WELCOME

ROAD SAFETY IN LATIN AMERICAN CITIES
WEBINAR

NOVEMBER 17, 2020
11:00 AM ET
OUR AUDIENCE TODAY
OUR AUDIENCE TODAY

Sector or Profession

- Research and academia
- Government
- Private sector
- Non-governmental organization
- Student
- Other
THE SALURBAL PROJECT

Salud Urbana en América Latina – Urban Health in Latin America

Drexel University, Philadelphia, Pennsylvania, USA
National University of Lanus, Buenos Aires, Argentina
Federal University of Minas Gerais, Belo Horizonte, Brazil
Universidade de Sao Paulo, Sao Paulo, Brazil
Oswaldo Cruz Foundation, Salvador Bahia, Brazil
Oswaldo Cruz Foundation, Rio de Janeiro, Brazil
Universidad de Chile, Santiago, Chile
Pontificia Universidad Catolica de Chile, Santiago, Chile
Universidad de los Andes, Bogotá, Colombia
Instituto Nacional de Salud Publica, Mexico City, Mexico
Universidad Peruana Cayetano Heredia, Lima, Peru
Institute of Nutrition of Central America and Panama (INCAP), Guatemala City, Guatemala
Pan American Health Organization, Washington, D.C., USA
University of California at Berkeley, Berkeley, California, USA
Washington University in St Louis, St Louis, Missouri, USA
How do urban policies impact urban built and natural environments?

How do urban built and natural environments impact urban health outcomes, disparities, and factors related environmental sustainability?

How can cities act to improve health, reduce disparities, and support environmental sustainability?
SALURBAL DATA

- SALURBAL has compiled data for 371 cities of 100,000 people or more in 11 countries.
- This data has been linked to sub-city units and neighborhoods in these cities.

<table>
<thead>
<tr>
<th>Health</th>
<th>Built Environments</th>
<th>Social Equity</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Deaths and causes of death</strong></td>
<td><strong>Land use and urban form</strong></td>
<td><strong>Poverty</strong></td>
</tr>
<tr>
<td>Life expectancy</td>
<td><strong>Transit options</strong></td>
<td><strong>Income inequality</strong></td>
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<tr>
<td>Health risk factors</td>
<td><strong>Traffic congestion</strong></td>
<td><strong>Housing conditions</strong></td>
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<tr>
<td>Health-related behaviors</td>
<td><strong>Walkability</strong></td>
<td><strong>Education</strong></td>
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<tr>
<td>Violence</td>
<td><strong>Green space</strong></td>
<td><strong>Employment</strong></td>
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<td><strong>Water and sanitation</strong></td>
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<tr>
<td></td>
<td><strong>Housing</strong></td>
<td></td>
</tr>
</tbody>
</table>
WEBINAR SPEAKERS

DR. ALEX QUISTBERG
City characteristics and road traffic mortality in Latin American cities

DR. CAROLINA PÉREZ
Evaluation of speed limits and traffic enforcement in Mexico City

GERMAN CARVAJAL
Bicycle Safety in Bogota
DISCUSSANTS

DR. DARIO HIDALGO
Senior Mobility Researcher, WRI

DR. CARLOS DORA
Incoming President, International Society for Urban Health
ROAD TRAFFIC DEATHS IN LATIN AMERICAN CITIES: CITY-LEVEL EPIDEMIOLOGY AND BUILT & SOCIAL ENVIRONMENT FACTORS

Dr. Alex Quistberg
Assistant Research Professor
daq26@drexel.edu
There are on average **95,000 road traffic deaths in Latin America** annually and are the leading cause of death of 5-14-year old's in the Americas and 2\(^{nd}\) leading cause of 15-44-year old's

https://www.childinthecity.org/2019/01/17/why-we-need-a-summit-on-youth-urban-road-safety/
ROAD SAFETY SYSTEMS

HUMAN TOLERANCE OF CRASH IMPACTS

SAFE ROADS
SAFE SPEEDS
SAFE VEHICLES
SAFE PEOPLE

Innovation
Standards
Coordination
Data, research and evaluation
Education and information
Licensing and registration
Road rules and enforcement
Work to prevent crashes that result in death or serious injury

They also result in a major economic impact of annual 4.4% Gross Domestic Product (GDP) loss in the region due to impacts on young lives, trauma care costs, employment, and other impacts.

