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Urban Environments, Health, and Environmental Sustainability: Findings From the SALURBAL Study

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Abstract Despite the relevance of cities and city policies for health, there has been limited examination of large numbers of cities aimed at characterizing urban health determinants and identifying effective policies. The relatively few comparative studies that exist include few cities in lower and middle income countries. The *Salud Urbana en America Latina* study (SALURBAL) was launched in 2017 to address this gap. The study has four aims: (1) to investigate social and physical environment factors associated

with health differences across and within cities; (2) to document the health impact of urban policies and interventions; (3) to use systems approaches to better understand dynamics and identify opportunities for intervention and (4) to create a new dialogue about the drivers of health in cities and their policy implications and support action. Beyond these aims SALURBAL, has an overarching goal of supporting collaborative policy relevant research and capacity -building that engages individuals and institutions from across Latin America. In this review we provide an update on the SALURBAL data resource and collaborative approach and summarize key findings from the first aim of the study. We also describe key elements of

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our approach, challenges we have faced and how we have overcome them, and identify key opportunities to support policy relevant evidence generation in urban health for the future.

Keywords Urban health · Health inequities · Policy · Environment · Global health · Epidemiology

Introduction

Urbanization is increasing worldwide, especially in low- and middle-income countries (LMICs)[1]. Despite the relevance of cities and city policies for health, there has been limited examination of the drivers of health across large numbers of cities. The few comparative studies that exist include few cities in LMIC and do not engage local teams across large regions.

The Salud Urbana en America Latina Study (SALURBAL) was launched in 2017 to address this gap [2]. The study has four aims: (1) to investigate social and physical environment factors associated with health differences across and within cities; (2) to document the health impact of urban policies and interventions; (3) to use systems approaches to better understand dynamics and identify opportunities for intervention and (4) to create a new dialogue about the drivers of health in cities and their policy implications and support action. The three first aims encompass the multiple sources of evidence needed to inform understanding. The fourth aim was designed to maximize stakeholder input and support dissemination activities to scientists, policy makers and the public in ways that promote transformative action.

In this review we summarize the SALURBAL approach to regionally engaged collaborative research and summarize select findings derived from the first aim of the study. We also describe challenges we have faced and identify opportunities for the future.

Methods

The SALURBAL Project, coordinated by the Drexel University Urban Health Collaborative, has engaged 11 institutions in Latin America based in 7 different countries, with one of them representing 5 countries in Central America, as well as two US partners [2]. An Executive Committee meets regularly to review

progress and set directions. A monthly team meeting including all investigators and trainees across all institutions provides regular updates and shares works in progress. The work in support of the first SALURBAL Aim (the focus of this paper) was organized via a series of Cores and Working groups (Table 1). As of 2023 the team included more than 200 members who regularly participate in team meetings and engage in SALURBAL activities, and 102 members who are supported by the study in various ways. The SALURBAL network evolved over time expanding across disciplines, sectors, and geography [3].

A Flexible Data Resource to Support Urban Health Research Across the Region

A first step in the SALURBAL collaborative process was the creation of a data infrastructure that would allow the characterization of cities at various geographic levels, over time, and across multiple domains. The SALURBAL cities encompassed all urban agglomerations of 100,000 people or more in 2010 in 11 participating countries (Argentina, Brazil, Chile, Colombia, Costa Rica, El Salvador, Guatemala, Mexico, Nicaragua, Panama, Peru). SALURBAL cities were identified by combining information from multiple data sources, [4] and operationalized in various standardized ways [4] [5].

Data domains of interest were defined a priori. Cross-country teams oversaw the compilation and harmonization of data using multiple sources and in close collaboration with regional partners (Table 2). Data were linked using a standardized set of geographic definitions, as well as indicators for time (year, month and even day when available). Issues of data quality and limitations in coverage or comparability were highlighted in data documentation. A number of steps were used to improve data [6–9]. Select data challenges and how they were addressed are shown in Table 3.

These efforts led to the creation of a unique data resource spanning multiple years, and across various geographic definitions encompassing all 371 cities. This data resource and associated metadata followed FAIR principles of findability, accessibility, interoperability, and reusability[10]. All data that can be made publicly available is made available on the SALURBAL Portal which also contains some data visualizations and various products SALURBAL has created [5].

