



Short communication

Relationship between county-level crime and diabetes: Mediating effect of physical inactivity

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ABSTRACT

This paper assessed the extent to which physical inactivity accounts for the relationship between the crime rate and prevalence of type 2 diabetes in the United States. Using 2018 US county-level data, we compared unadjusted and adjusted prevalence of type 2 diabetes between high and low crime counties for 2,966 US counties. Average causal mediating effects of residents' reported physical inactivity were estimated for each comparison. Counties with a higher crime rate were more likely to have higher percentages of people with type 2 diabetes than counties with a lower crime rate, even after adjusting for potential confounding factors such as racial distribution, income level, food insecurity, and neighborhood walkability (adjusted coefficient for top 40% vs. bottom 40% of crime rate distribution = 0.36; $p < 0.001$). Over 60% of the adjusted relationship between county-level rate of crime and type 2 diabetes was found to be mediated by physical inactivity. This study reinforces potentially overlooked public health benefits of effective anti-crime measures via improved physical activity.

1. Introduction

As of 2018, about 30 million adults in the US have diabetes and 88 million have prediabetes, a condition that often progresses to type 2 diabetes (T2D) if untreated (Centers for Disease Control and Prevention, 2020). The public health crisis of diabetes is expected to increase substantially - to more than 55 million Americans between 2015 and 2030 (Rowley et al., 2017).

The American Diabetes Association considers physical activity a "cornerstone" of diabetes management and prevention (Sigal et al., 2006), but only less than 20 percent of the American population participate in regular and adequate exercise (US Department of Health and Human Services, 2020). With established evidence of reducing diabetic risk factors such as body weight, inflammation, insulin resistance, and glycemic control (Sigal et al., 2006; Bassuk and Manson, 2005), physical activity has been found to positively affect the management and prevention of type 2 diabetes independently of BMI (Rana et al., 2007). Physical inactivity is significantly associated with demographic and socioeconomic factors, with a greater share of physical inactivity among minority (non-Hispanic black and Hispanic) children and adults than in non-Hispanic whites, and among lower income and

education groups (Gordon-Larsen et al., 2000; Marshall et al., 2007). Limited proficiency in English has also been associated with higher rates of physical inactivity (Lopez-Quintero et al., 2010). Characteristics of where people live also influence rates of physical inactivity. People who live in rural areas have lower rates of physical exercise than their urban counterparts (Patterson et al., 2004). Walkability of the built environment is correlated with rates of exercise among residents, notably diabetics (Hosler et al., 2014), and poverty and food insecurity in an area have a positive relationship with physical inactivity rates (Chung et al., 2012; Kelly et al., 2007). This may have influenced geographic clustering of T2D (Shrestha and Spatial, 2012).

Another important identified area-level influence on T2D is rates of violent crime (DeWall et al., 2011). Through its association with both crime and T2D, physical inactivity may be identified as a potential mediating factor between the observed relationship of violent crime and T2D prevalence. Previous research identifies violent crime as being associated with higher rates of physical inactivity, likely due to residents' not feeling safe walking and engaging in other physical activity in their neighborhood (Foster and Giles-Corti, 2008; Tamayo et al., 2016).

A better understanding of key mediating factors is critical in designing effective prevention and management strategies that target

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these factors. Accordingly, this research aims to examine the extent to which physical inactivity is associated with the potential effect of county-level crime on T2D while accounting for confounders in the relationships (appendix Fig. A1).

2. Methods

2.1. Data

We used the 2018 County Health Rankings and Roadmaps (CHRR) which provides key measures for the study including county-level rate of crime, type 2 diabetes, physical inactivity, and potential confounding factors. CHRR is an online database sponsored by the Robert Johnson Foundation in association with the University of Wisconsin Public Health Institute that aims to provide a “snapshot of how health is influenced by where we live, learn, work and play” (2018 County Health Rankings and Roadmaps). The provided data is a nationally representative sample of health variables for 3,142 counties in the US. All measures used for the study except for walkability are from this 2018 CHRR.

County-level walkability, a potential confounding variable, was constructed based on data from the US Environmental Protection Agency’s national walkability index (<https://catalog.data.gov/dataset/walkability-index>). This dataset uses a comparative system to rank 2010 Census block groups in the US according to characteristics of the built environment that influence relative walkability. Using this data, we created a county-level score of walkability by calculating a population weighted average score per county.