Paulozzi, 2007, Acc An Prev
More traffic fatalities

CITY-LEVEL FACTORS

LN (traffic fatalities per 100,000)

LN (sprawl index)

Less urban sprawl

NEIGHBORHOOD-LEVEL FACTORS

Ewing, 2003 AJPH

AAP Committee on Environmental Health, 2009, Pediatrics
STREET-LEVEL FACTORS
FIGURE 1—Association between socioeconomic position of census tract residents and the mean number of injured pedestrians at intersections in increasingly complex multivariate models including (a) household income only (model 1); (b) household income plus traffic volume (model 2); (c) household income, traffic volume, and intersection geometry (model 3); and (d) household income, traffic volume, intersection geometry, and proxies of pedestrian volume (model 4): Island of Montreal, Canada, 1999–2003.

SPEEDING

Street design modifications that can reduce speed

- Traffic Circle
- Road Closure
- Raised Intersection
- Raised Diverter
- Sidewalk Extension
- Diagonal Diverter
- Semi-Diverter (in)
- Speed Hump
- Curb Extension
- Choker
- Chicane
- On-Street Parking
- Semi-Diverter (out)
- Rumble Strips
- Raised Median Island
- All-Way Stop Signs

Vehicle Impact Speed (KPH)

Risk of Death

- Main results (weighted, complete cases only)
- Weighted, missing values imputed
- Unweighted, complete cases only

Tefft, 2013, Acc An Prev
ROAD TRAFFIC SAFETY POLICIES

TRADITIONAL APPROACH
Traffic deaths are INEVITABLE
PERFECT human behavior
Prevent COLLISIONS
INDIVIDUAL responsibility
Saving lives is EXPENSIVE

VISION ZERO
Traffic deaths are PREVENTABLE
Integrate HUMAN FAILING in approach
Prevent FATAL AND SEVERE CRASHES
SYSTEMS approach
Saving lives is NOT EXPENSIVE
RESEARCH OBJECTIVES

• Assess quality of road traffic death data
• Examine city-level epidemiology of road traffic deaths across cities in Latin America
• Evaluate the association between city-level built and social environment factors with road traffic mortality
METHODS

- 366 cities ≥100,000 population from 10 countries
- Deaths 2010-2016 from city-level vital registry data
- Examined 5-year age groups by sex
- Assessed factors like population density, urban fragmentation, intersection density, GDP in regression analyses
There are substantial differences in the distribution of road users by country in terms of fatal victims.
Pedestrians and bicyclists tended to be older, motorcyclists and car passenger occupants were younger.
More pedestrians were from older age groups, while pedal cyclists, motorcyclists and passenger vehicle occupants were from younger age groups.
AGE STANDARDIZED ROAD MORTALITY PER 100,000 POPULATION

Substantial variation between and within countries in terms of city-level road traffic death rates
ROAD MORTALITY PER 100,000 POPULATION

Highest rate city
Lowest rate city

Argentina  Brazil  Chile  Colombia  Costa Rica  El Salvador  Guatemala  Mexico  Panama  Peru

Juliaca  Piura  Panama City  Colon  Mexico City  Cuauhtemoc  Escuintla  Santa Ana  San Salvador  Yopal  Parauapebas  Santiago del Estero  Valparaiso-Villa del Mar  Barranquilla  San José  San Salvador  Guatemala City  Mexico City  Panama City  Piura

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Road mortality per 100,000 people
BY SEX AND 5-YEAR AGE GROUPS