Table 1 Collaborative groups related to Aim 1 in SALURBAL

Type	Group	Objective
Support Cores	Data and Methods Core	Oversee data compilation and harmonization of health (vital statistics and survey) and census data, linkages to environmental data, create documentation and datasets, support analyses.
	Physical and Built Environment Core	Lead identification, and creation of physical and built environment data, support the development of research questions and analyses using this data.
	Social Environment Core	Lead identification, and creation of social environment data, support the development of research questions and analyses using this data.
Working groups	Maternal and child health	Provide a forum for development of research questions, discussions of findings, and identification of additional collaborative opportunities involving infant mortality, birth rates, and perinatal outcomes.
	COVID-19/infectious diseases	Support compilation and enhancement of infectious disease data, including COVID-19. Develop research questions and discuss findings and analytical approaches.
	Climate change	Provide a forum for exploration of climate data and discussion of climate change questions relevant to SALURBAL.
	Food Environment	Provide a forum for development of research questions, discussions of findings, and identification of additional collaborative opportunities involving diet and food environment. Support harmonization of dietary data.
	Residential segregation and racial inequities	Provide a forum for development of research questions, discussions of findings, and identification of additional collaborative opportunities involving racial inequities and segregation. Support creation of segregation measures.
	Gender	Provide a forum for development of research questions, discussions of findings, and identification of additional collaborative opportunities involving gender inequities.
	Parks and health	Support the creation, analysis and interpretation of measures of access to parks in SALURBAL.
Analysis groups	Life Events	Support and coordinate analyses using vital statistics data (mortality, births) via works in progress presentations and consultation follow up as needed.
	Survey Analysis	Support and coordinate analyses of survey data using via works in progress presentations and consultation follow up as needed.
	Small area analyses	Support estimation and analyses of outcomes for small areas (eg neighborhoods) within cities. Advance papers involving small area analyses.

A Collaborative Scientific Process: the SALURBAL Approach

To support collaboration while ensuring productivity and quality, SALURBAL created a collaborative process for the production and dissemination of scientific findings (Fig. 1). Key elements included (1) a clear publications and presentations policy with guidelines for authorship and collaboration; (2) internal peer review of all manuscript proposals and final manuscripts coordinated and managed by a Publications and Presentations Committee; (3)

creation of working groups around thematic topics to support analyses and interpretation; (4) delivery of analysis workshops and consultations as well as training and support of local analysts guided by a study Data and Methods Core; (5) review of full manuscripts and scientific presentations before submission by SALURBAL reviewers with opportunity for revision; and (6) oversight by the study executive committee to ensure that priority analyses were advancing. A dedicated dissemination team supported communicating findings via briefs, webinars and media outreach [11].

Table 2 Summary of key SALURBAL data compiled for SALURBAL Aim 1

Domain	Level of measurement	Time frame*	Sample measures	Source
Health				
Mortality and births	Cities, subcities,**, neighborhoods (select countries)	Annual, monthly/daily in some cases	Age-adjusted all cause and cause specific rates. Life expectancy at various ages; Birth rates; Prevalence of low birth weight.	Country vital statistics registries
Self-reported health/mental health	Individual-level linked to cities, subcities and neighborhoods (select countries)	Select years	Prevalence of poor health, depressive symptoms scores.	Surveys conducted by country agencies including Ministries of Health, Family Welfare Institutes, and National Statistical Agencies
Health risks factors	Individual-level linked to cities, subcities and neighborhoods (select countries)	Select years	Prevalence of diabetes and hypertension, body mass index; cancer screening rates.	Surveys conducted by country agencies including Ministries of Health, Family Welfare Institutes, and National Statistical Agencies
Population characteristics				
Total population by age, gender and race/ethnicity	Cities, subcities, and neighborhoods (some indicators)	Census years and interpolations and projections		National census offices
Social and economic characteristics	Cities, subcities, and neighborhoods (some indicators)	Census years and interpolations	Percent population with high school education; living below poverty; unemployment; Income Gini coefficient; segregation; gender equity; GDP.	Organization for Economic Cooperation and Development (OECD) data, national censuses and household surveys conducted by country national census offices and national statistical agencies.
Housing and services	Cities, subcities, and neighborhoods (some indicators)	Census years and interpolations	Percent durable walls and floors; overcrowding; access to water and sanitation.	National censuses.
Health care	Provinces/states, cities (some indicators)	Select years	Physicians per capita; hospital beds per capita.	National health ministries and statistical agencies, World Health Organization (WHO).
Built environment and transportation	Cities and subcities	Select years	Population density; Fragmentation; Isolation.	Modelled land surface from the DLR's Global Urban Footprint (GUF); population from national censuses and Worldpop; green-spaces from a supervised classifier using Sentinel-2 images from 2017; greenness processed from MODIS (MOD13Q1.006).

