anjum Hajat,[1,3] Frederick Rivara,[2,4] Paula Nurius,[3,5] Ross Matsueda,[3,6] Ali Rowhani-Rahbar[1,2,3]

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[1]Department of Epidemiology, University of Washington, Seattle, Washington, USA
[2]Harborview Injury Prevention and Research Center, University of Washington, Seattle, Washington, USA
[3]Center for Studies in Demography and Ecology, University of Washington, Seattle, Washington, USA
[4]Seattle Children's Hospital, Seattle, Washington, USA
[5]Department of Social Work, University of Washington, Seattle, Washington, USA
[6]Department of Sociology, University of Washington, Seattle, Washington, USA

Correspondence to
Dr Brianna Mills, Harborview Injury Prevention and Research Center, University of Washington, Seattle, WA 98195, USA; bmills@uw.edu

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ABSTRACT

Research on spatial injury patterns is limited by a lack of precise injury occurrence location data. Using linked hospital and death records, we examined residence and injury locations for firearm assaults and homicides in or among residents of King County, Washington, USA from 1 January 2010 to 31 December 2014. In total, 670 injuries were identified, 586 with geocoded residence and injury locations. Three-quarters of injuries occurred outside the census tract where the victim resided. Median distance between locations was 3.9 miles, with victims 18–34 having the greatest distances between residence and injury location. 40 of 398 tracts had a ratio of injury incidents to injured residents of >1. Routine collection of injury location data and homelessness status could decrease misclassification and bias. Researchers should consider whether residential address is an appropriate proxy for injury location, based on data quality and their specific research question.

INTRODUCTION

Firearm assaults are spatially clustered.[1–5] The underlying environmental context of these 'hot spots'[2] shapes the risk to individuals within them. Using residential address as a proxy for the location of injury occurrence (hereafter referred to as injury location) is not uncommon, but is a widely noted suboptimal approach to delineating environmental contributors to risk.[6–8] Neighbourhoods where individuals spend their time can be significantly distant from, and different than, their homes.[9]

Studies comparing residential address and all-cause injury location have found that most injuries occur within about 10 miles of a person's residence; however, wide variations exist in the distance between residence and injury location, depending on injury mechanism and intent.[5 10] When aggregating up to the county level, discordance between residence and injury locations is minimal[10 11]; however, at more granular geographical levels, these are frequently distinct locations.[4 10 12 13] These studies have typically relied on single data sources, often with notable amounts of missing location data. Most studies aggregated mechanisms and intents, although several noted variation in the distance between residence and injury location based on mechanism or age.[10–12] Other studies avoided the issues associated with geographic location data by using injury place codes to characterise injuries occurring in public or in homes.[14 15]

We conducted a study of fatal and non-fatal firearm assault injuries occurring in King County or among King County residents over a 5-year period. Our purpose was to present a case study demonstrating (1) the potential degree of misclassification involved in using residence location as a proxy for injury location at varying geographical levels and (2) the non-random missingness of location data. As research on spatial distribution of injury advances and location-based interventions are planned, it becomes increasingly important to consider when to use residential address as a proxy for injury location and when those locations should be treated as distinct.

METHODS

Firearm assault injuries treated at Harborview Medical Center (HMC) in Seattle, Washington (the regional Level I trauma centre) in 2010–2014 were abstracted from the HMC Trauma Registry based on international classification of disease (ICD)−9 code E965.xx. Firearm homicides were abstracted from Washington State death records based on ICD-10 codes X93-X95. Probabilistic linkage (see online supplementary appendix) was used to combine duplicate records across data sources using The Link King.[16] When hospital and death records disagreed on injury intent (n=4), death record intent was used.

The geographical location where each firearm assault occurred ('injury location') and the residential address of each injured person ('residence location') were identified based on HMC and death records. Internet news archives (see online supplementary appendix) were used to supplement/triangulate injury locations missing from official records. Assaults were included in the study if they occurred in King County or the victim resided in King County. We included both types of injuries in order to capture county-level discordance in residence and injury location. Injury location types (eg, 'outdoors', 'street') were summarised as 'home' or 'public'.

Residential and injury location addresses were geocoded. Locations were geocoded using the Here Geocoding API (here.com, Amsterdam, Netherlands). Mapping was done in ArcGIS (ESRI, Redlands, CA, USA). Where both locations were known, the distance between them was calculated. Summary counts of firearm assaults were aggregated at the census tract level using Census 2010 boundaries, for both the tract where each injury victim *resided* and the tract where each injury *occurred*. Assaults were defined as 'inter-municipal' if the victim was shot in a different municipality

Table 1 Characteristics of firearm assault injuries in King County, WA, USA, 2010–2014