**Men**

<table>
<thead>
<tr>
<th>Country</th>
<th>Argentina</th>
<th>Brazil</th>
<th>Central America</th>
<th>Chile</th>
<th>Colombia</th>
<th>Mexico</th>
<th>Peru</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road Traffic Mortality Rate per 100,000</td>
<td><img src="image1" alt="Graph" /></td>
<td><img src="image2" alt="Graph" /></td>
<td><img src="image3" alt="Graph" /></td>
<td><img src="image4" alt="Graph" /></td>
<td><img src="image5" alt="Graph" /></td>
<td><img src="image6" alt="Graph" /></td>
<td><img src="image7" alt="Graph" /></td>
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</table>

**Women**

<table>
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<tr>
<th>Country</th>
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<tr>
<td>Road Traffic Mortality Rate per 100,000</td>
<td><img src="image8" alt="Graph" /></td>
<td><img src="image9" alt="Graph" /></td>
<td><img src="image10" alt="Graph" /></td>
<td><img src="image11" alt="Graph" /></td>
<td><img src="image12" alt="Graph" /></td>
<td><img src="image13" alt="Graph" /></td>
<td><img src="image14" alt="Graph" /></td>
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</tbody>
</table>

The road traffic mortality rate for one of the Central American cities goes up to 544.

The road traffic mortality rate for one of the Central American cities goes up to 232.
WHICH CHARACTERISTICS OF THE URBAN ENVIRONMENT ARE LINKED TO ROAD TRAFFIC MORTALITY IN CITIES?

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Definition</th>
</tr>
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<tbody>
<tr>
<td>Population Density</td>
<td>2010 Population per 2010 built-up area in square kilometers</td>
</tr>
<tr>
<td>Population Growth</td>
<td>Annual average change in population 2010-2016</td>
</tr>
<tr>
<td>Annual GDP</td>
<td>Annual gross domestic product in 2010</td>
</tr>
<tr>
<td>Social Environment Index</td>
<td>% population age 25+ ≥ primary school level</td>
</tr>
<tr>
<td></td>
<td>% Households overcrowding (&gt;3 people/bedroom)</td>
</tr>
<tr>
<td></td>
<td>% Households piped water access</td>
</tr>
<tr>
<td></td>
<td>% Households sewage network connection</td>
</tr>
<tr>
<td>Urban Development Isolation</td>
<td>Average distance between urban developments in city boundaries</td>
</tr>
<tr>
<td>Intersection Density</td>
<td>Number of intersections per square kilometer</td>
</tr>
<tr>
<td>Street Length Average</td>
<td>Average length of street segments</td>
</tr>
<tr>
<td>Streets per Intersection</td>
<td>Average number of streets emanating from intersections</td>
</tr>
<tr>
<td>Mass Transit System</td>
<td>Presence or absence of a bus rapid transit system or subway system</td>
</tr>
<tr>
<td>Urban Travel Delay Index</td>
<td>Average minutes delay</td>
</tr>
</tbody>
</table>
## WHICH CHARACTERISTICS OF THE URBAN ENVIRONMENT ARE LINKED TO Road Traffic MORTALITY IN CITIES?

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Association</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population Density</td>
<td>6% Lower</td>
</tr>
<tr>
<td>Population Growth</td>
<td>5% Higher</td>
</tr>
<tr>
<td>Annual GDP</td>
<td>4% Lower</td>
</tr>
<tr>
<td>Social Environment Index</td>
<td>No Association</td>
</tr>
<tr>
<td>Urban Development Isolation</td>
<td>5% Higher</td>
</tr>
<tr>
<td>Intersection Density</td>
<td>8% Lower</td>
</tr>
<tr>
<td>Street Length Average</td>
<td>4% Lower</td>
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<tr>
<td>Streets per Intersection</td>
<td>3% Higher</td>
</tr>
<tr>
<td>Mass Transit System</td>
<td>7% Lower</td>
</tr>
<tr>
<td>Urban Travel Delay Index</td>
<td>No Association</td>
</tr>
</tbody>
</table>

