Local-level Association of Social Deprivation and Serious Injuries in Washington State: An Ecological Cross-sectional Study

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Abstract

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Background

Injuries, a major source of morbidity and mortality, are associated with social determinants of health. To inform strategic prioritization and targeting of injury prevention resources, there is a need to better understand the relationship between community-level risk factors and serious injuries.

Methods

We conducted an ecological cross-sectional study in ZIP Code Tabulation Areas (ZCTAs) level in Washington State. Community-level risk was assessed through Social Deprivation Index (SDI) (i.e., a composite score that measures deprivation using American Community Survey (ACS) demographic data). Serious injury was defined as injury hospitalization or death. Negative binomial regression was used to examine the relationship between SDI score and injury incidence and pattern.

Results

SDI score, nonfatal injury hospitalization and death all showed substantial variation across ZCTAs. Compared to communities with the lowest SDI quintile (i.e., lower deprivation), communities with the highest deprivation quantile had higher nonfatal all-cause injury hospitalization incidence rate (IRR=1.38, 95% CI: 1.18,1.6), unintentional injury rates (IRR=1.29, 95% CI: 1.11, 1.50), interpersonal injury rates (IRR=5.22, 95% CI: 3.04, 8.90), and self-inflicted injury rates (IRR=1.69, 95% CI: 1.16, 2.46). Similarly, communities with the highest quantile also had higher all-cause injury mortality rate (MRR=1.79, 95% CI: 1.27, 2.51), unintentional injury mortality rate (MRR=1.96, 95% CI: 1.29, 2.95), homicides (MRR=4.17, 95% CI: 1.63, 10.4), and suicides (MRR=1.23, 95% CI: 0.78, 1.94).

Conclusion

We observed a positive relationship between SDI score and serious injury at the ZCTA level. Community deprivation indices such as SDI may be a valuable tool for injury prevention targeting at the local level.

INTRODUCTION

Injuries are the leading cause of death among people between 1 and 44 years of age in the United States, and a major source of morbidity and mortality for all age groups (1). Most injuries are preventable and can be addressed through coordinated initiatives that target environmental, situational, and individual risk factors. There is substantial research on targeting injury prevention resources and broad acceptance of “community-based models”, which emphasize shared expert/community responsibility, multidisciplinary collaboration, and are implemented at the community level (2); however, few studies have rigorously assessed the relationship between community-level risk factors and injury occurrence and patterns, particularly those relating to the social determinants of health (3).

Public health resources for injury prevention are limited and should be developed with cross-sector collaboration to improve efficiency in implementation and maximize the implementation of addressing shared risk factors (4,5). To develop and deploy effective strategies, it is imperative that policy makers understand where injuries are occurring, how they are distributed across populations and communities, and what modifiable community-level risk factors are associated with specific injury mechanisms and rates. Although increased availability of novel methodologies, data visualizations and other tools have helped meet the demand for local-level data by smaller jurisdictions and implementers (6), there is a need to better understand how community-level differences affect injury epidemiology to justify the targeting of prevention intervention packages and to produce effective, equity-driven results (7).

There is strong evidence linking lower individual and household socioeconomic status with higher rates of injury, particularly for interpersonal injuries and injuries occurring in children (8–10). However, two main gaps in this evidence exist. First, the impacts of community-level risk factors on unintentional injury rates across all ages are not well known. Second, the utility of proxy measures that represent multiple community-level risk factor domains (e.g., community deprivation indices) are under-utilized in injury prevention research in the US.

Deprivation indices aim to quantify not only the direct levels of socioeconomic inequality, but other related, indirect factors such as employment, housing, and education, that are associated with worse health outcomes (11). These indices have been frequently used in other countries to support health resource allocation; in this subject area, studies from New Zealand, Canada, and England have found positive relationships between measured community deprivation and injury risk (8,11–14). There are few reports using US-based community deprivation indices, and most have focused only on interpersonal injuries or other health issues; furthermore, the unique aspects of healthcare funding in the US may limit generalization of results from other countries (11).

To address these gaps, we aimed to describe the distribution of community deprivation as measured in a publicly and nationally available index, and serious injuries (i.e., those that required hospitalization or resulted in death) in Washington State. We also aimed to determine the association between deprivation and serious injury rates. The findings may inform strategic targeting of scarce injury prevention resources and increase effectiveness in reducing health inequalities.

METHODS

Study Design and Population

We used an ecological cross-sectional study design to assess the relationship between community-level social deprivation and serious injury incidence, pattern and mortality in Washington State in 2014. We defined serious injuries as nonfatal injury-related hospitalizations and injury-related deaths among state residents; less serious injuries were not assessed in this study due to differences in coverage area between state-wide databases. Injuries due to adverse effects of medical care or drugs and late effects of injury were excluded from the study; to restrict hospitalizations to nonfatal events, visits with a discharge status of “expired” were excluded.

Data Sources and Management

The Robert Graham Center developed and validated a US-based community deprivation index [i.e., Social Deprivation Index (SDI)] with the intention of quantifying “levels of disadvantage” across small areas, of assessing their relationship with health outcomes, and ultimately of reducing health disparities (15). Specifically, the SDI score is a composite measure of demographic characteristics collected in the American Community Survey (ACS): “percent living in poverty, percent with less than 12 years of education, percent single parent household, percent living in rented housing unit, percent living in overcrowded housing unit, percent of households without a car, and percent non-employed adults under 65 years of age” (16). Factor analysis is used to create weighted scores for each demographic characteristic, which are converted to

centiles and compiled to produce an SDI “score” ranging from 1-100 (16). 2015 SDIs were developed using 2011-2015 ACS data and are nationally and publicly available at several geographic scales; as they span a 5-year period, 2015 SDI scores were assumed to be representative of SDI scores in 2014.