Table 2 (continued)

Domain	Level of measurement	Time frame*	Sample measures	Source
Streets	Cities, subcities, and neighborhoods (some indicators)	Select year	Street connectivity and density.	Street network from OpenStreetMap
Transportation	Cities and subcities	Select year	Vehicle registration; congestion index; BRT/subways/trams.	Local and national transportation agencies, national statistical agencies, brtdata.org website, road safety agencies, OpenStreetMap, and Google Maps.
Parks	Cities, subcities, and neighborhoods (some indicators)	Select year	Size, number, and density of parks.	Satellite images from Sentinel-2 and Google Cloud collaborators database.
Air pollution, temperature, and natural environment				
Air pollution and emissions	Cities, subcities and neighborhoods	Daily, monthly and annual	Particulate matter less than 2.5 microns (PM2.5) and nitrogen dioxide (NO2); Carbon footprint.	Monitor data from any available air quality monitoring systems in each country, modelled satellite data from Atmospheric Composition Analysis Group (ATMOS), and Gridded Global Model of City Footprints (GGMCF).
Green space	Cities, subcities and neighborhoods	Annual, select year	Maximum and median Normalized Difference Vegetation Index (NDVI); Percentage of green space, green space fragmentation and isolation.	Modelled satellite data from NASA Earth Observatory and OpenStreetMap.
Temperature	Cities and subcities	Daily	Mean and maximum daily temperature.	Modelled 2-m air temperature from ERA5-Land available from the European Center for Medium-Range Forecasts (ECMWF) with machine learning imputation to address missing values.

*For most measures time span is 2000–2020 but only select time points may be available

**Subcities are administrative units within cities such as municipalities or similar. Additional details on sources and variables can be found at data.lacurbanhealth.org

Results

We summarize key study findings to date across several broad research areas related to SALURBAL's aim 1 (for details see Supplement Table 1). Results related to SALURBALs policy evaluation aim (aim2)[12–18] and systems aim (aim 3)[19–21] can be found elsewhere. A full list of SALURBAL Publications is at <https://data.lacurbanhealth.org/products/catalog>.

Associations of Urban Environments with Life Expectancy and Cause of Death

Life expectancy and causes of death vary significantly across cities in the region, even among cities in the same country

SALURBAL characterized life expectancy (LE) for all SALURBAL cities [6, 22]. We found significant heterogeneity in LE at birth across 363 cities in 9 countries [range 8 years for women (74.4–82.7) and 14 years for men (63.5–77.4)] [6]. This heterogeneity was present not only across countries but also within countries: differences in LE across cities within countries were sometimes as large as 7–10 years. The proportions of deaths from specific causes also varied across cities: some causes of death (unintentional and violent injuries) showed large variation across cities within countries, whereas other causes of death (communicable, maternal, neonatal and nutritional, cancer, cardiovascular disease and other noncommunicable diseases) varied substantially across cities between countries [6].

Life Expectancy Also Varies Substantially Within Cities

The exploration of within city differences in health in LMIC remains rare. SALURBAL documented important differences in LE across administrative areas within cities (municipios, comunas or departamentos,) in 6 large cities of the region. Spatial differences in life expectancy at birth within cities (defined as differences between the 90th and the 10th percentile of LE) ranged from 9.8 and 11.2 years in men and women, respectively in Panama City, Panama to 3.9 and 3.0 years in San José, Costa Rica [22]. Analyses investigating even smaller areas (akin to neighborhoods) using spatial Bayesian approaches to

accommodate sparse data also found important heterogeneity even within the subcity units [23] [24].

City Size has no Unique Relation to Mortality

In contrast to results for 376 cities in the United States in which all-cause mortality is lower in larger than in smaller cities, we found no clear relation between city population size and all-cause mortality in 366 SALURBAL cities [25]. However, associations differed by causes of death. Deaths from cancer, other noncommunicable diseases, and communicable, maternal, neonatal, and nutritional conditions were unrelated to city size in Latin American cities. In contrast, rates of nonviolent injuries, including road traffic deaths and suicides, were lower in larger cities while homicide rates and mortality rates due to sexually transmitted infections, HIV/AIDs, and tuberculosis were generally (although not always) higher in larger cities.

Social and Economic Conditions are Associated with Life Expectancy and Cause-Specific Mortality at Multiple Geographic Levels

Differences in city social conditions were linked to differences in life expectancy across cities: a one standard deviation higher social environment index (SEI, reflecting higher population educational attainment, water and sewage access and less overcrowding) was associated with a 0.78 and 0.48-year longer life expectancy in men and women, respectively [6]. In addition, a higher SEI was linked to a lower proportion of deaths from communicable, maternal, neonatal and nutritional deaths but a higher proportion of deaths from cancer, cardiovascular disease and other noncommunicable diseases [6]. Better city socioeconomic conditions were also associated with lower amenable mortality[26], lower infant mortality [27], lower road traffic mortality[28], lower homicides among youth [29], and lower COVID mortality [30].

