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Spectrum of Disease Burden in Urban Informal Settlements of Brazil

By

Robert Eugene Snyder

A dissertation submitted in partial satisfaction of the  
requirements for the degree of  
Doctor of Philosophy  
in  
Epidemiology  
in the  
Graduate Division  
of the  
University of California, Berkeley

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Professor Eduardo Faerstein

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## Abstract

### Spectrum of Disease Burden in Urban Informal Settlements of Brazil

by

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Doctor of Philosophy in Epidemiology

University of California, Berkeley

Professor Lee W. Riley, Chair

There are more than one billion urban informal slum residents worldwide, comprising almost one-third of the global urban population. Slums are characterized by their abundance of risk factors for communicable and non-communicable diseases. Some of these include poor water and sanitation infrastructure, in addition to poor structural housing quality, overcrowding and insecure residential status (i.e. lack of land tenure). Residents of these communities shoulder a greater burden of biologic, spatial and social health determinants of disease and their corresponding disease outcomes than residents of the same city who do not live in slums. Due to systematic disenfranchisement and the complicated logistics involved in studying these populations, our knowledge about their health conditions and determinants of disease occurrence is sparse. This dissertation describes three approaches to begin to address this gap in knowledge.

Chapter 1 sets the tone for this dissertation by describing the concept of slums and lays out the evidence for the disproportionate burden of disease borne by slum residents. While not being representative of all slums worldwide - Brazil is now considered an upper-middle-income country by the World Bank– the country's slums serve as an important case study. Brazil has a relatively robust healthcare system, a functional democracy, and an active research sector, all of which facilitate the collection and comparison of data inside and outside of the country's slums. Estimates of Brazil's slum population range from 11,425,644 (6% of the total population) in the 2010 Brazilian Census (the official government estimate) to 45.7 million (28%) estimated by the United Nations Human Settlements Program. In 2010, the Brazilian government carried out a census with the goal of systematically enumerating and describing the physical and demographic characteristics of the country's slums, coining the technical term *aglomerados subnormais* (AGSN) to describe slums.

Perhaps the most recognizable of all slums in Brazil are the *favelas* of Rio de Janeiro; these architecturally colorful and culturally vibrant communities accentuate the city's magnificent physical geography and beauty. Unfortunately, due to their precarious physical location, the quasi-legal land tenure of slum

residents, the blatant political corruption, and the persistently poor implementation of the national healthcare system (in 2010 approximately 50% of Rio de Janeiro's population had access to the Sistema Único de Saúde – SUS), these communities' residents suffer from stark health inequalities. Chapter 2 uses the 2010 Census to describe the spatial distribution of social determinants of health in Rio de Janeiro. The findings from this analysis highlight differences in age, income, and access to electricity, sanitation, water, and solid waste disposal throughout the city, and point to the possibility that differences in these characteristics contribute to an inequitable distribution of disease between the city's slum and non-slum areas.

Chapter 3 delves more deeply into these inequalities. Given our group's previously published evidence suggesting that the burden of tuberculosis is greater among residents of Rio de Janeiro's slums than among residents of non-slum areas, we seek to fulfill a principle public health axiom: that we must seek and apply solutions to improve the health of populations. Chapter 3 evaluates the effectiveness of the directly observed treatment (DOT) program for tuberculosis treatment outcomes among TB cases inside and outside of Rio de Janeiro's slums. Using the Brazilian Notifiable Disease System, Sistema de Informação de Agravos de Notificação (SINAN), we compare treatment outcomes between TB cases on DOT in AGSN and non-AGSN census tracts. While we found that DOT coverage was low inside and outside of AGSNs, we report that DOT had a greater impact on the cure rate for TB cases in AGSN areas compared to TB cases in non-AGSN areas.

Chapter 4 shifts the lens to non-communicable diseases (NCD) and to a different city, Salvador, where thirty-three percent of the population lives in slums. We compare the burden of several NCD (i.e. diabetes mellitus, hypertension, dyslipidemia) and the prevalence of risk factors (i.e. overweight, obesity and smoking) in a convenience sample of residents of Pau da Lima, an urban slum, with residents of the entire city as captured in a telephone survey. This telephone survey is an annual landline-based survey undertaken by the Brazilian Ministry of Health with the express purpose of monitoring the prevalences of NCD and NCD risk factors in Brazil's capital cities. We age- and sex- standardized the prevalences of these conditions and risk factors and compared them between these two populations. We found that the age- and sex-adjusted prevalences of diabetes mellitus, smoking, being overweight/obese, and being obese, were higher among residents of Pau da Lima than in residents of the entire city of Salvador. A striking finding was that women living in slums suffered a disproportionate burden of being overweight or obese, and men in slums smoked at almost twice the frequency as men in the city as a whole.

While these observational studies and analyses do not provide causal evidence for a link between slum residence and adverse health outcomes, they provide preliminary data in support of the hypothesis that residents of slums in several major Brazilian cities have unique social and spatial determinants of

health, and subsequently distinct disease profiles, compared to residents of non-slum neighborhoods in the same city.

Because of poor access to healthcare and a host of other slum-specific obstacles, slum residents rarely appear in official disease or mortality estimates. Consequently, slum-specific analyses such as those presented in this dissertation that describe the burden of disease among slum residents can be used to design policies aimed at mitigating the inequitable distribution of disease in these communities, also serving as a baseline to evaluate the impact of these policies on the health of this population. The findings from this dissertation should be used to encourage further epidemiologic analyses of slum populations, not only in Brazil, but also among slum populations of megacities elsewhere in the world.

For the mentors, colleagues, professionals, students, friends and family whose lives intersected with mine over the course of my graduate career, who left us too soon. Rest easy.

## Table of Contents

List of Tables.....	iii
List of Figures.....	v
Acknowledgements.....	vi
Chapter 1: Background.....	1
Chapter 2: A Comparison of Social and Spatial Determinants of Health Between Formal and Informal Settlements in a Large Metropolitan Setting in Brazil.....	12
Chapter 3: Differential Treatment Outcomes Among Recipients of Directly Observed Treatment (DOT) for Tuberculosis in Slum and Non-slum Residents.....	32
Chapter 4: Differences in the Prevalences of Select Non-communicable Diseases and Risk Factors for Select Non-communicable Diseases Between Slum Dwellers and the General Population in a Large Urban Area in Brazil.....	45
Chapter 5: Conclusions.....	62



## List of Tables

### Chapter 2

Table 1: Brazilian Census Bureau (IBGE) and Millennium Development Goal definitions of adequate access to services, 2010.

Table 2: Rio de Janeiro, slum (*aglomerados subnormais* – AGSN), and non-slum (non-AGSN) census data with standard deviations (SD), 2010.

Table 3: Rio de Janeiro, municipal planning areas, slum-only (*aglomerados subnormais* – AGSN) census data with standard deviations (SD), 2010.

### Chapter 3

Table 1: Clinical and treatment characteristics of residents with tuberculosis living in slum (*aglomerados subnormais* – AGSN) and non-slum (non-AGSN) areas, Rio de Janeiro, Brazil, 2010.

Table 2: Treatment outcomes of patients with tuberculosis receiving and not receiving directly observed treatment (DOT), separated by census tract of residence: slum (*aglomerados subnormais* - AGSN) and non-slum (non-AGSN), Rio de Janeiro, Brazil, 2010.

Table 3: Logistic regression model predicting risk of cure after treatment for tuberculosis among all TB cases in Rio de Janeiro, Brazil, 2010.

Table 4: Logistic regression model predicting risk of abandoning treatment for tuberculosis among all TB cases in Rio de Janeiro, Brazil, 2010.

Table 5: Logistic regression model predicting risk of death from tuberculosis among all TB cases in Rio de Janeiro, Brazil, 2010.

### Chapter 4

Table 1: Demographic and social characteristics of Reis et al. (2008) cohort who participated in a non-communicable disease (NCD) survey, compared to cohort participants who did not participate in NCD survey, Pau da Lima urban slum, Salvador, Brazil, 2010.

Table 2: Unadjusted total, sex-, and age-specific prevalences of non-communicable diseases (NCD) and NCD risk factors in Pau da Lima, Salvador, Brazil, 2010.

Table 3: Age- and sex-adjusted total, sex-adjusted age-specific, and age-adjusted sex-specific prevalences of non-communicable diseases and non-communicable disease risk factors in Pau da Lima, Salvador, Brazil, 2010 and in respondents to the 2010 Vigitel telephone survey in Salvador.