2.2. Measures

The outcome of type 2 diabetes (T2D) is measured as the percentage of adults in the county aged 20 and over with diagnosed diabetes. The main independent variable is county-level crime rate, or the number of violent crimes per 100,000. For the purposes of this project, violent crime rate was dichotomized into two groups “high” and “low” crime rate using various cut points: top 50% vs. bottom 50%; top 40% vs. bottom 40%; top 30% vs. bottom 30%; top 20% vs. bottom 20%. For example, the 30/30 cut point compares between 30% of counties with

the lowest crime rates and 30% of counties with the highest crime rates among all counties in the US. We use a series of dichotomized measures of crime rate rather than a continuous measure because we suspect that there may be a threshold effect in the association between the crime rate and T2D. Physical inactivity, the mediating variable of interest, is measured as the percentage of the county population reporting no leisure time physical activity (such as running, golf, house or yardwork, or walking for exercise) in the past month, based on responses to the nationally representative Behavioral Risk Factor Surveillance Survey (2018 County Health Rankings and Roadmaps).

Based on the prior literature, following measures were used to adjust for confounding factors in the relationship of interest:

- Race/ethnicity
 - o Percentage of population who are Non-Hispanic blacks in the county
 - o Percentage of population who are Non-Hispanic whites in the county
 - o Percentage of population who are Hispanic in the county
- Nonproficient English speakers: Percentage of population who are not proficient in English in the county
- Rural: Percentage of population residing in rural areas
- Income: Median household income in the county
- Food insecurity: Percentage of the county population that experienced the “social condition of limited or uncertain access to adequate food” at some point during the year (2018 County Health Rankings and Roadmaps).
- Neighborhood walkability: Walkability score in the county, which is a population weighted average score of block-level walkability scores within the county

2.3. Statistical analysis

We first summarized sample characteristics for high crime counties and low crime counties and indicated statistical significance level from a series of two-sided t-tests to assess the equality of means between high vs. low for each dichotomization of interest: top 50% vs. bottom 50%, top 40% vs. bottom 40%, top 30% vs. bottom 30%, and top 20% vs. bottom 20%.

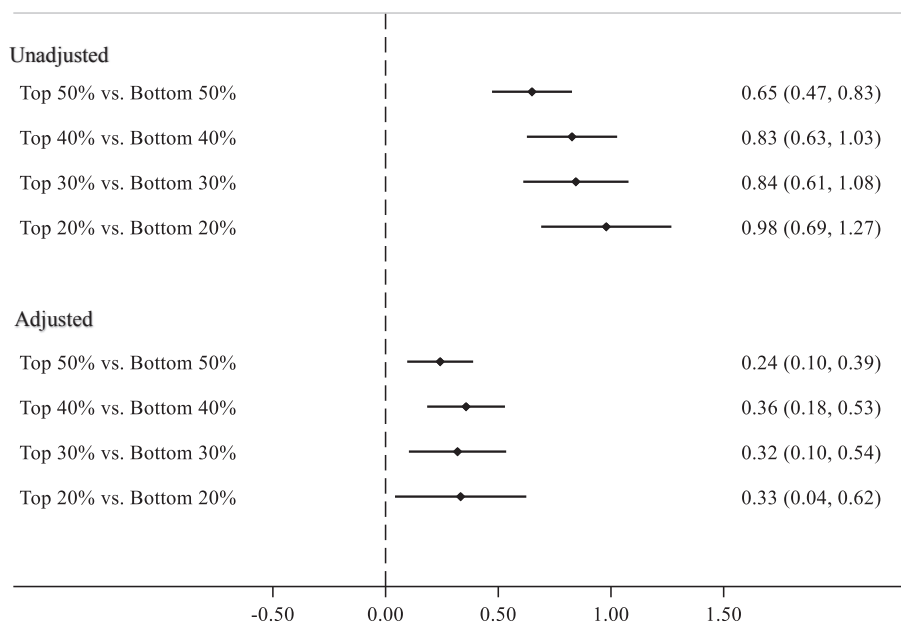


Fig. 1. Potential Effects of High Crime on Diabetes (Coefficients and 95% Confidence Intervals from OLS).

Data: 2018 US County Health and Rankings and Roadmaps, US Environmental Protection Agency National Walkability Index.

Note: Variables included for adjustments are race/ethnicity, non-proficient in English, rural status, income, food insecurity, and neighborhood walkability.

Table 1
Average Causal Mediation Effect (ACME) of Physical Inactivity on the Relationship between Crime and % Diabetic.