Socioeconomic conditions are also associated with life expectancy differences across subcity areas (eg municipios) within cities, although the strength of the association differed by city (difference in LE comparing 90th to 10th percentile of area education ranged from 8–11.8 years in Santiago and Panama City to 0.6–0.7 years in San Jose) [22]. Analyses of even smaller areas (neighborhoods) also showed

Table 3 Key data challenges encountered by SALURBAL and examples of how they were addressed

Domain	Sample challenge	How it was addressed
Data availability	Not all countries have same data availability.	Develop a data system that allows incorporation of whatever data is available, for whatever timeframe or level of aggregation is available. Allow papers that focus on all cities as well as single countries or even single cities to take full advantage of data available.
Data access	Access to data differs across country and type or data.	Focus on data (eg, remote sensing, congestion index, parks) that can be collected systematically across countries and develop protocols to do so. Develop flexible Data Use Agreements that can be adapted as needed.
Lack of comparability of measures	Measures available (eg in surveys or in censuses) differ across countries	Work with country teams to develop relationships and partnerships with local agencies. Support local needs (eg georeferencing).
Sampling differences	Surveys employ various sampling strategies and cover different populations.	Harmonize using or adapting previously used measures whenever possible. Create several versions or harmonized variables that allow inclusion of different sets of variables.
Missing data or ill-defined categories	Data is missing (eg age in death certificates) or lumped into categories not useful for analysis (eg ill defined causes). Temperature data is missing for some areas. Small numbers of events create instability in estimates	Analyze with attention to sampling issues, including adjustment factors as necessary. Develop methods to derive needed estimates when possible.
Sparse data	Air pollution monitors not available in many locations.	Use appropriate imputation and readjudication strategies based on prior work whenever possible.
Lack of environmental data	Air pollution monitors not available in many locations.	Develop and use methods appropriate for small area analyses.
Definition of geographic units changes over time	New municipalities are created and/or boundaries are redefined.	Use modelled estimates derived from other sources to systematically assess cities across the sample. Calculate and model our own data (greenness, greenspaces, water) from remote sensing data.
Data collected at different time points for different countries	Temporal coverage varies, creating unevenness in the availability of data over the years.	Create cross-walks that identify time invariant geographic units; create "harmonized" definitions by combining various units at different time point; flag units with large changes. Develop methods to impute or approximate data for years with missing information; aggregate data across time.

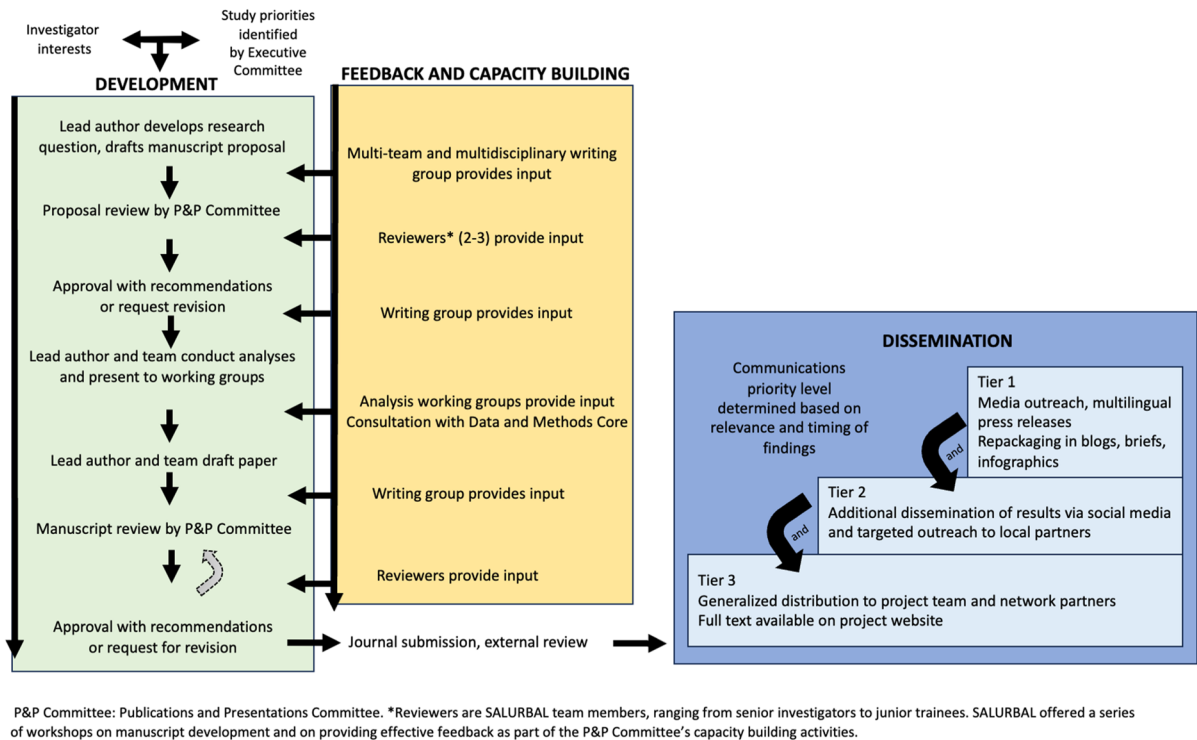


Fig. 1 Overview of SALURBAL publication development, review, and dissemination process