## **List of Figures**

### **Chapter 2**

Figure 1: Rio de Janeiro, municipal planning areas (AP), 2010.

Figure 2: Rio de Janeiro, population distributions, slum (aglomerados subnormais – AGSN), and non-slum (non-AGSN), 2010.

Figure 3: Rio de Janeiro, slum (aglomerados subnormais – AGSN), and non-slum (non-AGSN), self-reported race (2010).

Figure 4: Rio de Janeiro, percentage of households earning less than minimum wage (US\$309), 2010.

Figure 5: Rio de Janeiro, percentage of households with adequate sanitation (treated or untreated and drained from the area, or connected to a septic system), 2010.

Figure 6: Rio de Janeiro, percentage of households with exclusive, metered electricity, 2010.

### **Chapter 4**

Figure 1: Prevalences of non-communicable diseases and non-communicable disease risk factors, Salvador, Brazil, 2010.

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## Chapter 1: Background

### 1.1 The Challenge of Slums

In 2003, The United Nations Human Settlements Program (UN-Habitat) estimated that there were one billion people living in urban slums worldwide and that this number would double by 2050. (1) This estimate has fluctuated since then, (2-4) seemingly at the whim of national governments and the political implications of their continued disenfranchisement of resident slum populations. (5-7) This population makes up one-third of the global urban population. (8) The global slum population, which in reality is comprised of a diverse amalgamation of millions of different populations, communities, ethnicities and cultures across the world, is unified by their shared lack of basic human rights: shelter, clean water, and health, among others. (9-16)

This work approaches the challenge of slums from multiple angles, in several different cities, in one country: Brazil. The slums of Brazil, colloquially known as *favelas*, have unique physical and cultural characteristics as well as a rich historical context. (17) Even within the same Brazilian city, these communities demonstrate tremendous variation. (18) What this work does not seek to do is broach or evaluate the complex urban planning and development theory of slums that has been evolving since the ‘first’ slums arose during the Industrial Revolution. It also does not make the argument that all (or any) residents of different slums suffer from the same diseases, or the same risk factors for disease.

**This thesis seeks to develop a literature base for and bring awareness to health disparities in urban informal settlements.** Each chapter uses data to compare social and epidemiologic determinants of health and adverse health outcomes between residents of Brazilian slums, and residents of the same city who do not live in slums. This subset of epidemiologic literature is lacking. In 2003, when UN-Habitat published the first international report on slums by the United Nations, titled *The Challenge of Slums*, it failed to mention or describe any epidemiologic research describing the differential burden of disease shouldered by these disadvantaged populations. (1) This dissertation and the analyses contained within highlight the need for global society to consider the ways in which the relative status of slum dwellers affects their health and wellbeing, but also how these inequalities and diseases can affect non-slum dwellers (e.g. as a source of epidemics or new viral and bacterial strains, as a source of antibiotic resistance, an unnecessary drain on health resources, etc.). (19) Further, it seeks to fulfill a principal axiom of public health, “that the health of the public is a social good we commit ourselves to pursue, thus assuming an obligation to contribute to its achievement.” (20)

### 1.2 Defining a ‘slum’

In the United States we call them ghettos. In Brazil, they are called *favelas*, and elsewhere they are known as *banlieues* (France), *barrios* (Mexico), shanty towns (South Africa), *gecekondus* (Turkey), or *bidonvilles* (Tunisia, Haiti, other former French colonies). Every culture has its own slang to describe its areas of concentrated urban poverty. Until 2003, these diverse communities lacked a unifying definition for their identification. With the publication of *The Challenge of Slums*, the principal intergovernmental organization worldwide, the United Nations, formally recognized their existence. (1)

Slums are too complex to define by only one parameter. Further, slums are relative concepts: what one country considers a slum may not be considered a slum elsewhere. There is a tremendous amount of local variation between slums in the same country, and due to their highly provisional nature and rapidly changing physical, demographic, and economic contexts, it becomes even more difficult to develop a single unifying definition of what is a 'slum'. However, UN-Habitat's 2003 report did just that.

It defined slums as areas with:

- Inadequate access to safe water, defined as more than 50% of homes in a settlement being without an improved drinking water supply (household collection, public standpipe, or rainwater collection) at a minimum rate of 20 L/person/day and within a reasonable collection distance.
- Inadequate access to sanitation and other infrastructure, defined as more than 50% of homes in a settlement being without improved sanitation (public sewer, septic tank, pour-flush toilet, or ventilated improved pit latrine) and being shared by a maximum of two households.
- Poor structural quality of housing, defined in two dimensions, the first being location: residing on or near a hazardous site (geologically hazardous – earthquake/landslide zones, garbage mountains, industrial pollution, or other high risk zones, such as being near railroads, airports, or power lines); and the second the permanency of its structures: (temporary or dilapidated, as identified by the quality of construction materials and being in compliance with local building codes).
- Overcrowding, defined either as more than two persons per room or a minimum of five square meters per person.
- Insecure residential status, defined as a lack of title to either land or home. (1)

As this dissertation highlights the Brazilian context of slums, the second chapter is a detailed analysis of the 2010 Brazilian Census and the method used by the Brazilian government to identify and enumerate all of these communities within the country's borders. (23)

### **1.3 Health and place**

The relationship between health and place is well-described, having gained increasing recognition in recent decades. (24-28) Elsevier even publishes a bimonthly journal titled *Health and Place*. The physical location and characteristics that define the locations where we live have a tremendous impact on our collective health and wellbeing. This relationship between health and place complements biological and genetic disease processes, and underscores the ways in which systematic social inequalities can contribute to differences in disease burden in different populations. The 2014 Centers for Disease Control and Prevention (CDC) report describing the top five causes of death in the USA (and the largest number of preventable deaths in the American Southeast) was sensationalized in news media as showing that one's zip code plays a greater role in longevity than one's genetic code. (29) However, even CDC director Tom Frieden has been quoted as saying, "It's unfortunate, but your longevity may be more likely to be influenced by your zip code than by your genetic code." (30)

Slums are areas of concentrated poverty, possessing a predominance of determinants that engender disease. (12, 31) The inequitable spatial distribution of resources further contributes to this imbalance. (32) Biological disease agents are almost ubiquitously present in the environment, yet it is only when our resistance mechanisms break down that we develop disease. These failures occur when one is under emotional or physical duress, often deriving from stressors in the environment. (33) Lapses in our immunity can also occur during the fragmentation and breakdown of a population's social context and social relationships. (34) Both of these phenomena are common in urban slums, including those in Brazil.

Chapter 2 compares the physical characteristics of slums with the physical characteristics of non-slum areas in Brazil's second largest city, Rio de Janeiro. In terms of slum dwellers, it is the most populous in Brazil (1.39 million, 22% of the city's population). (23) The 2010 Brazilian Census was the first nationwide effort by any country, to enumerate and identify all slums within its borders. Other efforts have been undertaken to conduct censuses in individual slums, (35) and even of slums in multiple cities within the same country, (36, 37) but never before had a census been done across all slums in the entire country. However, even the 2010 Brazilian Census failed to compare disease burden among those living in the country's slums with those living in non-slum areas.

Disaggregating health data into small geographic units is absolutely essential for understanding the distribution of disease in populations. (38) Indeed, a key component of ecosocial theory is that chronic exposure to a lack of resources and environmental risk factors adversely affects biological regulatory systems. (39) Chronic exposure to stressors and disease has been shown to accumulate in the epigenome, (40) providing a mechanism for the way in which social and political conditions interact with individual subjective experiences to alter gene expression and lead to differential health outcomes. (41) Chapter 2 does not link specific risk factors to specific health outcomes, but highlights the unequal distribution of social determinants of health (i.e. education, income, property



ownership, and the proportion of homes with female heads of household), as well as differences between slums and non-slum areas in well-established biological risk factors for disease (i.e. age, sex, population density) and the physical infrastructure of a place (i.e. water, sanitation, electricity, and trash collection). This chapter disaggregates these health determinants in an effort to encourage the explicit recognition of slum residents in future epidemiologic analyses, and to highlight how differences in these characteristics provide a basis for the inequitable distribution of disease in urban areas.