	Injuries* N=670		Homicides N=165	
	n	%	n	%
Male	585	87.3	135	81.8
Female	85	12.7	30	18.2
Homeless at time of injury	16	2.4	<5	--
Age (years) at injury				
12–17	33	4.9	7	4.2
18–34	469	70.0	101	61.2
35–49	120	17.9	37	22.4
50–64	38	5.7	15	9.1
65+	10	1.5	5	3.0
Location where injury occurred				
Home/residential	127	21.8	47	28.5
Public area	449	77.0	118	71.5
Industrial/work area	7	1.2	0	--
Missing	87		0	--
Injured in municipality of residence†	358	61.0	82	59.4
Injured outside municipality of residence†	229	39.0	56	40.6
Injured in census tract of residence‡	129	25.1	41	31.1
Injured outside census tract of residence‡	384	74.9	91	68.9
Median distance between injury and residential location (miles) (IQR)‡	3.9	(0.4–9.8)	4.1	(0.1–10.4)
Median distance if injury location is 'home'‡§	0.0	(0.0–4.3)	0.0	(0.0–4.0)
Median distance if injury location is 'public'‡¶	5.2	(1.4–10.8)	6.0	(1.9–12.2)

*Includes both fatal and non-fatal injuries.
†Based on residents of King County injured in King County (n=587 injuries, including 138 homicides).
‡Based on complete geocoding of victims who resided and were injured in King County (n=513 injuries, including 132 homicides).
§n=107 injuries, including 39 homicides.
¶n=340 injuries, including 94 homicides.

than they resided (based on the city, town or unincorporated community listed in the 'city' field of the address). Counts of injuries occurring within each tract and incidence rate of firearm assaults among residents per 10 000 person-years were mapped to King County census tracts. Scatterplots were used to examine the association between distance and victim's age. Plots were stratified by 'home' versus 'public' settings to examine the accuracy of the injury category 'home' as a proxy for residential location. As many studies rely on death records for addresses, and there is a known association between age and risk of firearm assault, we examined how fatality and age may relate to missing location data. Logistic regression was used to quantify risk of missing location data based on age and fatality.

Study protocol and procedures were approved by the University of Washington Institutional Review Board and the Washington State Institutional Review Board. For the incidence rate denominator, 2014 American Community Survey estimates of tract population 2010–2014 were accessed through the National Historical Geographic and Information System.[17] All statistical analyses were done using Stata V.14 (StataCorp LP, College Station, TX).

RESULTS

We identified 665 individuals injured in 670 firearm assaults (165 homicides) occurring in King County or to King County residents between 1 January 2010 and 31 December 2014. Five individuals were shot in two separate incidents. The cohort includes 67 non-King County residents shot in King County and 16 county residents who were shot elsewhere. In total, 587 injuries (87.6%) occurred in King County to county residents ('local' injuries). Of these 'local' injuries, 39% (n=229) occurred in a different municipality from the victim's residence (table 1). Table 2 describes the completeness of geocoding within the cohort, including identification of both residence and injury location for 87.4% of 'local' injuries (95.7% of 'local' homicides).

Missing location data were not at random. The majority of missing residence locations in King County were due to homelessness or unstable housing (16/20). Missing injury location was more common in non-fatal assaults (OR 6.5, 95% CI 2.0 to 21.2) and among victims 18–34, compared with those 35–49 (OR 2.9, 95% CI 1.1 to 7.4).

Both residence and injury location were geocoded for 513 (87.4%) 'local' firearm assaults. The median distance between residence and injury locations was 3.9 miles (IQR 0.4–9.8) (table 1). Figure 1 illustrates how distance between residence and injury location varied by age and location type. Although 'public' assaults occurred further from victims' residences than 'home' assaults, both location types were frequently distant from a victim's residence, especially for young adult victims. Only 25% of injuries occurred within a one-half mile of the victim's residence. Seventy-five per cent of injuries occurred outside the victim's census tract of residence.

Figure 2 maps the spatial distribution (count) of firearm assaults within each tract over the study period and the incidence rate of assaults to tract residents per 10 000 person-years. Based on both locations, assaults were concentrated in urban areas. Injury locations were particularly concentrated. In all, 40 tracts had a ratio of injury incidents to injured residents of >1, suggesting that using injuries sustained by tract residents underestimates the incidence of firearm assaults

Table 2 Location data completeness of firearm assault injuries in King County, WA USA, 2010–2014

	Injuries* N=670		Homicides N=165	
	n	%	n	%
Injuries geocoded by residential location	647	96.6	161	97.6
Missing geocoded residential location	23	3.4	4	2.4
Injuries geocoded by injury location	601	89.7	160	97.0
Missing geocoded injury location	69	10.3	5	3.0
Injuries with both residential and injury location geocoded	586	87.5	156	94.5
Missing geocoded residential and/or injury location	84	12.5	9	5.5
Injuries to King County residents	603	90.0	148	89.7
Injuries to King County residents geocoded by residence location	583	96.7†	145	98.0‡
Missing geocoded residence location	20	3.3†	3	2.0‡
Injuries incidents occurring in King County	654	97.6	155	93.9
Injuries incidents occurring in King County geocoded by injury location	589	90.1§	152	98.1¶
Missing geocoded injury location	65	9.9§	3	1.9¶
'Local' injuries (both residence and injury located in King County)	587	87.6	138	83.6
'Local' injuries with both residence and injury location geocoded	513	87.4**	132	95.7††
Missing geocoded residence and/or injury location	74	12.6**	6	4.3††

*Includes both fatal and non-fatal injuries.
†Out of all injuries to King County residents.
‡Out of all homicides of King County residents.
§Out of all injuries occurring in King County.
¶Out of all homicides occurring in King County.
**Out of all 'local' injuries (residence and injury located in King County).
††Out of all 'local' homicides (residence and injury located in King County).

within the tract. In total, 13 tracts had an injury incident:injured resident ratio >3.