Individual-level hospital visit and death data were collected for January-December 2014 to allow proximate comparison to the SDI. Hospital admissions data were sourced from the Washington State Department of Health (DOH) Comprehensive Hospital Abstract Reporting System (CHARS). Death data were collected from the DOH Vital Statistics Division. Injuries were defined by first-listed ICD-9 and ICD-10 billing codes, and DOH definitions were followed for type and intent. For hospitalizations, first-listed ICD-9 external cause codes (hospitalizations) of E800-E848, E850-869, or E880-E928 were categorized as unintentional, E960-969 or E979 as interpersonal (assault or homicide), E950-959 as self-inflicted (suicide), E980-989 as of undetermined intent, and E970-978 or E990-E999 as injuries due to legal or war causes. For deaths, first-listed ICD-10 cause codes of V01-X59 or Y85-Y86 were categorized as unintentional, X60-X84 or X87.0 as interpersonal (assault or homicide), X85-Y09 or Y87.1 as self-inflicted (suicide), Y10-Y34, Y87.2, or Y89.9 as of undetermined intent, and Y35-Y36, Y89.0 or Y89.1 as injuries due to legal or war causes. Both CHARS hospital record and death data sources were de-identified and thus exempt from Institutional Review Board review.

“Community” was defined as the 2010 ZIP Code Tabulation Areas (ZCTA), statistical entities developed by the United States Census Bureau. ZCTAs are aggregated from census tracts and based on postal ZIP codes. In the 2010 update, large bodies of water,

parks, and other uninhabited areas were not assigned to ZCTAs and left as “holes” in the area coverage; these are reflected in maps in this study (17). SDI scores were available at ZCTA-level and patient residential ZIP codes for were used to assign injuries to ZCTAs using the 2014 USDS ZIP Code to ZCTA Crosswalk (18). 2014 5-year population estimates from ACS were used to calculate person-years at risk.

Analysis

For a practical assessment of the SDI score, ZCTA’s were divided into 5 quantiles and modeled as categorical predictors. Areas with small population are more sensitive to variation in population estimates (e.g., 1 vs 5-year ACS estimates), and chance variation in year-to-year injury occurrence. Therefore, the analysis was restricted to ZCTAs with at least 1,000 inhabitants per the 2014 5-year population estimate from ACS. Incidence and mortality were calculated at the ZCTA level per 100,000 person years. ZCTA’s with no matched deaths and/or hospitalizations were assumed to have zero incidence and mortality for 2014.

To account for possible overdispersion as evaluated in a likelihood ratio test, negative binomial regression models were constructed to assess incidence and mortality rate ratios across the quantiles of SDI score by ZCTA, using the quantile with the lowest calculated social deprivation (first quantile) as a reference group (19). Separate models were developed to examine nonfatal injury hospitalizations and deaths and the subgroups of unintentional, interpersonal and self-inflicted injuries. 95% confidence intervals were generated for rate ratios, and $p<0.05$ was considered statistically

significant. Data management was performed in SAS (Version 1.0.14393, SAS Institute Inc.), regressions and descriptive analysis were performed in R Statistical Software (Version 1.1.463, R Foundation for Statistical Computing) and maps were generated using QGIS (Version 3.8.0, QGIS Geographic Information System).

RESULTS

Of the 590 2010 ZCTAs in Washington State, 422 had at least 1,000 residents, which represented 6,831,454 person-years in 2014. SDI scores ranged from 1-93 out of 100 and were distributed across the state as shown in Figure 1. Population per included ZCTA ranged from 1,000 to 75,273, with the lowest median population per ZCTA in the first quantile (lowest deprivation).