#### 1.4. Communicable disease in slums

Slums are areas with poor sanitation, little to no waste removal, and overcrowded homes. Each of these is a well-established risk factor for communicable disease. (12) Poor sanitation, poor infrastructure, and a lack of clean water leads to diarrheal disease, leptospirosis, cholera, and hepatitis, among others. (42) Inadequate waste removal leads to the accumulation of trash and subsequent breeding areas for mosquitoes (malaria, yellow fever, dengue, Zika, and chikungunya). The *Aedes aegypti* mosquito (the vector for dengue virus and of Zika virus) thrives in tropical climates and in areas with poor infrastructure. It has been linked to the ways in which a community stores its drinking water (most drinking water storage in slums is improvisational, offering many opportunities for mosquitoes to breed). (43)

Overcrowding is associated with to high rates of respiratory diseases, in addition to a number of other communicable diseases. (31) In a commentary published in the *Lancet Global Health* in 2014, I argued that the severity of the Ebola virus disease epidemic in Sierra Leone and Liberia was in part due to overcrowding in slums. (44) A previous study in which I participated also reported a 10% difference in nasal colonization rates of *Staphylococcus aureus* inside and outside of urban slums. (45) *S. aureus* is the causative agent of many skin and soft tissue infections, with colonization being an important precursor for infection, and overcrowding and frequent skin-to-skin contact being important risk factors for colonization. (46)

Chapter 2 compares the demographic characteristics of residents as well as the physical characteristics of slum and non-slum census tracts. Chapter 3 focuses on one infectious disease, tuberculosis, as a paradigm to highlight how this disease could be treated differently among residents of slums and residents of non-slum areas in Rio de Janeiro. It addresses another disease associated with overcrowding, one of mankind's oldest scourges: tuberculosis (TB). The disease, caused by *Mycobacterium tuberculosis*, is more easily transmitted in overcrowded conditions, and rampant in slums. Key determinants of TB epidemiology that are also common in slums include food insecurity, malnutrition, poor housing and environmental conditions, and barriers to healthcare access. (47, 48) TB continues to account for a significant portion of the global burden of disease. (49) Other studies have shown high rates of TB in the urban slums of Southeastern Asia. (50) In a study conducted in several slums in Dhaka,

Bangladesh, investigators found that the prevalence of TB was twice the national average and four times as high as elsewhere in the same city. (51) Another study highlighted a greater TB disease burden inside of slums than elsewhere in the same city (Rio de Janeiro). (52) The number of disability adjusted life years (DALYs) due to TB in Rio de Janeiro in 2010 was 306 DALYs/100,000 population among residents of slums, compared with 236/100,000 population among residents of non-slum areas, also revealing spatial differences in TB burden in that city.

Chapter 3 delves more deeply into inequalities in disease burden between residents of slum and non-slum areas, and explores potential treatment options that could reduce this differential disease burden. Having established that the burden of TB is greater in slums, I describe different options for ameliorating this burden. To do so, I use the TB case-reporting system from Brazil - Sistema de Informação de Agravos de Notificação (SINAN), which is estimated to have captured 88% of TB cases in 2010. The database reports case-outcomes and treatment characteristics for all diagnosed cases of TB nationwide. (53) Using the subset of all TB cases in Rio de Janeiro in 2010, I demonstrate the differential effectiveness of the directly observed treatment (DOT) program in slums. DOT is explicitly designed for vulnerable and high-risk populations (neither the World Health Organization nor the Brazilian Ministry of Health include slum dwellers as members of these high-risk populations), and I show the differential beneficial effect of implementing DOT in slums. (54, 55) These results suggest that both providers and patients should consider slum residence when deciding how to treat TB.

### **1.5. The dual burden of communicable and non-communicable disease in slums**

In the past thirty years, we have seen a global epidemiologic transition, with non-communicable diseases (NCD) replacing communicable disease as the major causes of disease worldwide. Slum residents in many emerging-economy nations suffer from a dual burden of communicable and non-communicable diseases. As highlighted above, the traditional risk factors for infectious diseases persist in slums. Now, the global surge of NCD has led to a dual burden of NCD and communicable diseases in these communities, a distinctly different disease profile inside of these communities than that seen elsewhere in the same urban environment. (56, 57) The risk factors for NCD among residents of slums vary from community to community, but in many of these communities the globalization of the Western diet and lifestyle interact to simultaneously lead to malnutrition, undernutrition, and obesity. (58, 59) Western diet and lifestyle are not the only risk factors for NCD present in slums. The insecure residential status of many slum residents and their reliance on biomass combustion for cooking, with the resultant exposure to particulate air pollution, increases the risk for chronic obstructive pulmonary disease, ischemic heart disease, and stroke, not to mention increasing the risk for selected respiratory diseases. (60-62) These

are only a few of the numerous ways that living in a slum can cause or exacerbate NCD. (12, 31)

The last thirty years in Brazil have exemplified the emergence of a dual burden of communicable and NCD in slums. In this time, Brazil has seen a tremendous demographic transition. The country's demographic pyramid has shifted to include more adult and elderly individuals, even while remaining, on average, younger in slums. (23, 63) More income, increasing industrial mechanization, urbanization and the globalization of calorie-dense, low-nutrition foods, coupled with the adoption of more sedentary lifestyles has triggered a nutritional revolution in the country. (64) This revolution has been accompanied by a simultaneous epidemiologic transition, in which the burden of NCD has increased dramatically (and continues to do so), even as the burden of communicable diseases has decreased. (49) In 1990, the burden of disease in Brazil, measured in DALYs was 52% NCD, 34% communicable diseases (called 'Group I' in the 2013 Global Burden of Disease Study), and 13% injuries. By 2010, NCD represented 73%, Group I, 13%, and injuries, 13%. Respectively this corresponds to annual changes of 0.5%, -5.2%, and -0.92% in the number of DALYs in Brazil. (49)

Chapter four seeks to describe the burden of NCD and NCD risk factors among those living in one slum community in Salvador, Brazil. Our study population is a 2010 convenience sample of residents of Pau da Lima, a community that comprises roughly 10% of Salvador's slum population. Researchers at the Oswaldo Cruz Foundation (FIOCRUZ) in Salvador measured the prevalence of diabetes mellitus, hypertension, dyslipidemia, overweight, obesity, and smoking in this population. After age- and sex-standardizing the prevalences of these conditions to the 2010 age- and sex- distributions of Salvador, I compare the prevalences of these diseases with the Brazilian Ministry of Health's VIGITEL survey from the same year. (65) The Vigitel survey is a landline-based telephone survey used by the Ministry of Health to monitor the prevalences of NCD and risk factors for NCD in the capital cities of Brazil.

I show that the age- and sex- adjusted prevalences of several diseases and risk factors among residents of Pau da Lima (diseases: diabetes mellitus, risk factors: overweight, obesity, and smoking) are higher than the prevalences of these conditions among the general population of Salvador.

## **1.6. Spectrum of disease burden in urban informal settlements of Brazil**

The goal of this dissertation is to explore and contrast differences in social and spatial health determinants, ways to treat prevalent disease, and disease outcomes inside and outside of Brazil's urban informal settlements. I do so, using several cities and communities in Brazil as examples. Acting on these findings means more than just fulfilling the mandate to alleviate disease burden in populations. We must work together, using epidemiologic approaches, to demonstrate the magnitude and distribution of adverse health outcomes in these

communities, in turn providing data and new knowledge to public health and government officials, NGOs, private health providers, as well as to communities to help improve the lives of the more than one billion people who live in slums.

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## **Chapter 2: A Comparison of Social and Spatial Determinants of Health Between Formal and Informal Settlements in a Large Metropolitan Setting in Brazil**

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### **2.1 Introduction**

Urban informal settlements are characterized by a combination of concentrated poverty, insecure and poor-quality housing, political disenfranchisement, and a lack of access to essential life-supporting services, such as clean water, sanitation, and healthcare. (1) These slum-associated conditions contribute to a wide variety of adverse health outcomes. (2) Yet, globally, few cities report intra-urban health determinants in combination with health outcomes for small geographic units. This data gap is profound when comparing slum and non-slum populations in different areas of the same city or multiple cities in the same country. For example, neither the Demographic and Health Survey, nor the 2010 Global Burden of Disease (GBD) study capture intra-urban variation of health determinants or gather specific data in urban informal areas. (3,4)

In 2010, Brazil's decennial census incorporated a novel method that intended to rigorously and explicitly identify informal settlements, providing us with the opportunity to disaggregate the collected data for the comparison of population and residential characteristics that influence health outcomes within and outside of informal settlements.