associations of higher area SES with longer life expectancy [8, 24] and with less excess mortality from COVID [31, 32].

Cause-Specific Death Rates are Linked to Policy-Relevant Features of Urban Built and Social Environments

Based on hypothesized causal mechanisms and using detailed data on city-level natural, physical and social environments, SALURBAL researchers explored the association of city and neighborhood environmental features with specific causes of death. Road-traffic mortality was higher in cities where urban development was more isolated but lower in cities with higher population density, higher gross domestic product per capita, higher intersection density, and in cities with mass transit [28]. Higher homicide rates among youth and young adults were

associated with lower subcity education, lower city GDP, greater isolation of urban development and higher city Gini coefficient [29]. Higher population growth, better living conditions, better service provision, presence of mass transit, and greater women's empowerment were associated with lower infant mortality [27] [33] [34].

SALURBAL has begun to leverage the longitudinal data compiled by the study. Total annual mortality as well as several cause-specific rates (cardiovascular, cancer, diabetes, respiratory infections, and road traffic injuries) were found to be procyclical (they increase during periods of economic expansions), whereas homicides are countercyclical (they decrease during periods of economic growth) [35]. Using monthly mortality data, SALURBAL researchers found that increases in monthly $PM_{2.5}$ levels are associated with increases in cardiovascular and respiratory mortality [36].

Associations of Urban Environments with Health and Health Risk Factors

Individual-Level Inequities in Health Risk Factors are Pervasive But not Invariant and Differ by Gender and Levels Socioeconomic Development

Analyses of harmonized survey data across hundreds of cities found that self-reported diabetes, measured obesity and self-reported hypertension are strongly and inversely associated with education in women [37–39]. However, associations in men were more variable and sometimes opposite in direction to those observed in women. For example, in men associations of individual-level education with diabetes were inverse (albeit weaker than in women) in Argentina, Brazil, Colombia, Chile, and Mexico, yet, they were positive in Peru, Panama, and El Salvador, and generally became more inverse as city socioeconomic development (indexed by water access, sanitation, overcrowding and education) improved [37]. A similar pattern was observed for obesity and hypertension in men [38] [39]. These findings showing heterogeneity in socioeconomic patterning by gender and broader socioeconomic city context are similar to findings previously reported for countries across the world [40].

An important yet understudied dimension of health inequities in Latin America is the presence of health inequities across racialized groups. An analysis of over 35,000 adults in the 27 state capitals of Brazil found substantial racial disparities in self-rated health and larger disparities in more segregated cities than in less segregated cities for both income and race segregation [41]. In partnership with the Ubuntu Center on Racism, Global Movements and Population Health Equity, SALURBAL conducted an assessment of available data on race and ethnicity in the region and made recommendations for improvement [42].

Urban Environments are Related to Measures of Self-Reported Health and Mental Health

Better social conditions and services at the subcity level (a services score indicating access to water and sanitation) and at the city-level (a summary score of services, crowding and education as well as higher GDP) were associated with lower odds of poor self-reported health. [43] [44] Mental health was also

found to be associated with city features: in 84 Mexican cities, the presence of more greenspace was associated with lower odds of depressive symptoms [45]. In analyses of 11 cities, longer commuting, experience of traffic delays, commuting by personal vehicle, and worse access to transit were associated with more depressive symptoms [46].

Urban Built Environment Features are Related Non-Communicable Disease Risk Factors but Associations are Heterogeneous

Work conducted primarily in high income countries has hypothesized that urban features that signal greater “walkability” can promote walking in daily life and consequently impact physical activity related conditions such as obesity, diabetes, and hypertension. Little research has explored these associations in cities of LMIC. We investigated these associations using over 90,000 survey responses from over 200 cities in 8–10 countries. As hypothesized, living in subcity areas with higher population density was associated with lower rates of diabetes [47] and lower rates of hypertension [48]. Living in greener areas was associated with lower prevalence of BMI, obesity and diabetes [47] and with lower blood pressure [48]. However, contrary to expectation, living in subcity areas with higher intersection density was associated with higher body mass index, obesity, diabetes and hypertension [47, 48]. Findings for city fragmentation were mixed: living in cities where development is more fragmented was associated with higher rates of hypertension [48] but with lower BMI and obesity [47]. It is possible that some of these metrics (eg intersection density and fragmentation) are confounded by other factors or simply are not as important as predictors of physical activity in cities were a significant amount of the population already walks by necessity as part of their commute [49]. These results highlight the importance of examining these relationships in various settings.