Figure 1. Social Deprivation Index (SDI) score quantile by ZCTA

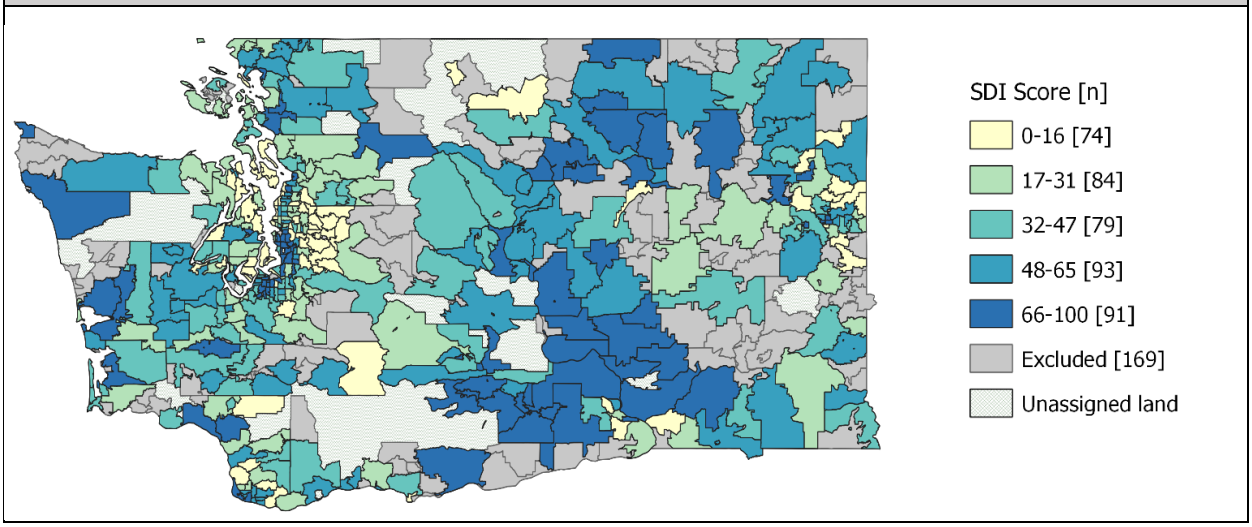


Table 1. Population distribution by Social Deprivation Index (SDI) score quantile[1]			
Quantile of Social Deprivation Index (SDI)	**Number of 2010 ZCTAs**	**Total 2014 5-year ACS population**	**Median population per ZCTA**
Lowest deprivation **1st (0-16)**	74	1,006,830	8,897
2nd (17-31)	84	1,414,896	13,494
3rd (32-47)	79	1,231,561	9,286
4th (48-65)	93	1,616,410	14,634
5th (66-100) *Highest deprivation*	91	1,561,757	12,345

[1]Only includes ZCTAs with at least 1000 residents in 2014 (n=422)

44,340 nonfatal injury hospitalizations and 2,856 injury-related deaths among Washington State residents in 2014 occurred in the 422 ZCTAs with population ≥1,000. Unintentional injuries constituted the majority of nonfatal injury hospitalizations (88%) and injury-related deaths (53%) with self-inflicted injuries representing the next largest proportion of each (7%, 37%) (Appendix Table 1).

Nonfatal injury hospitalizations

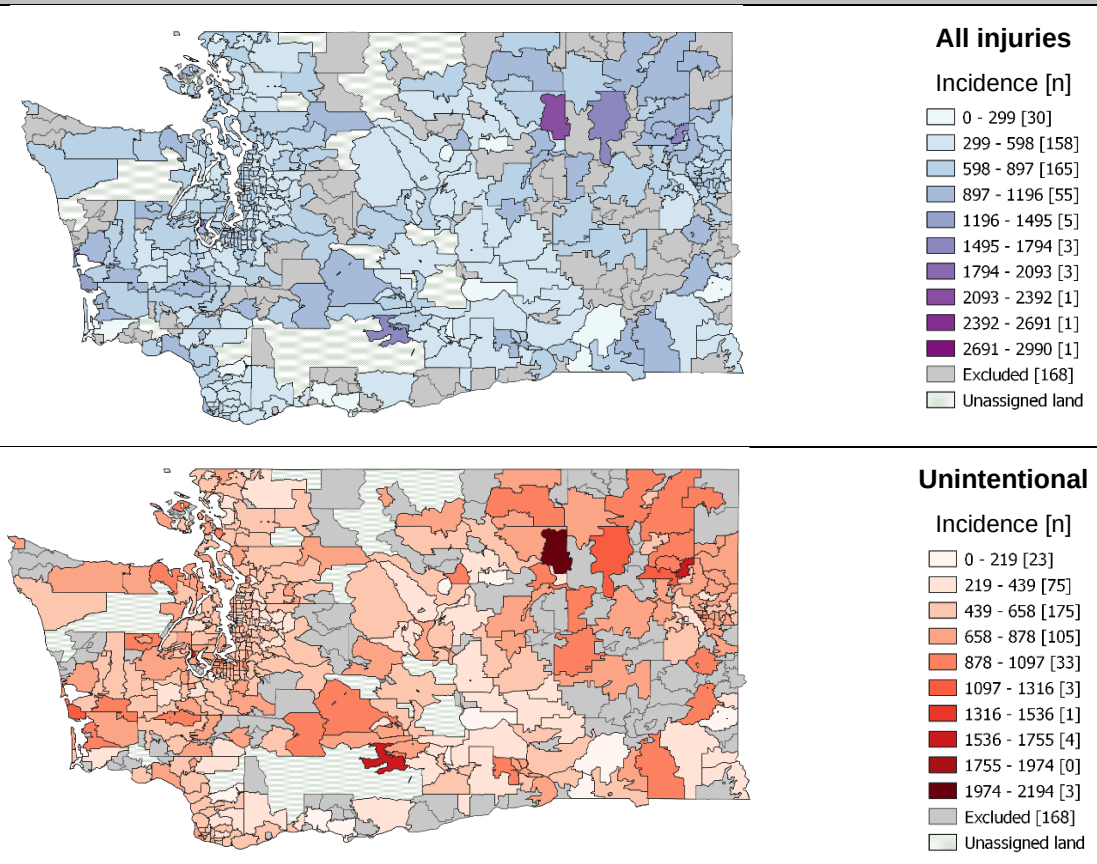
Nonfatal injury hospitalization incidence rates ranged from 0 - 2,990 visits per 100,000 person-years in 2014. For all injury types, median incidence was highest in ZCTAs with the highest level of deprivation, and lowest in those with the lowest level (Table 2). Geographic distribution of nonfatal hospitalization incidence by injury type is shown in Figure 3.