Here, we describe some aspects of Rio de Janeiro's informal settlements by disaggregating census data to identify differences between these communities. This is an important, albeit incomplete, data set that can help address the specific recommendation of the Roundtable of Urban Living Environment Research commission, which proposed in 2011 that data describing social determinants of health disaggregated by population groups that are defined by socioeconomic status, gender, or place are essential to uncover and address health inequities. (5)

Due to this lack of information, many drivers of health disparities within and between these communities are frequently unrecognized. (6-8) A comprehensive

understanding of the extent of the differences in the social determinants of health in urban settings has implications for the entire urban population: neighborhood-specific data can be used to enable the development of place-specific policy measures designed to mitigate the drivers of disparities in vulnerable communities and populations. (9) Further, programs designed to address urban health disparities where we work, live, and play can have a greater effect on health outcomes than interventions directed only at the population level or those focused on individual behavioral change. (10,11)

Rio de Janeiro is the second largest city in Brazil, with more residents living in informal settlements than any other Brazilian municipality (1.39 million people, 22% of the total population). Further, the city is rapidly growing. Between the 2000 and 2010 Censuses, the municipality grew by 8.0%, from 5.86 to 6.32 million people. Reclassification of the definition of an informal settlement by the Census Bureau makes comparisons between 2000 and 2010 difficult. However, previous estimates suggest that between 1990 and 2000, the informal settlement population grew at more than three times the rate of growth of the population of the municipality as a whole. (12)

We conducted a detailed analysis of the 2010 Brazilian census in Rio de Janeiro, assessing the differences in socio-demographic and infrastructure characteristics that influence health outcomes between informal and non-informal communities. From the census data, we identified variables that have been previously linked to adverse health outcomes. (13,14) Drawing from these data, we offer suggestions for how data disaggregated by slum/non-slum status could inform more detailed studies and urban decision-making aimed at reducing health inequities.

## **2.2 Methods**

While the Brazilian Census Bureau (Instituto Brasileiro de Geografia e Estatística, IBGE) has been regularly collecting and releasing information on informal settlements since the early 1980s, the 2010 Census resulted in the Bureau's first formal publication on the subject since 1950. (15) In 2010, the IBGE defined an “informal settlement” in Brazil using the unique term subnormal agglomeration (aglomerado(s) subnormal-(is) (AGSN)), which encompasses communities made up of at least 51 housing units that meet the following criteria:

(1) illegal occupation of the land characterized by construction on the property of others or receipt of land title in the previous 10 years, and

(2) one of the following:

(a) construction outside of existing municipal patterns, reflected by

the presence of narrow and uneven roads, land parcels of inconsistent shape and size, and development not overseen by regulatory agencies, or

(b) a general scarcity of public services. (16)

Prior to the 2010 Census, the IBGE selected potential AGSN census tracts with the following method:

(1) a review of census tracts in the 2000 national census and the 2007 national population count identified as informal, in addition to other census tracts from these surveys possessing socioeconomic characteristics similar to confirmed AGSN census tracts, and

(2) a review of additional areas identified by IBGE field workers in each municipality. (17)

The IBGE systematically assessed these tracts with a territorial informational survey (Levantamento de Informações Territoriais, LIT) developed specifically for the 2010 Census, that explicitly delineated the boundaries separating formal and AGSN communities using advanced satellite imagery and subsequent confirmation of the location as a slum by census enumerators visiting the area of interest. After collecting Census data, the IBGE then hosted meetings with the local governments of 350 Brazilian municipalities to verify the classification of these AGSN census tracts.

### **2.2.1. Data Sources**

We accessed the 2010 Brazilian Census data through the official open-access IBGE 2010 Census website (<http://www.censo2010.ibge.gov.br/>). We downloaded the state of Rio de Janeiro's spatial files, as well as Microsoft Excel (Microsoft Corporation, Redmond, USA) data files in which data are organized by census tract. Each census tract is given a unique 15-digit geocoded identification number, identical in both spatial and data files, from which we selected all census tracts in the municipality of Rio de Janeiro. Excel data were imported for analysis with Stata v.12.1 (StataCorp, College Station, USA). Spatial files, coded with census tract boundaries by the IBGE, were loaded into ArcGIS v.10.1 (ESRI, Redlands, USA).

### **2.2.2. Data Analysis**

Details concerning the methods for data collection and descriptions of each variable have been previously published. (16,18) We selected and analyzed infrastructure and demographic variables that are frequently used in the urban development literature and available in the census data that we deemed to be

possibly relevant health determinants. These variables included total population, age distribution, literacy rate, household responsibility (female vs. male), race (self-reported), property ownership, and household access to services such as water, sanitation, electricity, and solid waste collection. Income is expressed in US dollars, using the exchange rate from October 1, 2010 of 1.69 Brazilian Reais per dollar. Minimum wage was defined as the federal minimum wage in 2010, approximately US\$309 per month.

The IBGE defined “adequacy” of basic utility services for households in urban areas (Table 1). (19-21) We based our analyses on the Brazilian government's definition of adequate urban service provision, but note the similarities and differences between the IBGE's definitions and those used by the Millennium Development Goals (MDG) (Table 1).

The area of each census tract was calculated with census shape files in ArcGIS v.10.1 (ESRI, Redlands, USA). Density measurements were produced by dividing this area by the number of residents in each tract. The average number of residents per household was calculated by dividing the total number of residents by the number of households in that tract. Household monthly income was calculated by dividing the sum of reported incomes by the number of households for which income data were reported in that tract. Gini coefficients were calculated from monthly per household income using Stata code adapted from a program by Aliaga-Diaz and Montoya. (22)

We stratified eligible census tracts by Rio de Janeiro's five major planning areas (Área de Planejamento, AP), a geographic organizational unit used for administrative purposes by many government agencies, including the Federal Ministry of Health, for the aggregation and analysis of epidemiologic data across five distinct geographic units in the city (Fig. 1). (23)

Further, three 14.5 square kilometer areas were identified to illustrate spatial variation within the same neighborhood: Complexo do Alemão, Centro, and Copacabana (Figs. 4, 5, 6). Complexo do Alemão is often referred to as one informal settlement in the city's industrial north, but the IBGE classifies it as a grouping of 11 AGSN communities. It is the site of multiple social interventions aimed at improving wellbeing in the area, including the Unidade de Polícia Pacificadora Social program (Social UPP). While much of Rio's wealth is concentrated in the Copacabana district and surrounding neighborhoods, there are also AGSN communities in this region, including Morro de Cantagalo, Babilônia, and Morro dos Cabritos. The city's historical center (Centro) encompasses some of Rio's oldest AGSN communities, including what is often referred to as Rio's first slum: Morro da Providência. Our analysis of Centro includes the neighborhoods of Centro, Catumbi, Gamboa, and Saúde.

## **2.3. Results**

### **2.3.1. Comparison of AGSN and non-AGSN Census Tracts**

There were 10,504 census tracts in the municipality of Rio de Janeiro. We excluded 379 census tracts because they were uninhabited (n= 309), data were withheld by the IBGE for privacy concerns (n= 61), or reported data were less than 50% complete (n= 9). Nineteen of those excluded were AGSN census tracts.

Residents of AGSN census tracts were younger, poorer, had a lower literacy rate, and more racially diverse while AGSN census tracts were more densely populated, with more equal distribution of income than residents of non-AGSN census tracts and non-AGSN census tracts, respectively (Table 2, Figs. 2 and 3). The AGSN population in Rio de Janeiro had a different age profile than the non-AGSN population. Residents of AGSN census tracts were younger, and their population's age structure was consistent with that of a rapidly growing population, whereas non-AGSN census tracts had a more stable population structure, similar to the city's aggregate age pyramid. The proportion of the population over 60 years old in non-AGSN census tracts (18.1%) was more than twice the proportion of the population over 60 in AGSN tracts (8.1%).

AGSN census tracts in Rio were more populous, with more houses per square kilometer than non-AGSN census tracts. AGSN census tracts occupied only 7% of the total inhabited area of Rio de Janeiro, but they housed 22% of the population. AGSN census tracts had a mean density of 42,991 persons per square kilometer, whereas non-AGSN census tracts had a mean of 26,371 persons per square kilometer, with more residents per house in AGSN census tracts (3.3) than in non-AGSN tracts (2.8).

In non-AGSN tracts, on average, 96.2% of households had adequate sanitation and 91.8% had adequate electricity in contrast to AGSN communities where 86.2% and 67.4% had adequate sanitation and electricity. On average, 99.6% of non-AGSN households in a census tract had adequate trash collection, while only 97.3% of AGSN households had access to this service.