Association is per 1 standard deviation.
• Urban planners and traffic engineers can consider ways to increase street connectivity and reduce fragmented urban development

• Cities can consider mass transit systems, such as BRT and subways, which also can provide other health benefits (e.g., less air pollution)

• Future work should examine other road safety outcomes (e.g., police reports), subgroups (e.g., pedestrians) and smaller geographic areas within cities

• Given heterogeneity, it is important to look beyond only the largest capital cities and see what smaller and middle-sized cities are doing successfully
THANK YOU!

• Collaborators:
  • Philipp Hessell
  • Usama Bilal
  • Olga Lucia Sarmiento
  • Daniel Rodriguez
  • Fatima Pina
  • Waleska Caiaffa
  • Carlos Guevel
  • Akram Hernandez-Vasquez
  • Jaime Miranda
  • Ana V. Diez Roux
EVALUATION OF SPEED LIMITS AND TRAFFIC ENFORCEMENT IN MEXICO CITY

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• Tonatiuh Barrientos, INSP
ROAD SAFETY IN MEXICO CITY

• Mortality rate of 8.7 per 100,000 in 2015
• Mexico City adopts Vision Zero in 2015
• New road traffic regulations - December 15, 2015

1) lower speed limits, introduction of speed radars and higher fines for speeding vehicles
2) traffic enforcement devices to detect nine motoring offences.
66 new automated traffic enforcement devices installed which were linked to the new fines.
Location of enforcement devices

- Speed radar
- Fotomulta
THE EVIDENCE ON SPEED LIMITS AND ENFORCEMENT DEVICES

• Speed management interventions are effective to reduce the number of injured and dead (Sadeghi-Bazergani, H 2016)

• The use of cameras for detecting multiple motoring offences has been associated with a reduction of 19% of all crashes and a 25% reduction of injury and fatal crashes (Martínez-Ruíz DM 2019, Wilson C, 2010).

• In Mexico City these interventions were unpopular and never formally evaluated, resulting in the suspension of economic fines in early 2019.
OBJECTIVE AND HYPOTHESIS

Objective: To estimate the effect of the road traffic regulations implemented in December 2015 in Mexico City on police-reported collisions, police-reported collisions resulting in injury and mortality from road traffic collisions.

• Hypothesis: Total collisions, collisions resulting in injury and mortality will decline in Mexico City after December 2015. Collisions and mortality will decline more in municipalities with enforcement devices compared with control municipalities.
METHODS

• **Data sources for collisions**: police reported collisions (ATUS, INEGI), number of registered vehicles (INEGI)

• **Data sources mortality**: vital registry data, total population (CONAPO)

• Weekly data from January 2013 to December 2018

• Compared trends before and after the intervention
TOTAL COLLISIONS RATE PER 100,000 VEHICLES

Adjusted for seasonality

Increase of 0.2%* per week after the intervention

*(95% CI, 0.1% ± 0.3%)
COLLISION RESULTING IN INJURY RATE PER 100,000 VEHICLES, MEXICO CITY

Increase of 0.3%* per week after the intervention

*(95% CI, 0.2% ± 0.4%)
TOTAL COLLISION RATE FOR CONTROL AND INTERVENTION MUNICIPALITIES

Adjusted for seasonality

Intervention group: Received enhanced speed limit and traffic enforcement
Control group: No intervention
COLLISION RESULTING IN INJURY RATE FOR CONTROL AND INTERVENTION MUNICIPALITIES

Adjusted for seasonality
MORTALITY RATE PER 1M, MEXICO CITY

Decrease of 0.2%* per week after the intervention

*(95% CI, -0.3% ± 0.1%)
CONCLUSIONS

Hypothesis: Total collisions, collisions resulting in injury and mortality will decline in Mexico City after December 2015. Collisions and mortality will decline more in municipalities with automated traffic enforcement compared with control municipalities.