Group based on the distribution of county crime rate	N	ACME (95% CI)	Direct effect (95% CI)	Total effect (95% CI)	Share of total effect mediated (95% CI)
Top 50% vs. Bottom 50%	2,966	0.14 (0.06; 0.21)	0.10 (−0.03; 0.22)	0.24 (0.09; 0.38)	0.59 (0.36; 1.49)
Top 40% vs. Bottom 40%	2,377	0.23 (0.14; 0.32)	0.13 (−0.02; 0.27)	0.35 (0.18; 0.52)	0.64 (0.43; 1.24)
Top 30% vs. Bottom 30%	1,776	0.28 (0.17; 0.39)	0.04 (−0.15; 0.22)	0.32 (0.10; 0.53)	0.89 (0.53; 2.73)
Top 20% vs. Bottom 20%	1,191	0.24 (0.09; 0.39)	0.09 (−0.16; 0.36)	0.33 (0.04; 0.61)	0.72 (0.36; 3.67)

Data: 2018 US County Health and Rankings and Roadmaps, US Environmental Protection Agency National Walkability Index.

Note: Variables included for adjustments are race/ethnicity, non-proficient in English, rural status, income, food insecurity, and neighborhood walkability.

Bivariate and multivariable analyses were performed using ordinary least squares (OLS) regression to examine whether there is a significant difference in diabetes prevalence between “high” crime and “low” crime areas (relationship (a) in [appendix Fig. A1](#)) after controlling for the potential outlined confounding factors. The average causal mediation effect (ACME) method was used to assess the extent to which the relationship between crime rate and diabetes was mediated by physical inactivity ([Hicks and Tingley, 2011](#)) (relationship (b) × (c) in [appendix Fig. A1](#)). Sensitivity analyses were performed to assess how robust the results are to the violation of the sequential ignorability assumption ([Hicks and Tingley, 2011](#)).

3. Results

3.1. Characteristics of county by crime rate

[Appendix Table A1](#) provides summary statistics (mean, median, or percentage) of covariates, mediator, and outcome variable by levels of crime rates. The mean percentage of minority race/ethnicity populations (% Non-Hispanic blacks and % Hispanics) was greater in counties with high crime compared to low crime for all dichotomizations of crime rate (e.g., 4.4% vs. 13.0% of Non-Hispanic blacks in 50/50 dichotomization of crime rate ($p < 0.001$); 2.7% vs. 20.3% of Non-Hispanic blacks in 20/20 dichotomization ($p < 0.001$)). Mean percentages of people not proficient in English were higher for high crime counties as well. Higher crime counties tended to have lower percentages of population living in rural areas (e.g., 67.1% vs. 47.3% of the share of rural area for 50/50 dichotomization ($p < 0.001$); 76.3% vs. 40.0% in 20/20 dichotomization ($p < 0.001$)). Median household income was significantly less in counties with high crime rates than with low crime rates (e.g., \$51,875 vs. \$47,746 average median household income for 50/50 dichotomization ($p < 0.001$); \$52,199 vs. \$46,301 in 20/20 dichotomization ($p < 0.001$)). The share of residents who report food insecurity was higher for counties with high crime rates than with low crime rates. Mean of walkability score was higher for high crime counties (e.g., 6.0 vs. 6.7 mean walkability score for 50/50 dichotomization ($p < 0.001$); 5.9 vs. 7.0 for 20/20 dichotomization ($p < 0.001$)), which might be attributable to the greater share of the population residing in urban areas in high crime counties. The share of physically inactive residents was significantly greater for counties with high crime rates than low crime rates (e.g., 26.3% vs 27.1% mean physically inactive in 50/50 dichotomization ($p < 0.001$); 26.7% vs. 27.6% in 20/20 dichotomization ($p < 0.01$)). The prevalence of type 2 diabetes was significantly associated with county-level crime rates (e.g., 11.1% vs. 11.7% in 50/50 dichotomization ($p < 0.001$); 11.1% vs. 12.1% in 20/20 dichotomization ($p < 0.001$)).

3.2. Association between county-level crime and type 2 diabetes

[Fig. 1](#) summarizes coefficient estimates of the percentage difference along with 95% confidence intervals within each dichotomization of counties based on crime rates for both unadjusted and adjusted OLS regressions. The unadjusted percentage of type 2 diabetes was greater for high crime counties by 0.65 percentage point (95% CI 0.47–0.83) for

the 50/50 crime rate dichotomization and by 0.98 percentage point (95%CI 0.69–1.27) for the 20/20 crime rate dichotomization. The adjusted coefficients were substantially smaller compared to the unadjusted coefficients, but still statistically significantly different from zero, ranging from 0.24 percentage point (95% CI 0.10–0.39) for the 50/50 crime rate dichotomization to 0.33 percentage point (95% CI 0.04–0.62) for the 20/20 crime rate dichotomization.