### **2.3.2. Comparison of AGSN Census Tracts in Different Municipal Planning Areas**

We stratified AGSN data by municipal planning area (AP) to explore spatial differences in the 2010 Census data between districts (Fig. 1). The historic city center, AP 1, includes the city's port and main commercial zone. In the south, AP 2 consists primarily of high-density middle class residential neighborhoods, such as Copacabana and Botafogo, as well as wealthier neighborhoods, like Jardim

Botânico and Leblon. AP 3 is in the city's northeast, which encompasses much of the city's industrial and commercial activities. To the southwest is AP 4, where luxury residential communities have been recently developed. The large landmass encompassing AP 5 includes the city's last remaining farmland and several large industrial complexes. (24)

Household responsibility, income, home ownership, and access to utilities varied between AGSNs in different AP regions of Rio de Janeiro (Table 3).

Population density was lower in the western AGSNs (AP 4, 5) than in AGSN tracts in older areas of the city (APs 1, 2, 3). AGSN population density was higher in the wealthier zones of APs 2 and 4 (60,097 and 52,618 persons per square kilometer, respectively). AP 5 had the greatest land area and lowest population density (19,259 persons per square kilometer).

AGSN households in APs 3 and 5 were poorer than AGSN households in other municipal planning areas (per household monthly income of \$696 and \$672, respectively). AGSN households in AP 4 were the wealthiest, earning a mean of \$847 per month per household.

AGSN census tracts in older parts of the municipality (APs 1, 2, 3) had more homes with adequate sanitation than more recently settled AGSN census tracts in APs 4 and 5 (Table 3). The oldest AGSN census tracts in the city, in AP 1, had more homes with adequate utility access than did AGSNs in other planning areas, except electricity. Fewer than 70% of homes in all AGSN census tracts, regardless of AP, had access to adequate electricity.

### **2.3.3. Comparison of Three Urban Environments in the Municipality of Rio de Janeiro**

In 2010, the municipality of Rio de Janeiro encompassed more than 1,200 square kilometers. Our analysis explored spatial heterogeneity of access to services between AGSN and non-AGSN census tracts within three areas of the municipality: Centro, Copacabana, and Complexo do Alemão (Fig. 1). We found that wealth was concentrated in Copacabana's non-AGSN census tracts (Fig. 4) but this did extend to the region's AGSN census tracts, some of which were as poor as AGSN census tracts elsewhere in the city. AGSN households in Copacabana earned approximately the same amount of money as AGSN households in Centro and Complexo do Alemão.

There was marked spatial heterogeneity in the distribution of income in the city. For example, we observed that many homes in census tracts that were immediately adjacent to AGSN communities in both Centro and Complexo do Alemão earned less than the minimum wage, but this was not the case in

Copacabana, suggesting that spatial concentration of poverty and relative inequality was intense in certain districts of Rio in both AGSN and non-AGSN tracts.

Figures 5 and 6 show the percentages of households in these three districts with access to adequate sanitation and electricity in 2010. In all areas, access to sanitation and electricity had a distinctive spatial pattern in which AGSN areas were less-well served. Fewer than 70% of AGSN households had adequate sanitation in Complexo do Alemão and Centro. In contrast, more than 90% of the households outside of AGSNs in Copacabana and Complexo do Alemão had adequate electricity, but fewer than 80% of households within AGSNs in these areas had adequate electricity. Census tracts in the oldest area of the city, Centro, had a lower proportion of households with adequate electricity than Copacabana and Complexo do Alemão.

## **2.4. Discussion**

The 2010 Brazilian Census showed that there is heterogeneity in demographic and infrastructure characteristics between and within AGSNs in the municipality of Rio de Janeiro. In general, AGSN residents in Rio de Janeiro were poorer, less likely to be able to read, younger, and had less access to basic services than residents of non-AGSN census tracts. These variables are important determinants of health outcomes. (13, 25)

We also documented spatial variation in the distribution of poverty and services between different AGSN census tracts in different regions of the city. Relative inequality and service needs in Rio's different districts suggest that policy and planning should pay special attention to the most impoverished areas. For instance, the AGSN census tracts in the western district of Rio de Janeiro (APs 4, 5) were more impoverished and had fewer homes with adequate utilities than AGSN census tracts in the central part of the city (APs 1, 2, 3). More in-depth analysis after field-based verification of these data will be necessary to confirm these findings and should be completed before determining spatial allocations of health-promoting planning and policy interventions.

An important aspect of the 2010 Brazilian census that differentiates it from other efforts to document urban health disparities is the definitions used by the IBGE to describe adequate infrastructure. These definitions reflect decades of progress that Brazil has made in delivering basic services to urban areas, differing from those used in global measures of adequate service delivery, such as the MDG, (19,20,21) UN-HABITAT's Global Urban Indicators, (26) and even the World Health Organization's Urban Health Equity Assessment and Response Tool. (27) In most cases, the IBGE uses more rigorous criteria to assess the adequacy of service than the MDGs (Table 1). For example, the MDG definition

of improved sanitation facilities allows for certain kinds of latrines to be considered “improved sanitation,” whereas the IBGE considers a connection to the municipal wastewater network or a septic system to be adequate sanitation.

A key limitation of these metrics is that they do not consider other core issues for understanding whether infrastructure access promotes good health, such as water quality, the frequency and cost to households of electricity (i.e. was it available 24 hours a day and were prices relatively stable over time), waste collection, and sewerage, as well as whether or not access to a toilet is safe, especially for children and women. The MDGs suggest that adequate solid waste management should include such details as storage of waste in containers and removal at least once a week, in addition to the stipulation that waste should be effectively disposed of once removed (ensuring that waste isn’t inappropriately disposed of nearby). (20) Adequate trash collection was vaguely and poorly defined by the IBGE in contrast to the MDGs, as either having a central collection point for trash in the community, or having trash collected at a domicile’s curbside by a public or private service. The IBGE definition does not offer information on the frequency or disposal of household waste. Similarly, neither the IBGE nor MDG address the cost or frequency of electricity in a home. (21) This is important because long-term exposure to chronic financial stressors can contribute to adverse cardiovascular events, with frequent utility outages having adverse effects on local medical facilities (in Brazil local medical facilities often do not have backup generators). These definitions, and their shortcomings are important for our understanding of disparities in health outcomes between formal and informal communities.

Our analyses suggest possible avenues for more detailed investigation into how some of these factors relate to human health. For example, according to the 2010 GBD study the largest contributor to years of life lost (YLL) in Brazil was interpersonal violence. (3) Interpersonal violence disproportionately affects young people. (28) A younger population profile in Rio’s AGSNs may be contributing to the observed increase in YLL caused by interpersonal violence.

## **2.5. Conclusion**

Too often, census data are not analyzed specifically for vulnerable areas within a city, obscuring specific urban health risks that face the urban poor. We have attempted to analyze socio-demographic characteristics and the distribution of basic services to assess ecological neighborhood factors that influence health and wellbeing.

We believe that this preliminary analysis represents an important step towards understanding some of the drivers of health disparities between formal and informal communities. We identified discrepancies in key health



determinants and identified potential risk factors for elevated disease rates in informal communities; these disaggregated data will enable specific analyses correlating health determinants described in this study, and disaggregated data describing health outcomes in informal settlements. Our results suggest that one-size-fits-all interventions for the urban poor will likely miss intra-city differences. Strictly and rigorously disaggregated slum census data can also act as baseline data for analyzing potential changes in living and household conditions for Rio's poor residents as policies such as the Social UPP and other urban development projects associated with the Olympic Games and World Cup are implemented. Additional confirmation of these data is necessary to verify that these data correspond with the “on-the-ground” experiences of residents, but census data disaggregated by slum status are important for understanding social determinants of health of the urban poor.