• The **effect on mortality at city level was a decrease of 0.2% per week after the intervention.**
• **Effect on police reported collisions not as expected** – looking into explanations for this.
• However, **municipalities that did not have automated traffic enforcement experienced a larger increase in collisions** compared to municipalities with devices.
BICYCLE SAFETY IN BOGOTÁ: A SEVEN-YEAR ANALYSIS OF BICYCLISTS’ COLLISIONS AND FATALITIES

Germán Carvajal
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• Daniel. A. Rodríguez, University of California, Berkeley
• D. Alex Quistberg, Drexel University
• Segundo López, World Resources Institute Ross Center for Sustainable Cities
OUTLINE

• The city of Bogotá
• Bicycling: status and concerns
• Research questions
• Data source
• Results
• Policy recommendations
THE CITY OF BOGOTA

- **7.2 million inhabitants**
  - 17.2 million trips per day.
  - 5% of bicycle modal share

- **Largest network of bicycle pathways in Latin America**
  - 500 Km of dedicated infrastructure
  - Add 126 Km with Sunday’s Ciclovía

- **2016 – 2020 Policy interventions**
  - Vision Zero
  - Speed limits reduction

---

1 Bicycle by Creatica Creative Agency from the Noun Project 2 Dedicated bicycle pathways in Bogotá at the end of 2017. Own elaboration based on IDECA information. 3 Secretaría Distrital de Planeación, 2018; 4, 5 Transconsult & Infometrika, 2015b; 6 Instituto Distrital de Recreación y Deporte, n.d.; 7 EL TIEMPO & Secretaría Distrital de Movilidad, 2017; Secretaría Distrital de Movilidad, 2018); 8 Target by Vectors Point from the Noun Project
PUBLIC POLICY: BICYCLING

Multisectoral perspective policies, including transportation, sports and recreation, education, and health

Bogotá as the world’s bicyclist’ capital with the greatest total traveled Km by bicycle in the year 2038

“Build it and they will come”\(^6\)
BICYCLING: STATUS

Road safety concerns are a major barrier to bicycling. More than half of all road traffic deaths are among vulnerable road users including bicyclists, pedestrians, and motorcyclists. Traffic collisions are the leading cause of death among children and young adults in low- and middle-income countries. Road traffic collisions are the second leading cause of mortality in men and the first in women.
City officials in Bogotá have reported an increase of the frequency of bicycle-related fatalities over the last decade\(^1\).

\(^1\) Concejo de Bogotá, 2018; Gil et al., 2009
RESEARCH QUESTIONS

Examine spatiotemporal trends and potential contextual risk factors explaining bicyclist collisions and fatalities in Bogotá.

1. To analyze temporal trends in bicyclist mortality and nonfatal collision rates

2. To identify areas within the city where there is higher risk of bicyclist mortality

3. To determine the individual and contextual risk factors associated with bicyclist mortality.

1 Downward Trend by Joel Olson from the Noun Project; 2 Standardized rates by total bicyclists’ population; 3 Chain created by David from the Noun Project
DATA SOURCES: COLLISIONS

SAMPLE

Data source:
Secretaria de Movilidad and Despacio / WRI
2011 – 2017

- 366,814 total collisions
  - 10,043 bicycle collisions (2.73%)
  - 9,950 usable bicycle collisions (2.71%)\(^1\)
  - 358 fatal collisions (0.09%)

MORTALITY DEFINITION

A death in a road traffic accident is declared whenever the person involved dies because of the traffic collision between the moment of the event until February of the following year\(^2\)

Fatal collisions
Subject to stricter control and validation

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1 bicyclists’ collisions involving people less than 5 years old were removed;
2 Secretariat of Mobility, personal meeting, May 24th of 2018
DATA SOURCES: EXPOSURE CONTROLS