3.3. Mediating effect of physical inactivity

[Table 1](#) reports the mediating effects of physical inactivity on the relationship between county crime rate and percent of individuals with T2D after adjusting for covariates. The average causal mediation effect (ACME) was statistically significant ranging from 0.14 (95% CI 0.06–0.21) for the 50/50 crime dichotomization to 0.28 (95% CI 0.17–0.39) for the 20/20 crime dichotomization. This means that a substantial share of the total effect was mediated by physical inactivity, ranging from 58.6% (50/50 dichotomization) to 89.2% (30/30 dichotomization). The sensitivity in parameter estimates for all dichotomizations are described in [Appendix Fig. A2](#). It suggests that to have null effect in mediation, the correlations (ρ) between residuals in the mediator regression and the main outcome regression need to be at least about 0.5, for example, for the 50/50 dichotomization.

4. Discussion

Results of this study reinforce a previously established positive correlation between rates of violent crime and type 2 diabetes. Demographic, socioeconomic and built environment factors play important roles; the magnitude in the association was significantly reduced in the multivariable analysis but remained significant. Findings also expand upon these results by suggesting physical inactivity as the primary mediator in the potential effect of crime rate in a local area on residents’ risk of having type 2 diabetes; the majority of the total effect of crime rate on the rate of residents with type 2 diabetes was mediated by the share of residents who were not physically active. This result was robust across the different magnitudes of contrast in crime rates.

There are a few limitations in the study. First, the study used cross-sectional data of US counties. The estimated mediating effect based on cross-sectional data may be biased if the mediation consists of longitudinal causal process ([O’Laughlin et al., 2018](#)). Future study using a longitudinal approach to mediation to account for the temporal sequence of the influence among crime rate, physical activity, and diabetes risk of the residents would be important. Second, although our analyses controlled for a number of important potential confounding factors, there might be unobserved factors (e.g., diabetes screening rate in the area) that are associated both crime rate and the rate of type 2 diabetes in a county. The substantial mediating effects of physical inactivity in the relationship are not necessarily causal as it may be also affected by diabetes (i.e., reverse causality). Third, the analyses in this paper were based on county-level data. Multi-level data including individual-level information as well as area-level information would be necessary to assess the contextual effect of an area-level crime on residents’ health outcomes and the mediating factors at individual- and

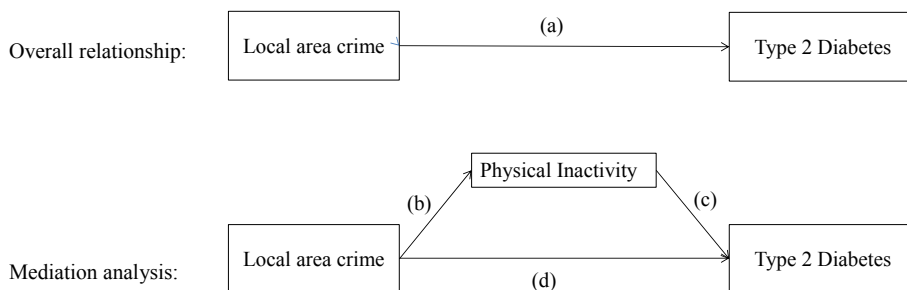


Fig. A1. Analytic framework for the link between neighborhood crime and type 2 diabetes. Potential area-level confounding factors influencing both crime rate and Type 2 diabetes: sociodemographic factors (e.g., race/ethnicity, English proficiency, income), rural/urban status, built environment (e.g., walkability).