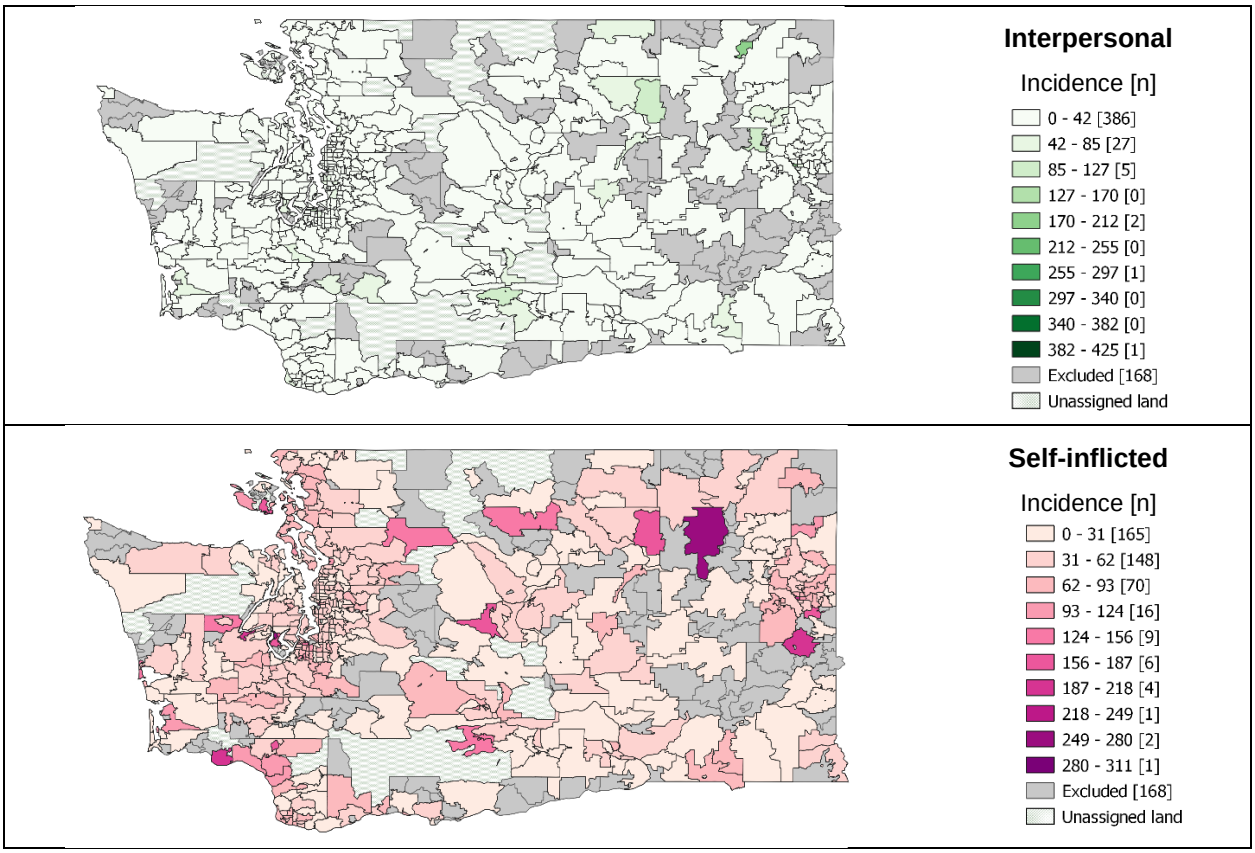
Table 2. Median incidence of nonfatal injury hospitalization of ZCTAs in Washington State, 2014[1]

SDI quantile	All injuries[2]	Unintentional injuries	Interpersonal injuries	Self-inflicted injuries
Lowest deprivation **1st (0-16)**	546.2 (453-699)	509.4 (398-666)	0.0 (0-8)	31.4 (15-53)
2nd (17-31)	594.9 (489-760)	532.9 (443-688)	6.2 (0-14)	32.7 (20-50)
3rd (32-47)	666.7 (516-814)	581.0 (453-742)	8.6 (0-21)	44.8 (27-58)
4th (48-65)	645.5 (527-803)	578.3 (467-704)	11.2 (0-22)	43.2 (21-63)
5th (66-100) *Highest deprivation*	730.9 (518-905)	624.7 (463-795)	19.3 (8-44)	50.8 (24-87)

[1]Presented as rate per 100,000 residents (interquartile range)
[2]Includes injuries due to war and legal intervention, and of undetermined intent.

Figure 3: Nonfatal injury hospitalizations per 100,000 residents by type and ZCTA, Washington State, 2014





Higher SDI quantile (i.e., higher social deprivation) was associated with greater nonfatal injury hospitalization incidence across all injuries and in each of the injury types. ZCTAs in the highest SDI quantile had 38% higher overall nonfatal injury hospitalization incidence compared to those in the lowest quantile (95% confidence interval (CI): 1.18, 1.60). Unintentional injuries had the lowest level of association, with 29% (95% CI: 1.11, 1.50) higher incidence in the ZCTAs with the most reported deprivation, followed by self-inflicted injuries, with 70% (95% CI: 1.16, 2.46) higher incidence in those areas. The largest association was between SDI score and interpersonal injuries, with 422% (95% CI: 3.04, 8.90) percent higher injury incidence at areas with the highest level of deprivation compared to those at the lowest level, and at least two times higher incidence in the third and fourth quantiles. Both the overall injury and injury types had a

statistically significant association in nonfatal injury hospitalization incidence between the highest and lowest quantiles of SDI score.