**SOURCES**

**Multipurpose Survey**
- 2014
- 2017

**Mobility Survey**
- 2005
- 2011
- 2015

**Bicyclists: commuter population**
- Estimation by interpolation

**Daily trips**
- Estimation by interpolation

**Shortest bicycle paths**

**Daily Vehicle Kilometers traveled (VKmT)**
RESULTS: COLLISION RATE TRENDS

Yearly averages of **fatal** and **nonfatal** bicyclist collisions

Rates standardized per bicyclists’ population

- 55% reduction in **nonfatal** collision rates
- 46% reduction in **fatal** collision rates
RESULTS: COLLISION RATE TRENDS

Yearly averages of fatal and nonfatal bicyclist collisions

Rates standardized per bicyclists’ population: Women
- 30% reduction in nonfatal collision rates
- no reduction in fatal collision rates

Rates standardized per bicyclists’ population: Men
- 58% reduction in nonfatal collision rates
- 53% reduction in fatal collision rates
## HIGHER RISK GEOGRAPHICAL AREAS

<table>
<thead>
<tr>
<th>Income level</th>
<th>Neighborhood</th>
<th>Fatalities per km²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>Casablanca / Kennedy</td>
<td>3.8</td>
</tr>
<tr>
<td></td>
<td>León XII / Bosa</td>
<td>3.1</td>
</tr>
<tr>
<td></td>
<td>Santa Rita / San Cristobal</td>
<td>2.4</td>
</tr>
<tr>
<td>Middle</td>
<td>Calle 68 with Avenida Boyacá / Engativá</td>
<td>3.8</td>
</tr>
<tr>
<td></td>
<td>Autopista Medellín with Avenida Ciudad de Cali / Engativá</td>
<td>3.1</td>
</tr>
<tr>
<td></td>
<td>San Felipe / Barrios Unidos</td>
<td>2.4</td>
</tr>
<tr>
<td>High</td>
<td>Calle 127 with Avenida Boyacá / Usaquen</td>
<td>2.5</td>
</tr>
</tbody>
</table>

Fatal collision quadrat analysis with a grid of 1 by 1.2 Km squares.
FACTORS ASSOCIATED WITH **HIGHER RISK OF BICYCLIST FATALITIES**

**BICYCLIST’S AGE (YEARS)**

**TERRAIN SLOPE (%)**

**ROAD SURFACE FAILURES**

**TIME (HOUR)**

**Higher risk:**

- Higher age of cyclist (over 40 years)
- Higher terrain slope (steeper roads over 3%)
- Moderate to bad road surface conditions
- Collisions that occur during nighttime
FACTORS ASSOCIATED WITH LOWER RISK OF BICYCLIST FATALITIES

Safer infrastructure:
- Medium size lane widths
- Reduced average vehicle speed
- Narrow roads
FACTORS ASSOCIATED WITH RISK OF FATALITY: SEX DIFFERENCES

**WOMEN**

- **Terrain slope (%)**
  - Odds of a fatal collision

- **Vehicle type**
  - Automobile: 1
  - TransMilenio: ?
  - Cargo vehicle: 43.1
  - Bus: 11.9
  - Motorcycle: 1
  - Other: 9.5

**MAN**

- **Terrain slope (%)**
  - Odds of a fatal collision

- **Vehicle type**
  - Automobile: 1
  - TransMilenio: 6.6
  - Cargo vehicle: 8.9
  - Bus: 2.5
  - Motorcycle: 0.5
  - Other: 1.7

FACTORS ASSOCIATED WITH RISK OF FATALITY: SEX DIFFERENCES

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  - Motorcycle: 0.5
  - Other: 1.7
FACTORS ASSOCIATED: DEDICATED BICYCLE INFRAESTRUCTURE

PRESENCE OF A BICYCLE PATHWAY

80% reduction in the probability of a fatal collision compared to roads with no presence of a bicycle pathway.
CONCLUSIONS AND POLICY RECOMMENDATIONS