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## 2.7 Tables

	<b>Adequate Access (IBGE) *</b> (16)	<b>Millennium Development Goals</b>
<b>Water</b>	<ul style="list-style-type: none"> <li>Household connection to municipality's water distribution network</li> </ul>	<b>Improved Drinking Water Sources (19)</b> <ul style="list-style-type: none"> <li>Household connection to general water distribution network</li> <li>Public standpipe</li> <li>Borehole</li> <li>Protected, dug well</li> <li>Protected spring</li> <li>Rainwater collection</li> </ul>
<b>Sanitation</b>	<ul style="list-style-type: none"> <li>Connected to drain from area (treated or untreated)</li> <li>Septic system</li> </ul>	<b>Improved Sanitation Facilities</b> <ul style="list-style-type: none"> <li>Connection to a public sewer</li> <li>Septic system</li> <li>Pour-flush/simple-pit/ventilated-improved pit latrine</li> </ul>
<b>Solid Waste Disposal</b>	<ul style="list-style-type: none"> <li>Collected in domicile and removed by public or private service from curbside</li> <li>Collected in domicile and taken to location where removed by public or private service</li> </ul>	<b>Good solid waste management (20)</b> <ul style="list-style-type: none"> <li>Storage of waste in containers</li> <li>Removal at a frequency of once per week</li> <li>Effective disposal</li> </ul>
<b>Electricity</b>	<ul style="list-style-type: none"> <li>Access to electricity</li> <li>Exclusive electric meter</li> </ul>	<ul style="list-style-type: none"> <li>Access to non-biomass fueled electricity (21)</li> </ul>

**Table 1:** \* Brazilian Census Bureau (IBGE) and Millennium Development Goal definitions of adequate access to services, 2010.

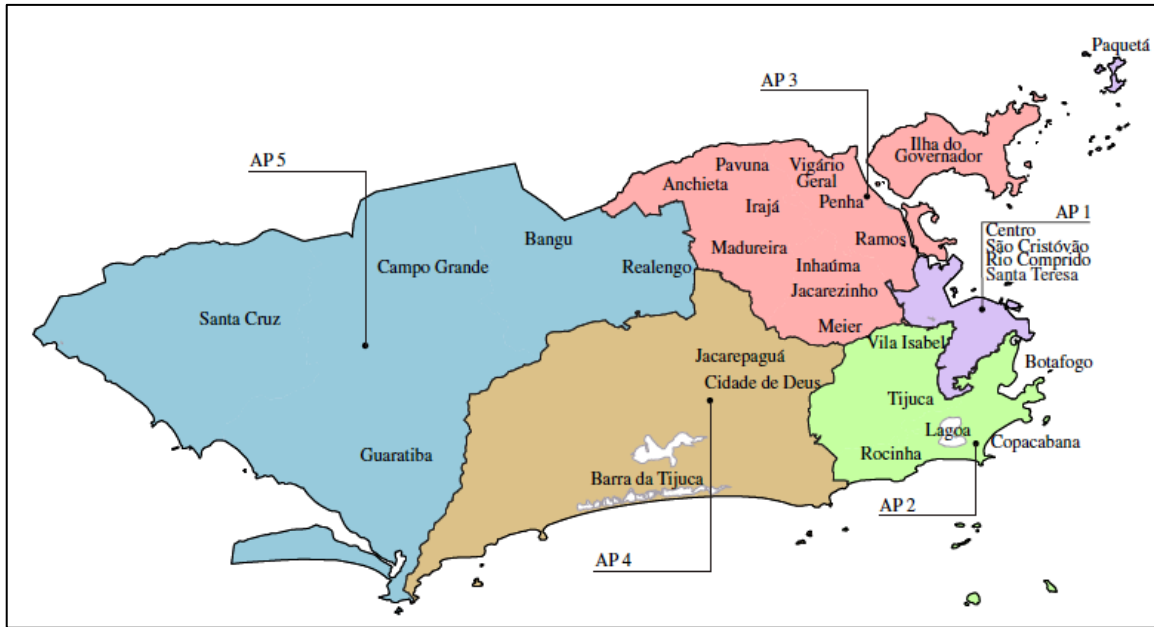
	Average in AGSN* census tracts (SD)	Average in non-AGSN census tracts (SD)
Households (n)	426,358	1,717,452
Population (n)	1,393,690	4,922,739
Years (IQR)		
50 <sup>th</sup> percentile age	26 (13,41)	35 (19,52)
Education (% population)		
Literacy ages 15-24	98.3 (2.0)	99.4 (1.2)
Literacy ages 25 and older	91.7 (4.7)	97.7 (2.8)
Income (% of households)		
Average household monthly income (US\$)	708 (208)	2,362 (1,953)
Households earning less than the minimum wage	73.5 (12.2)	34.8 (23.6)
Households earning less than three times the minimum wage	98.0 (2.8)	70.0 (27.84)
Gini Index	0.142	0.401
Population density		
Population density (people/km <sup>2</sup> )	42,991 (40,281)	26,372 (36,386)
Average residents per house	3.3 (0.4)	2.8 (0.4)
Property ownership (% households)		
Rented	18.1 (15.2)	22.7 (11.7)
Owned	77.4 (16.9)	66.7 (15.3)
Household access to services (% households adequately provisioned)		
Water (municipal connection)	95.5 (16.1)	98.7 (7.0)
Solid waste disposal (collected in home or central location for removal)	97.3 (10.6)	99.6 (3.3)
Sanitation (drained from area or septic system)	86.2 (27.0)	96.2 (13.4)
Electricity (exclusive, metered access)	67.4 (24.6)	91.8 (12.9)

**Table 2:** Rio de Janeiro, slum (*\*aglomerados subnormais* – AGSN), and non-slum (non-AGSN) census data with standard deviations (SD), 2010.

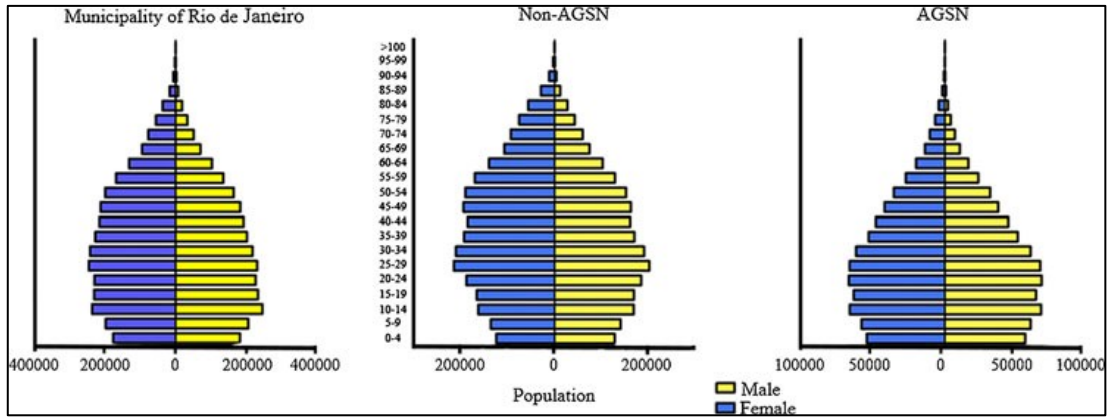
Municipal Planning Area (AP)	1 (SD)	2 (SD)	3 (SD)	4 (SD)	5 (SD)
Households (n)	30,857	54,987	186,822	74,115	79,577
Population (n)	99,545	173,697	626,533	228,475	263,286
Household responsibility (% household)					
Female head of household	512 (13.0)	49.4 (12.1)	47.0 (11.7)	44.42 (13.1)	46.15 (12.2)
Income (% of households)					
Mean household monthly income (US\$)	813 (250)	797 (20.4)	696 (187)	847 (237)	672 (160)
Households earning less than the minimum wage (%)	709 (12.3)	69.8 (12.4)	76.5 (10.7)	63.34 (12.7)	77.44 (9.1)
Households earning less than three times the minimum wage (%)	97.1 (3.2)	97.8 (2.9)	98.6 (2.0)	96.80 (4.2)	98.26 (2.1)
Gini Index	0.153	0.127	0.133	0.135	0.126
Population density					
Population density (people/km <sup>2</sup> )	48,800 (31,561)	60,097 (49,879)	46,748 (41,362)	52,618 (46,214)	19,259 (11,093)
Property ownership (% households)					
Rented	179 (11.6)	23.1 (16.3)	16.2 (10.9)	33.1 (21.78)	9.37 (7.22)
Owned	758 (18.4)	73.3 (16.4)	79.5 (13.6)	62.7 (21.6)	86.1 (10.4)
Household access to services (% of households adequately provisioned)					
Water (municipal connection)	99.2 (4.2)	91.3 (22.)	97.4 (11.8)	89.7 (25.6)	96.7 (12.0)
Solid waste disposal (collected in home or central location for removal)	97.8 (7.2)	98.0 (7.8)	96.5 (12.6)	97.4 (11.2)	98.1 (8.1)
Sanitation (drained from area or septic system)	93.8 (17.0)	89.5 (18.5)	90.9 (23.1)	76.6 (34.4)	79.7 (30.9)
Electricity (exclusive, metered access)	68.3 (26.2)	68.7 (29.2)	66.6 (25.1)	69.2 (23.3)	66.7 (21.3)

**Table 3:** Rio de Janeiro, municipal planning areas, slum-only (aglomerados subnormais – AGSN) census data with standard deviations (SD), 2010.