Table 3. Incidence Rate Ratios (IRR) for nonfatal injury hospitalizations by ZCTA, Washington State, 2014 (n=422) [1]

SDI quantile	All injuries[2]	Unintentional	Interpersonal	Self-inflicted
Lowest deprivation **1st (0-16)**	Reference (Intercept=579)*	Reference (Intercept=526)*	Reference (Intercept=6.3)*	Reference (Intercept=38.4)*
2nd (17-31)	1.08 (0.92, 1.26)	1.07 (0.92, 1.25)	1.39 (0.80, 2.41)	1.10 (0.74, 1.61)
3rd (32-47)	1.14 (0.98, 1.34)	1.13 (0.96, 1.32)	2.30 (1.32, 4.01)*	1.13 (0.77, 1.68)
4th (48-65)	1.19 (1.03, 1.38)*	1.18 (1.01, 1.37)*	2.55 (1.49, 4.34)*	1.16 (0.79, 1.69)
5th (66-100) *Highest deprivation*	1.38 (1.18, 1.60)*	1.29 (1.11, 1.50)*	5.22 (3.04, 8.90)*	1.69 (1.16, 2.46)*

[1]Structured as IRR (95% Confidence Interval) unless otherwise specified
[2]Includes injuries due to war and legal intervention, and of undetermined intent.
[3]Mean incidence for reference group
*****Statistically significant at p<0.05