DISCUSSION

To our knowledge, this study presents one of the most complete and granular investigations of differences between residence and injury locations, with a small amount of missing location data. By focusing on firearm assaults, we demonstrated how the spatial distributions of residence and injury locations among firearm assault cases vary based on age, and how age and unstable housing contribute to non-random missingness. We also found substantial inconsistency between residential location and the injury place code 'home'.

Our results agree with a few studies comparing injury and residence location in other parts of North America at more aggregated geographical levels in identifying meaningful differences between residence and incidence location.[10 12 13] Although most assaults within King County were among county residents, at the municipality or tract level using residence as a proxy for injury location introduced considerable misclassification. Three-quarters of firearm assaults occurred outside the victim's tract of residence—the neighbourhoods where people live are not where they are shot. Missing residence and injury location data may also lead to bias, as residence-based study criteria may exclude the homeless and unstably housed, or disguise injury hotspots where injuries are primarily among non-residents. A majority of missing address data for King County residents

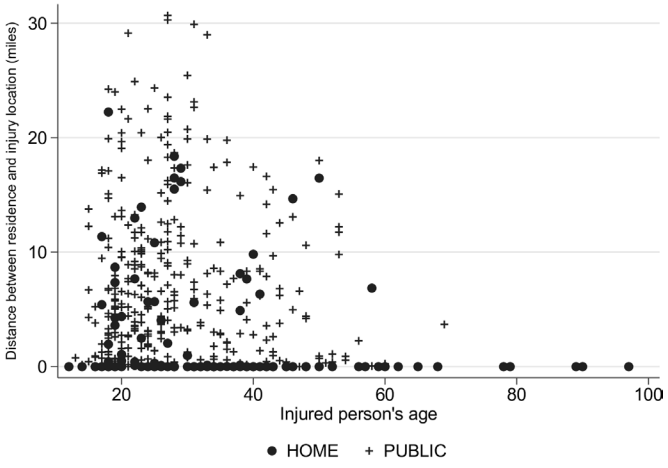

Figure 1 Distance between home and injury location by age and location type.

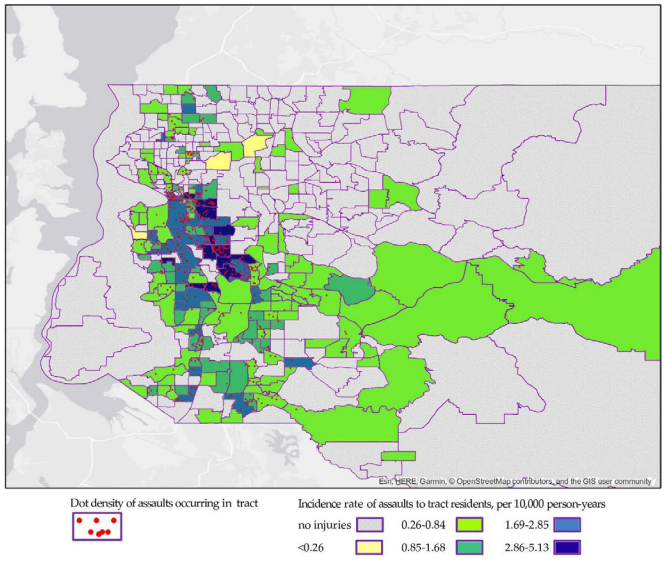

Figure 2 Incidence rate and dot density of firearm assault injuries in King County, 2010–2014.

were due to assaults on the homeless. Addressing injury disparities for this population requires accurate identification.

By combining medical records with death records to capture victims who died at the scene of their injuries, we were able to present a cohesive picture of both fatal and non-fatal firearm assaults within King County. As a majority but not 100% of firearm assaults are captured in our data sources, incidence rates are undercounts. Our study was conducted in a single urban county, aggregating firearm injuries over a 5-year period. Comparable data from other counties are necessary to judge the generalisability of our findings. It is likely that county-level characteristics, including physical geography and rurality, strongly influence distances and correlates of home and injury location.

CONCLUSION

Research on spatial distribution of injury should consider residence and injury locations separately, with appropriate care exercised in considering when to use residential address as a proxy for the location of injury occurrence. The accuracy of spatial analyses would be greatly improved with enhanced routine collection of injury location and unstable housing.

What is already known on this subject

- Residence is often used as a proxy for injury location.
- Studies of all-cause injuries show discordance between residence and injury location, and incomplete injury location data.

What this study adds

- Linked hospital and death records, and supplemental data collection reduces missing location data.
- Substantial discordance in residence and injury location at multiple geographical levels is present even within a single mechanism and intent group. One cannot assume census tract or neighbourhood is a good proxy for injury location.
- Missing injury location data are not random.

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