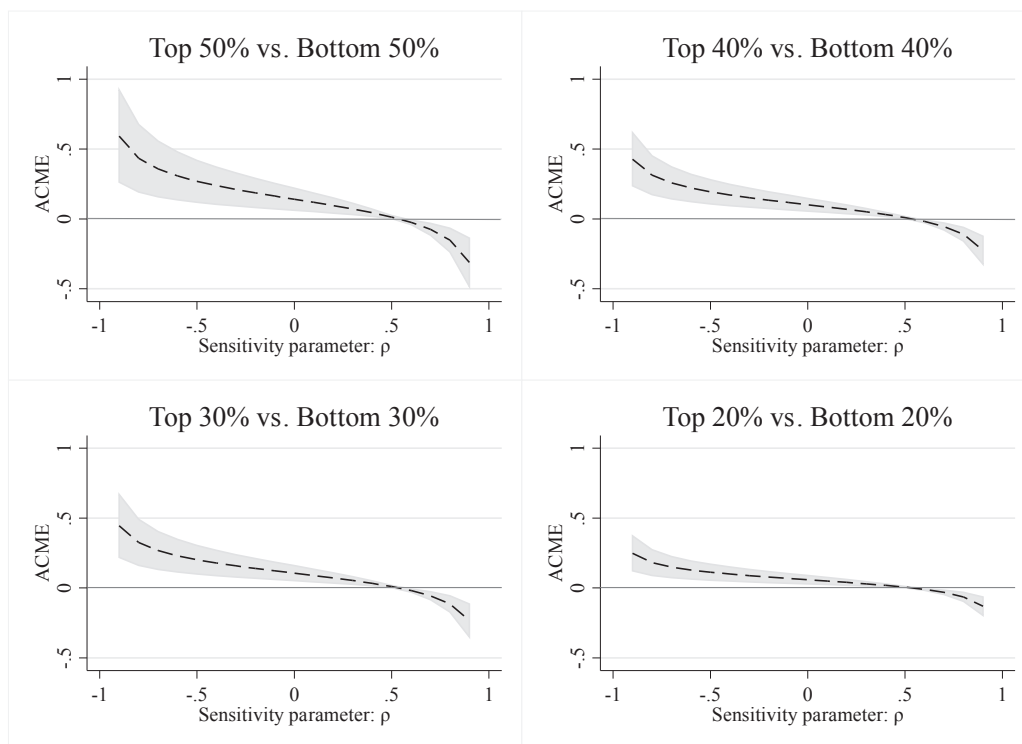


Fig. A2. Average Causal Mediation Effect (ACME) Sensitivity Parameters.

area-level.

Despite this limitations, findings of this study provide evidence for how an area’s crime rates might lead to worse health outcomes such as higher rates of T2D. This association held significant even if an area’s built environment such as walkability was conducive to physical activity. While it is important for policies to continue to seek to ameliorate high crime rates, in these counties strategies need to be developed and tested that promote physical activity and that take account of residents’ likely concerns about their physical safety.

CRedit authorship contribution statement

McKenzie Hanigan: Conceptualization, Formal analysis, Writing - original draft, Visualization. **Michele Heisler:** Conceptualization, Writing - review & editing. **HwaJung Choi:** Conceptualization, Writing - review & editing, Supervision.

Declaration of Competing Interest

The authors declare that they have no known competing financial

interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix

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Table A1
Characteristics of Counties by Crime Rate.

County Characteristics	Bottom 50% (low crime)	Top 50% (high crime)	Bottom 40% (low crime)	Top 40% (high crime)	Bottom 30% (low crime)	Top 30% (high crime)	Bottom 20% (low crime)	Top 20% (high crime)
	N = 1485	N = 1481	N = 1191	N = 1186	N = 891	N = 885	N = 599	N = 592
Covariates								
Race/ethnicity								
% Non-Hispanic black (mean)	4.4	13.0***	4.0	14.8***	3.3	16.7***	2.7	20.3***
% Non-Hispanic White, (mean)	83.8	69.7***	84.7	67.4***	86.2	64.7***	86.9	60.9***
% Hispanic (mean)	7.4	11.7***	7.1	12.4***	6.4	13.0***	6.2	13.2***
% Non-proficient English speakers (mean)	1.4	2.2***	1.3	2.4***	1.2	2.5***	1.2	2.5***
% Area of county that is rural (mean)	67.1	47.3***	69.1	45.5***	72.9	42.7***	76.3	40.0***
Average annual household income \$ (median)	51,875	47,746***	52,152	47,264***	52,010	46,976***	52,199	46,301***
Food Insecurity, %	12.7	15.4***	12.6	15.8***	12.4	16.1***	12.3	16.8***
Walkability score (mean)	6.0	6.7***	6.0	6.7***	5.9	6.9***	5.9	7.0***
Mediator								
% Physical inactivity (mean)	26.3	27.1***	26.3	27.4***	26.4	27.4***	26.7	27.6**
Outcome								
% Diabetes (mean)	11.1	11.7***	11.0	11.8***	11.0	11.9***	11.1	12.1***

Data: 2018 US County Health and Rankings and Roadmaps, US Environmental Protection Agency National Walkability Index.

Note: p-values are based on t-stat from testing equality between high crime vs. low crime in each dichotomization. (***) if p < 0.001, (**) if p < 0.01, (*) for p < 0.05).

Data: 2018 US County Health and Rankings and Roadmaps, US Environmental Protection Agency National Walkability Index.

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