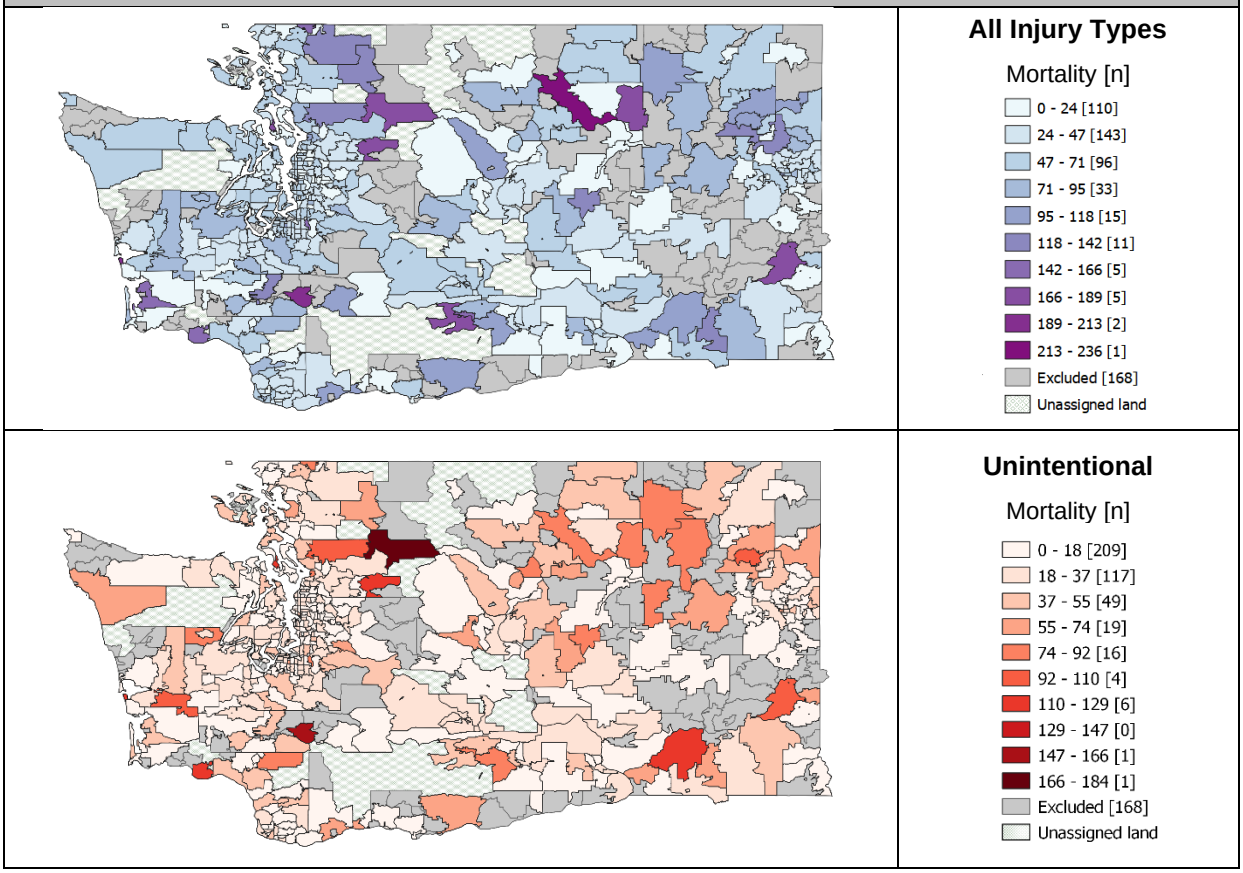
Deaths

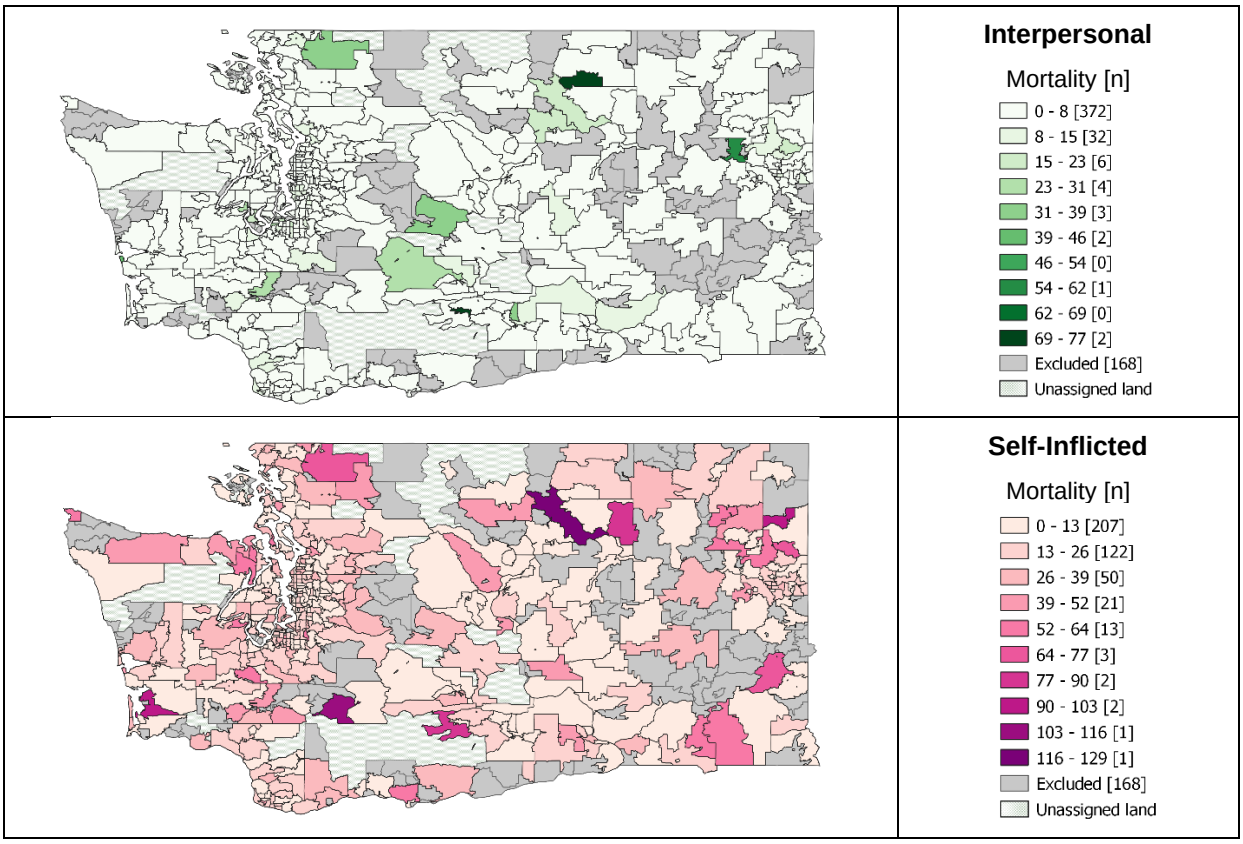
Deaths per 100,000 residents ranged from 0 - 236 in 2014, with no injury-related deaths observed in 15% of ZCTAs (n=64). As with nonfatal injury hospitalizations, median mortality rate was highest in the fifth SDI quantile (greatest deprivation) across all injuries combined and for unintentional injuries; however, interpersonal injury deaths, of which there were few (n=186), had median rate of zero at all quantiles, and self-inflicted injuries (n=1,060) had greater variability, with the highest median mortality at the central quantile (15.7 per 100,000 person-years).

Table 4. Median mortality rate of ZCTAs in Washington State, 2014[1]				
SDI quantile	**All injuries[2]**	**Unintentional injuries**	**Interpersonal injuries**	**Self-inflicted injuries**
Lowest deprivation				
1st (0-16)	28.9 (0-46)	12.1 (0-23)	0 (0-0)	8.2 (0-21)
2nd (17-31)	32.6 (17-52)	15.2 (5-29)	0 (0-0)	11.4 (0-21)
3rd (32-47)	44.0 (29-60)	20.7 (10-36)	0 (0-2)	15.7 (7-29)
4th (48-65)	43.4 (29-69)	21.6 (9-38)	0 (0-4)	14.8 (6-28)
5th (66-100)	50.6 (34-65)	25.2 (11-42)	0 (0-6)	12.6 (0-21)
Highest deprivation				

[1]Presented as rate per 100,000 residents (interquartile range)
[2]Includes injuries due to war and legal intervention, and of undetermined intent.