## 2.8 Figures

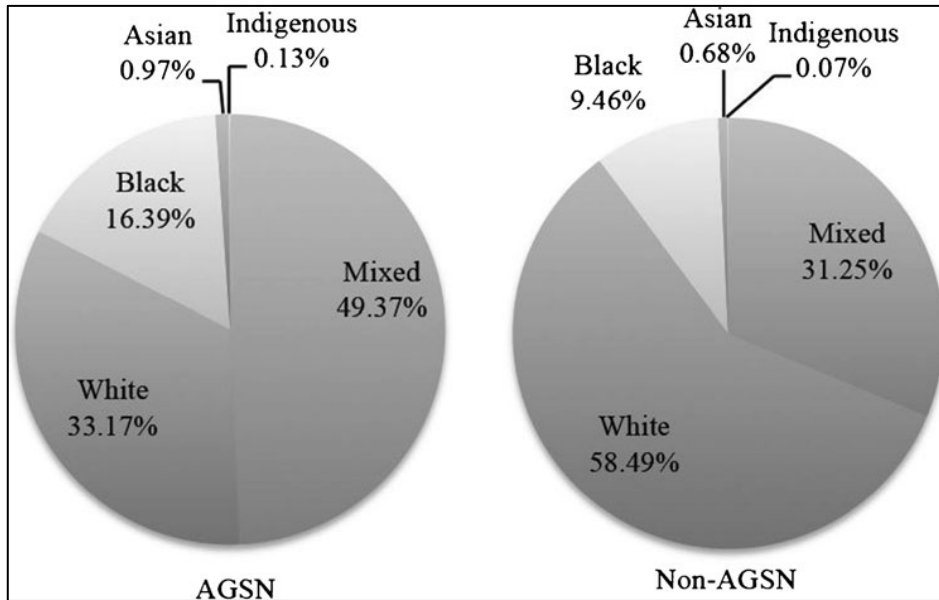


**Figure 1:** Rio de Janeiro, municipal planning areas (AP), 2010.

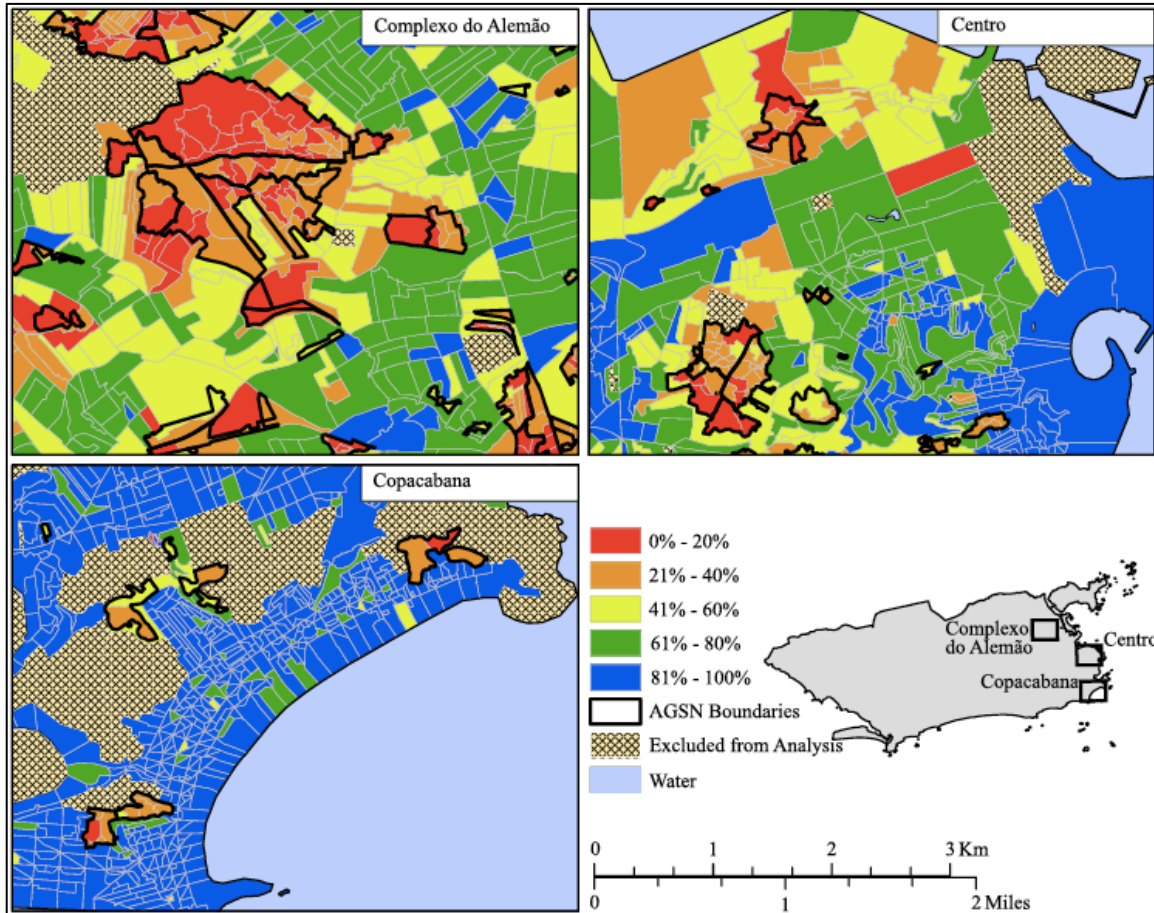


**Figure 2:** Rio de Janeiro, population distributions, slum (aglomerados subnormais – AGSN), and non-slum (non-AGSN), 2010.