Taking advantage of rich local data, SALURBAL examined impacts of the food environment on health risk factors in Mexico. Larger increases in the density of fruit and vegetable stores over time were associated with declines or slower increases in BMI over time among children [50]. We also found higher odds of diabetes and higher blood pressure in adults living in municipalities where fruits and vegetable stores

had decreased, or where convenience stores or supermarkets had increased over time [51] [52].

Many Latin American cities are characterized by high levels of traffic congestion. We found that travel time and travel delay were both associated with lower odds of frequent vegetable consumption. In addition, longer travel delay time was associated with more frequent consumption of sugar sweetened beverages [53]. However we found no association between city-level travel time an odds of obesity or diabetes, perhaps because it is difficult to isolate the impact of travel from the many other lifecourse factors influencing risks of obesity and diabetes in these contexts [54].

Urban Policies are Associated with Heterogeneous Urban Environments

SALURBAL used finite mixture modeling to identify city profiles based on landscape and street design metrics. We identified four profiles for landscape and four for the street design domain [55]. We investigated whether certain city landscape profiles were more likely to show positive or negative health and environmental co-benefits. Cities with the scattered pixels profile (representing low fragmentation, high isolation, and more compact development) were more likely than other city profiles to have positive co-benefits. In contrast, the contiguous large inkblot cities (higher fragmentation and complex shape, and often very large) were the least likely to be in the positive co-benefits class [56]. These results highlight the complex ways in which urban form can be linked to health and environmental co-benefits.

SALURBAL also developed an extensive characterization of green space and parks [57]. [58] Most SALURBAL cities experienced increases in greenness over time but cities with higher SES experienced larger increases in greenness [59]. There was some evidence that less greenness was associated with faster warming over time and that recent greening may lessen warming [60].

SALURBAL analyses described transportation-related features of Latin American cities. In an analysis of 300 cities we found a that the average car rate (number of passenger vehicles per 1000 inhabitants) increased by 30% between 2010 and 2015 (from 210.2 cars per 1000 inhabitants in 2010 to 273.3 care

per 1000 inhabitants in 2015). Development fragmentation, urban form complexity and circuitry of the street network were associated with higher motorization rates, whereas higher population density was associated with less pronounced increases in motorization over time [61]. We also found that despite increases in motorization, walking remains a major mode of transportation in Latin American cities [62], often driven by necessity, highlighting the need to make public transportation both accessible and safe to reduce excessive walking times while still promoting physical activity. We also examined population levels and trends in cycling. Persons with higher SES had lower odds of using bicycles but odds of bicycle use have increased over time, especially among high SES populations [63] emphasizing the need for policies to increase active travel to focus across social groups.

SALURBAL also characterized levels and drivers of air pollution in cities of the region. In analyses of PM_{2.5} levels across 366 cities[64] we found that about 172 million or 58% of the population lived in areas with air pollution levels above the then defined WHO-AQG of 10 $\mu\text{g}/\text{m}^3$ annual average. Larger cities, cities with higher GDP, higher motorization rate and higher congestion tended to have higher PM_{2.5}. Cities with higher population density and with mass transit had lower levels of PM_{2.5}. At the sub-city level, higher intersection density was associated with higher PM_{2.5} and more green space was associated with lower PM_{2.5} [64]. We also found that 85% of residents lived in neighborhoods with ambient annual NO₂ above WHO guidelines [65]. At the city level, higher vehicle congestion, population size, and population density were associated with higher ambient NO₂ whereas higher neighborhood-level greenness were associated with lower ambient NO₂. These results for two important pollutants highlight the potential role of urban policies in reducing exposures.

Climate Change as an Emerging Health Threat in Urban Areas of the Region

In an analysis of 326 cities we found that a substantial proportion of deaths is attributable to non-optimal ambient temperatures and that marginal increases in observed hot temperatures are associated with steep increases in mortality risk with stronger associations observed in older persons [7]. We also found that higher temperatures during gestation (especially

during months 7–9) were associated with lower birth-weight. [66] Greater greenness was found to provide modest protection against heat-related mortality particularly in arid climate zones [67].