Figure 3: Injury-related mortality per 100,000 Residents by type and ZCTA, Washington State, 2014





SDI score was positively associated with mortality across all injury types and for each group separately, with statistically significant ($p<0.05$) associations for all injuries, unintentional injuries, and intentional injuries in the areas with the highest level of deprivation. ZCTAs in the highest quantile had 79% (95% CI: 1.27, 2.51) higher overall injury mortality in 2014, nearly twice the unintentional injury mortality (MRR=1.96, 95% CI: 1.29, 2.95) and more than four times the interpersonal injury mortality (MRR=4.17, 95% CI: 1.63, 10.40) of the ZCTAs with the lowest deprivation scores. The suicide mortality rate was also higher with higher levels of deprivation than the reference group but was observed to be greatest in the central (MRR=1.56, 95% CI: 0.97, 2.49) and fourth quantiles (MRR=1.57, 95% CI: 1.00, 2.49).

Table 5. Mortality Rate Ratios (MRR) for deaths with injury at a primary cause by ZCTA, Washington State, 2014 (n=422) [1]

SDI quantile	All injuries[2]	Unintentional	Interpersonal	Self-inflicted
Lowest deprivation				
1st (0-16)	Reference (Intercept=32.1)*	Reference (Intercept=16.6)*	Reference (Intercept=1.50)	Reference (Intercept=12.8)*
2nd (17-31)	1.19 (0.84, 1.69)	1.31 (0.87, 2.02)	0.92 (0.35, 2.40)	1.09 (0.68, 1.73)
3rd (32-47)	1.50 (1.06, 2.13)*	1.47 (0.96, 2.26)	1.65 (0.63, 4.31)	1.56 (0.97, 2.49)
4th (48-65)	1.66 (1.18, 2.32)*	1.71 (1.13, 2.57)*	1.91 (0.75, 4.78)	1.57 (1.00, 2.49)*
5th (66-100)	1.79 (1.27, 2.51)*	1.96 (1.29, 2.95)*	4.17 (1.63, 10.40)*	1.23 (0.78, 1.94)
Highest deprivation				

[1]Structured as IRR (95% Confidence Interval) unless otherwise specified
[2]Includes injuries due to war and legal intervention, and of undetermined intent.
*****Statistically significant at p<0.05

DISCUSSION

In this place-based study of injury hospitalizations and deaths, we evaluated the relationship of SDI with community-level patterns of injury in Washington State. We observed large differences in rates of nonfatal injury hospitalization and death across ZCTAs in Washington state, and a positive association between SDI score and injury occurrence, particularly for interpersonal injuries. These findings support the importance of accounting for social determinants of health when designing injury prevention programs and add evidence towards expanded use of community deprivation indices in the US for public health.

Improved identification of excess risk and evidenced-based contributing factors at the local level can support local stakeholders in considering and deploying injury prevention packages that suit their communities, and effectively protect against poor health

outcomes (5). Numerous studies have demonstrated the importance of evaluating social determinants and geography when working on injury (12,20,21); in this study, the assessment of SDI score and injury patterns at ZCTA level may have special utility for policymakers and local stakeholders because of the familiarity of the related measure (postal ZIP codes) and its potential use as a balance between “neighborhood” and larger jurisdiction-level programming. Furthermore, a 2016 study by Bye et al. found that people who were more skeptical of an active governmental role in health were more receptive to improvements targeted at the community level (22). However, as noted in the 2013 systematic review of socioeconomic status measurement by Laflamme et al., there is a need to go beyond descriptive analysis in prevention work, and to assess not only the presence of but the reason behind socioeconomic differences (10).

In this study, we found that higher levels of injury occurrence were associated with greater social deprivation across all injury types combined; in nonfatal injury hospitalizations, this was likely driven by unintentional injuries, which represented 88% of hospitalizations and had a statistically significant relationship between SDI score in the two highest quantiles. Deaths showed a similarly positive but larger rate ratio for overall injuries and unintentional injuries; the reversal in which rate is higher is likely due to the larger proportional of self-inflicted injuries in the deaths (7% to 37%). We also observed an association between SDI and self-inflicted injury in both nonfatal injury hospitalizations and deaths, though with generally wider confidence intervals and a less of a dose-response relationship than the other subgroups (Table 3, Table 5). Other studies have also observed a relationship between area-level deprivation and injury occurrence; in South Korea, a multilevel study of a geographic deprivation index and

injury-related deaths found that the most deprived districts were at greater risk of injury mortality than the least deprived, even after controlling for individual-level socioeconomic variables (unintentional risk ratio (RR)= 1.14, 95% CI 1.01, 1.17; suicide RR=1.14, 95% 1.07, 1.02) (12,23,24). The South Korea study also observed greater risk of death due to traffic accidents (RR=1.34, 95% CI: 1.05,0.73) and falls (RR=1.63, 95% CI: 1.20,2.20) (12). Due to small numbers, mechanism of injury was not assessed in this study; for future work, expanded research on mechanism would likely benefit from the inclusion of known non-social determinant risk factors and covariates for well-studied mechanisms of injury, including falls and motor vehicle crashes.

There was a strong correlation between SDI score and interpersonal injury among both nonfatal hospitalizations and deaths for the communities with highest measured deprivation. This is consistent with existing literature on place-based studies of violence and neighborhood-level community characteristics, which have found higher experience of violent injuries in geographies with higher deprivation and among persons living in economically depressed areas (9,21,25). Furthermore, a systematic review evaluating indicators for community-level risk in violence prevention found that a shared risk, multi-factor structure more effectively identified relationships between worse health outcomes and social determinants of health, and has been used in violence prevention and other health programs (21). As deprivation indices share this structure and have been studied in the context of a variety of health conditions, they may be useful for area-level studies investigating multiple health issues, and in prevention programming involving cross-sector collaboration (26).