✓ Bicycling collision rates have **decreased during the 7-year period**. Reductions **differ by sex**: no reduction in the fatal collision rates for women
✓ Identified higher risk areas along main corridors and locations with inadequate infrastructure
✓ Identified factors associated with fatal collisions. The factors and their effects **differ by sex**
✓ Recommendations:
  • Continue building and enhancing safe bicycle infrastructure
  • Separate infrastructure bicyclists from large vehicles
  • Continue law enforcement of reduced speed limits
  • Prioritize geographical areas that could be intervened in the city
  • Design a public policy guideline with a **gender and equality focus**
✓ Efficient open-data methodology for monitoring and evaluating bicycle safety conditions could be a potential tool for monitoring and being applied in **other Latin American cities**
Bicycle safety in Bogotá: A seven-year analysis of bicyclists’ collisions and fatalities

Germán A. Carvajal, Olga L. Sarmiento, Andrés L. Medaglia, Sergio Cabrales, Daniel A. Rodríguez, D. Alex Quintero, Segundo López

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Abstract

Road safety research in low and middle-income countries is limited, even though ninety percent of global road traffic fatalities are concentrated in these locations. In Colombia, road traffic injuries are the second leading causes of mortality by external cause and constitute a significant public health concern in the city of Bogotá. Bogotá is among the top 15 most bike-friendly cities in the world. However, bicyclists are one of the most vulnerable road users in the city. Therefore, assessing the patterns of mortality and understanding the variables affecting the outcome of bicyclists’ collisions in Bogotá is crucial to guide policy action aimed at improving safety conditions. This study aims to determine the spatiotemporal trends in fatal and non-fatal collision rates and to identify the individual and contextual factors associated with fatal outcomes. We use collision impact data, post-mortem, and coronial data, and generalized additive mixed models (GAMM) corrected for spatial correlation. The collision records were taken from Bogotá’s Hospital of Mobility, complemented with records provided by the city’s transportation management (INVI). Our findings indicate that from 2011 to 2017, the total bicycling collision rate per bicyclist’s population has remained constant for females while decreasing 53% for males. Additionally, we identified high-risk areas located in the west, southeast, and southwest of the city, where the rate of occurrence of fatal events is higher than what would occur in other parts of the city. Finally, we identified some associated risk factors that differ by sex. Overall, we find that fatal collisions are positively associated with factors including collisions with large vehicles, the absence of dedicated infrastructure, speed norms, and logistics; whereas, accidents involving the safety of pedestrians are negatively associated with factors such as the absence of dedicated infrastructure, speed norms, and logistics.

1. Introduction

Bicycling provides substantial benefits to the health and well-being of the population and is relevant for the development of a healthy and sustainable environment (Cohen and Caulfield, 2015; Qiu et al., 2011). Among children and adolescents, bicycling can prevent obesity and improve cardiorespiratory fitness (Qiu et al., 2011; Sarmiento et al., 2013). Among adults, bicycling is associated with risk reduction for all-causes and cancer mortality; with risk reduction for cardiovascular, diabetic, cancer, and obesity mortality (Collier-Mercer et al., 2017); and with improvement in mental health (Meador et al., 2015). Hence, bicycling may result in reductions in healthcare costs (Ding et al., 2014; Ding et al., 2000) and increases in the gross domestic product (Wehmanen et al., 2013). Furthermore, increasing bicycling for commuting and recreation can mitigate greenhouse gas emissions, improve air quality, and can also reduce noise and vehicular congestion (Golding et al., 2011; Brown, 2007; Macmillan et al., 2014; Kall and de Nascalis, 2012).

Despite the benefits of bicycling, research has shown that concerns related to traffic safety constitute a significant adoption barrier for bicycling (Bhattacharya et al., 2011). A significant percentage of the population across cities and countries are interested in bicycling but remain...
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