Discussion

SALURBAL Aim 1 analyses have yielded several significant findings. First, Latin American cities and neighborhoods within them reveal significant heterogeneity in health. Second, socioeconomic inequities across cities as well as across neighborhoods within cities are important predictors of differences in health across and within cities. Third, individual-level inequities in health are substantial but differ by gender and inverse associations of individual level SES with health emerge or become stronger as city or country socioeconomic development increases. Fourth, policy relevant city features including features of the built and transportation environment amenable to urban planning policies and social factors amenable to social and economic policy impact specific health outcomes, and also impact environmental exposures (such as air pollution levels) that have been shown to have significant health effects. These sets of findings highlight significant ways in which urban policies can impact health and health equity in cities of LMICs.

The SALURBAL experience has shown that a large collaborative, multicountry partnership can be simultaneously participatory, scientifically rigorous and productive, and promote meaningful local engagement and regional capacity building. The SALURBAL project has published 137 papers in peer-reviewed journals to date, 58% of them led by investigators from the region and 88% led by junior/new investigators. SALURBAL facilitated the creation of a team and governance structure that meaningfully engaged local teams, understood local challenges, and leveraged the infrastructure and resources available in high income countries (in this case in the US) in direct support of the regional collaboration. The breadth of SALURBAL allowed the study to be goal and product oriented and yet flexible and opportunistic.

SALURBAL has been extraordinarily impactful in at least two ways. First, the study has generated a comprehensive set of findings describing levels and variations in urban health across the region with a

focus on inequities. It illustrated how country and city level factors interact with individual-level factors (such as education) in shaping inequities, highlighting the impact of city social and economic policies. It has also documented how a range of policy amenable factors (including features of social, natural and built environments) relate to health and could therefore be leveraged via multisectoral policies to improve health. Second, through its data compilation/harmonization and through its collaborative approach to paper writing it has built capacity in data and analysis, scientific writing and dissemination, and meaningful multi-country collaboration across the region, in ways that can translate to other scientific questions.

Two key strategies contributed to SALURBAL's success in achieving its first aim. The first key strategy was the creation of a data resource that was comprehensive in its geographic and temporal span and in the domains encompassed and yet flexible, allowing investigators to slot in different types of data according to availability. In compiling this data resource SALURBAL used a number of strategies and integrated a variety of sources in an opportunistic manner including (1) data that was available in a standardized manner across all countries and that could be processed in a systematic way to obtain measures for areas of various size (eg temperature and air pollution data, see Table 2); (2) data that was routinely collected by government agencies but that could be harmonized relatively easily using standardized approaches such as those adopted by prior international collaborations such as the Integrated Public Use MicroData Series (IPUMS) or other published global analyses of mortality data (census data and vital statistics) [6, 28]; and (3) data from surveys conducted by national agencies for surveillance or other purposes that were often quite different in survey questions and in sampling approaches but for which some harmonization (or harmonization across some countries) was possible [9]. A key lesson was that with time and resources, including strong engagement from countries in the leadership and implementation of the project, it is feasible to compile and process existing data from LMIC in ways that allow comparative analyses.

A second strategy fundamental to the success of SALURBAL Aim 1 was the creation of an organizational structure and a set of systems and processes that facilitated collaboration and scientific rigor,

including formal and informal supports for applied capacity building. This required substantial investment of time and effort in developing, communicating and implementing clear processes and guidelines for collaboration, regular meetings of multiple groups engaging partners across the region, a robust leadership team to oversee, guide and troubleshoot, and communication and outreach strategies to facilitate engagement of a very diverse group across multiple countries with varying levels of expertise and experience. The SALURBAL experience shows that meaningful multicountry research that fully engages and builds capacity in institutions from LMIC is feasible if appropriate governance and collaborative and support systems are put in place.

The study also faced a number of challenges. A first challenge was the definition of “cities”. Recognizing that there is no unique way to define cities, SALURBAL adopted a practical approach initially driven by data availability, but also created alternative more precise definitions based on built up areas [4]. However not all of the city definitions could be linked to available health data and the ones that could often include some areas that were not built up. In addition some of the definitions were not directly aligned with political responsibility or spanned more than one political jurisdiction (eg a city core and surrounding urbanized areas). Thus in operationalizing “cities” SALURBAL needed to balance theoretical relevance (eg using the broader urban agglomeration because of the interconnected nature of its various components), practicalities related to data linkage (some theoretically relevant definitions could not be linked to health data), and political relevance (direct implications for policy).