The results of this study are subject to several limitations. First, this study did not evaluate differing mechanisms of injury, many of which, like motor vehicle crashes and falls, have well-established risk factors and causal pathways. However, as noted in the discussion of unintentional injuries, variation around mechanism may be better studied with specific consideration of the known risks in the context of area-level deprivation. Second, although use of a composite measure may mask some heterogeneity in risk within the demographic characteristics, the goals of this study were evaluate the combined effect of related risks via an index, rather than to isolate strongly correlated individual factors (11). Furthermore, injury prevention targeting is often intended to address a set of risks, rather than individual predictors, especially for social determinants of health (7).

As this study only represents a single year of data, and there is known benefit towards lagging income inequality measures and health outcomes, we cannot infer causality between SDI score and injury occurrence (27). In addition, individual and area-level covariates were not assessed in these models; future research may benefit from inclusion of relevant covariates, especially if mechanism of injury is further considered. Finally, ZCTA's are not a governmental jurisdiction and may not be a practical level for programmatic implementation. However, their relationship to ZIP codes makes them a sub-county measure that may still be familiar to broader audiences, as might their relationship to existing metropolitan areas. For example, in an NIH-led assessing state desire for local population health data, composite profiles were compiled at the ZIP-code "neighborhood" level (6).

Despite these limitations, the findings show strong evidence of a relationship between community-level deprivation and various injury subgroups, and remain helpful in understanding the utility and precision of a community index in studying injury in the US.

Conclusion

Future research may investigate whether the relationships between community-level deprivation and injury outcome observed also hold true for injuries in primary care settings or at the emergency department, or whether the relationships change with a further look at mechanisms. The evidence in this study is suggestive of a positive association between area-level community deprivation and injury occurrence, and may be useful for injury prevention organizations for planning and delivery of programs, in informing allocation of limited resources, and meeting increasing demand for local-level data for action (6). As stated by Laflamme et al., prevention of inequities in safety requires addressing not only the proximal risk factors but also the “remote and fundamental ones inherent to poverty” (10); rigorous, actionable research on these factors can help both experts and community stakeholders make decisions that result in effective reduction of injuries.

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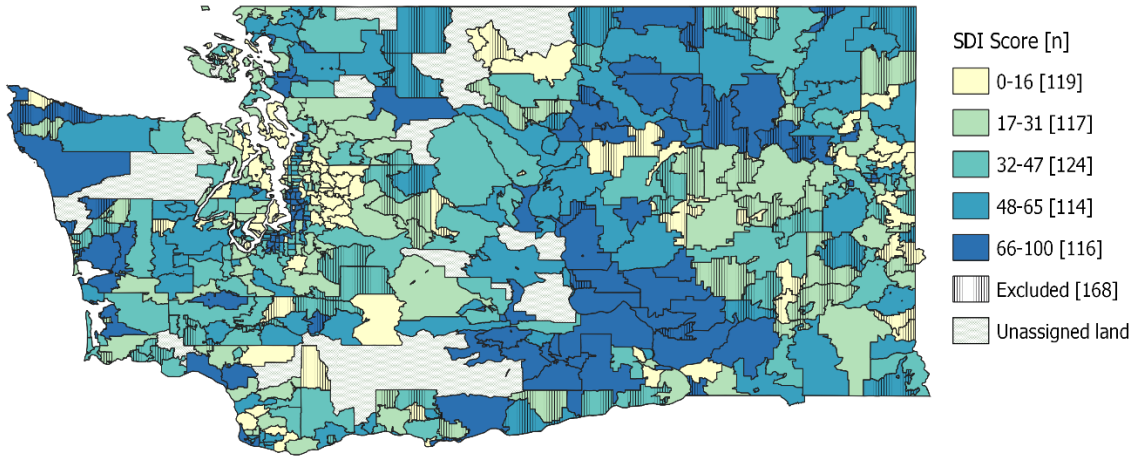
APPENDIX

Appendix Table 1. Nonfatal injury hospitalizations and deaths, Washington State, 2014

	Nonfatal Injury Hospitalizations	Incidence per 100,000 person-years		Deaths	Mortality per 100,000 person-years	
	n (%)	Median	Mean	n (%)	Median	Mean
All Injury Types	44,340 (100)	637.9	674.0	2,856 (100)	39.7	46.4
Unintentional	38,998 (88)	563.5	598.4	1,521 (53)	18.8	25.1
Interpersonal	1,152 (3)	8.9	16.2	183 (6)	0.0	3.0
Self-inflicted	3,302 (7)	39.8	47.2	1,060 (37)	13.1	16.6
Undetermined	817 (2)	6.2	11.5	73 (3)	0.0	1.4
Legal/war	71 (0)	0.0	0.8	19 (0)	0.0	0.3

Appendix Figure 1. Social Deprivation Index (SDI) Score Quantile by ZCTA (n=590)



ZCTAs with population <1000 were excluded from main analysis.

Appendix Figure 2. American Community Survey (ACS) 5-year population, Washington State, 2014 (n=590)