A second challenge was heterogeneity in data availability and quality. SALURBAL took a flexible approach to data compilation, incorporating as much data as possible (as long as it met basic quality requirements) but also noting quality issues and caveats in documentation. A range of strategies were deployed to address data challenges that emerged (Table 3). The team built many partnerships with local governmental data agencies to access official data, expand capacity to use the data and improve the data. SALURBAL also issued briefs on data availability and quality [68], improved data using state of the art methods [6] and also highlighted important data gaps [42]. The study faced challenges related to

data access and the absence of a tradition of public data sharing. In many cases this was overcome thanks to the initiative of local SALURBAL team members, the development of flexible data use agreements that were used to accommodate agency requirements whenever possible, and the development of partnerships with local agencies including the return of processed data and the invitation to engage in workshops or other activities hosted by SALURBAL. In many cases geographic identifiers smaller than SALURBAL subcities were not available. SALURBAL was able to directly support additional georeferencing thus providing a service to agencies that would subsequently share data with SALURBAL. A complex set of Data Use Agreements were required to implement a range of agreements that varied by data sources and by country, and even over time. By using what is available and encouraging cross-country comparisons, SALURBAL aimed to make visible what can actually be done with existing data and highlight why having additional accessible high quality data is important.

A third challenge was variability in the research experience of the team. SALURBAL purposefully engaged a wide range of researchers and trainees across the region and both formal and informal capacity building was embedded into all activities from leadership, to data processing, to paper writing to dissemination and outreach. This sometimes meant that publications required more time for completion. The study promoted a decentralized and bottom-up approach to identification of research questions while also ensuring that key questions were addressed via guidance on priority papers by the study executive committee. As a result, SALURBAL produced a range of scientific publications some more directly aligned with its original goals and others more tangential to those goals but also important as they reflected the priorities and interests of the broader research team. Recognizing the importance of disseminating the work SALURBAL has also published in a wide range of journals, including regional journals.

A fourth challenge was related to the generation of timely evidence relevant to local action. Compiling, harmonizing and analyzing data by a collaborative team takes time. SALURBAL addressed this challenge by generating descriptive information as quickly as possible and by also initially focusing

on reviewing and disseminating what was already known. [69] [70] A related challenge was balancing results generalizable to Latin American cities as a whole (and derived from an analysis of all cities, a big strength of SALURBAL) with locally-specific analyses that may be more motivating to local policy makers. SALURBAL embraced both the generation of evidence that is relevant across cities (e.g. [6, 28].) as well as country and even city specific analyses (e.g [24, 52]).

A project of this breadth and level of regional engagement requires significant resources. Wellcome Trust funding allowed us to establish a critical coordination infrastructure and data resource, support investigators and staff across the region, engage in capacity-strengthening, and invest in dissemination and outreach efforts. The funding also allowed us to be flexible, strategic and opportunistic. Institutions involved in the project provided cost sharing in various ways. We were also able to obtain ancillary funding from other sources (regional, US and global) to support extensions of the project. Most importantly, the culture of collaboration firmly grounded in the region, with multiple opportunities for exchange (in person and remotely) and a commitment to overcoming obstacles and “making the impossible possible” was fundamental to the project’s success.

SALURBAL has made remarkable progress but there is more to do. There are significant opportunities to expand use of the data resource by conducting longitudinal analyses, spatially explicit within city analyses, and policy evaluation. The growing aging populations of LMICs will need to receive increasing attention in urban health studies. The collaborative platform created by SALURBAL can be leveraged to support additional capacity building and increase the diversity of the team by deliberately engaging and supporting investigators from groups underrepresented in the research teams. SALURBAL is also working to enhance the utility of data and findings for policy making by developing new dissemination tools such as city profiles and interactive and dynamic ways to share findings. New funding will also allow a climate focused SALURBBAL (SALURBAL-Climate) to focus on quantifying climate change health impacts and identifying effective mitigation and adaptation policies in cities of the region.

Lastly it is critical to continue to build capacity across institutions of the region not only in conducting

and disseminating research but also in coordinating and leading large regional partnerships of this type. SALURBAL has shown the immense value of south-south collaborations in strengthening local capacity, while also highlighting how the resources and expertise in high income countries can be leveraged to support the goal of meaningful regional engagement that is not extractive. Ensuring long term sustainability of the platform and collaborative approach with increasing leadership by institutions in the region is the next major challenge for SALURBAL.

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SALURBAL acknowledges the contributions of many different agencies in generating, processing, facilitating access to data or assisting with other aspects of the project. Please visit <https://drexel.edu/lac/data-evidence> for a complete list of data sources. The findings of this study and their interpretation are the responsibility of the authors and do not represent the views or interpretations of the institutions or groups that compiled, collected, or provided the data. The use of data from these institutions does not claim or imply that they have participated in, approved, endorsed, or otherwise supported the development of this publication. They are not liable for any errors, omissions or other defect or for any actions taken in reliance thereon.”

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Data Availability Data is available at <https://data.lacurbanhealth.org/>.

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