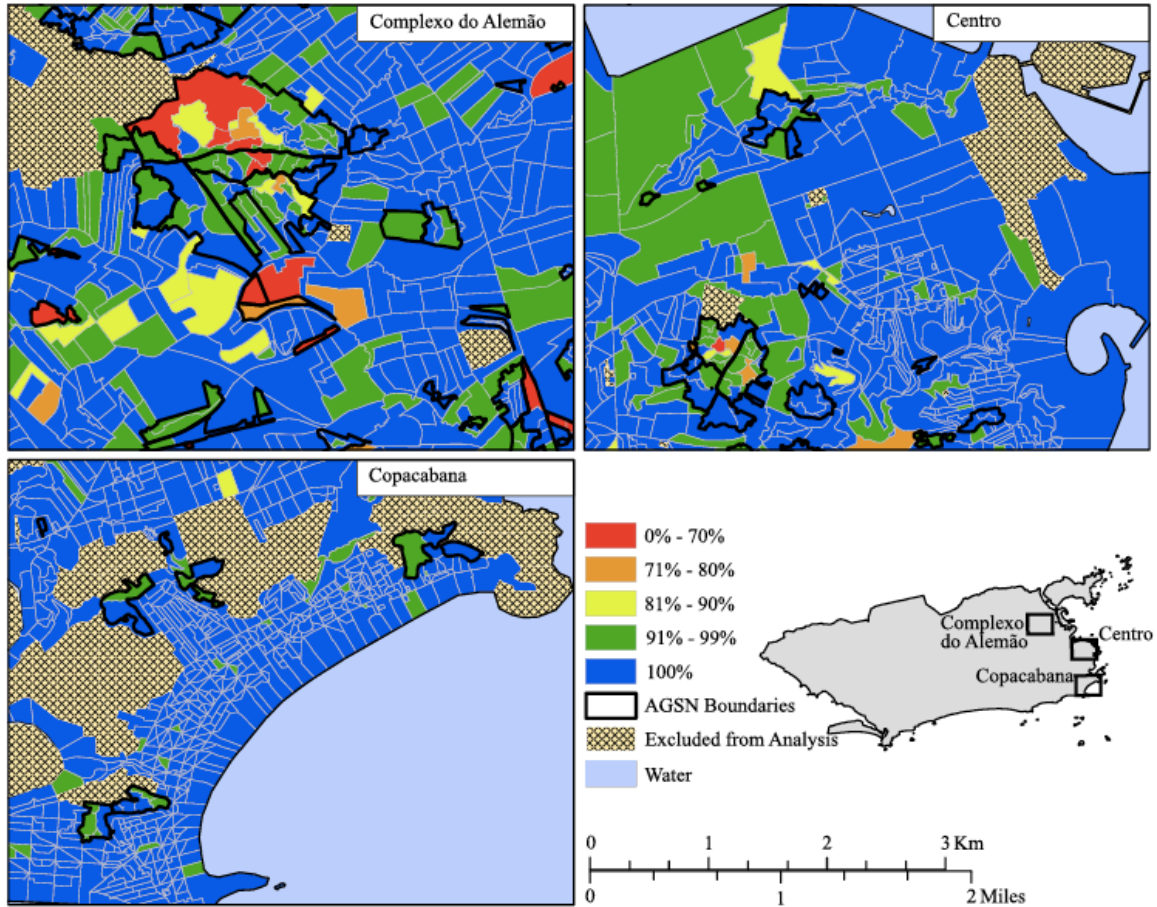




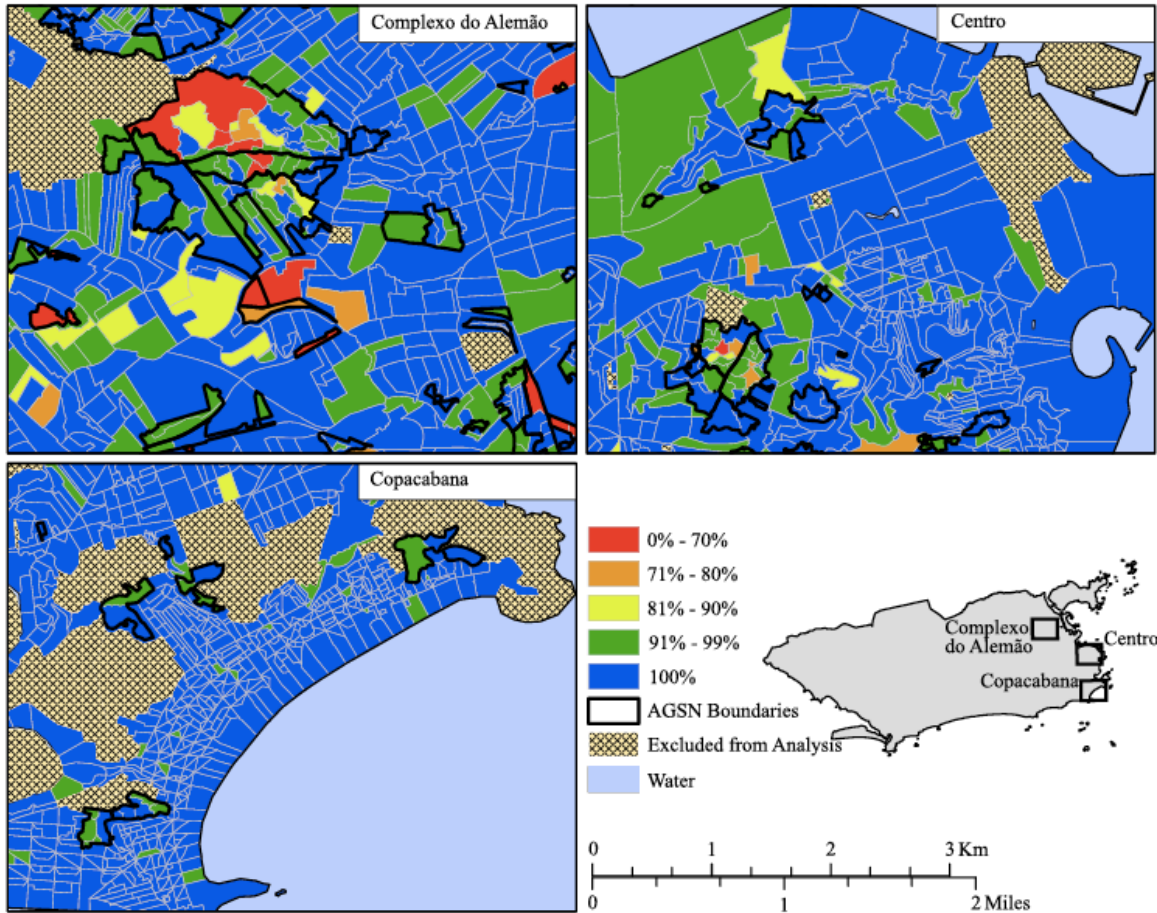
**Figure 3:** Rio de Janeiro, slum (aglomerados subnormais – AGSN), and non-slum (non-AGSN), self-reported race (2010).



**Figure 4:** Rio de Janeiro, percentage of households earning less than minimum wage (US\$309), 2010.



**Figure 5:** Rio de Janeiro, percentage of households with adequate sanitation (treated or untreated and drained from the area, or connected to a septic system), 2010.



**Figure 6:** Rio de Janeiro, percentage of households with exclusive, metered electricity, 2010.

## **Chapter 3: Differential Treatment Outcomes Among Recipients of Directly Observed Treatment (DOT) for Tuberculosis in Slum and Non-slum Residents**

### **3.1. Background**

Between 1990 and 2012, the incidence of tuberculosis (TB) in Brazil decreased by an average of 1.3% each year. Despite this decrease, the country remains one of twenty-two World Health Organization (WHO) high-burden TB countries. (1) Brazil also has a large urban slum population (as defined by both the United Nations and the Brazilian Census Bureau), where 11.4 million (6.0%) of its roughly 200 million people reside. Rio de Janeiro has the nation's largest slum population, with 1.4 million of the city's 6.3 million people (22% of the population) residing in these communities. (2)

The Sistema de Informação de Agravos de Notificação (SINAN) is the national Brazilian notifiable disease surveillance system to which all TB cases are compulsorily reported. The proportion of incident TB cases detected by SINAN ranges from 85 to 90%. (1)

The Stop TB Partnership's Global Plan to Stop TB has as its primary goals to address HIV-related TB, limit the spread and development of multidrug-resistant (MDR) TB, and empower communities and vulnerable populations afflicted with TB. (3) To this end, in 2006 Brazil augmented its National TB Control Program (NTCP) by expanding the use of directly observed treatment (DOT) and enhancing laboratory diagnostic capabilities. (4)

In 2010, the burden of TB (measured in disability-adjusted life years - DALY) was higher among residents of Rio's slums than among its non-slum residents. (5) While previous work has shown that DOT has been effectively implemented in vulnerable populations in Brazil, (6) a comparative analysis of the impact of DOT in slums and formal communities has yet to be done. This study examines the impact of DOT on TB treatment outcome in these two types of neighborhood in the city of Rio de Janeiro, Brazil.

### **3.2. Methods**

This is a retrospective analysis of all TB cases (7,276 cases) with onset in 2010 that were reported to SINAN in Rio de Janeiro, Brazil. The cases were geocoded by patient residential address with Google Geocoding API v.3 (<https://developers.google.com/maps/documentation/geocoding/>) and mapped in ArcGIS 10 (ESRI, Redlands, CA, USA). TB patients whose residences were outside of the city limits (142, 2.0%), who were incarcerated (452, 6.2%), or were homeless (81, 1.1%) were excluded.

The 2010 Census classified a census tract as "*aglomerado subnormal*" or AGSN if the tract included a portion (or all) of a community comprised of at least 51 homes that illegally occupied the land (i.e. was constructed on the property of

others or received a land title in the previous ten years) and at least one of the following: 1) a general scarcity of public services or 2) construction outside of existing municipal patterns. TB cases in the SINAN database were overlaid and mapped on the census tract shapefiles from the 2010 Brazilian Census. Individuals with TB who lived in or within 50 meters of an AGSN census tract were identified as slum TB cases. (2)

Demographic (age, sex), clinical characteristics (pulmonary or extrapulmonary, relapse or not), TB diagnostic results (tuberculin skin test and acid-fast bacilli smear results), treatment (e.g. DOT, time from diagnosis until notification) and follow-up (contact tracing) were compared between slum (AGSN) and non-slum (non-AGSN) TB cases in the city. Analyses were performed in Stata 12.1 (Statacorp, College Station, USA).

TB treatment outcomes were consistent with the Brazilian Ministry of Health's definitions. (7) Cure was defined as two consecutively negative sputum smears, one before and one after cessation of chemotherapy. Treatment abandonment was defined as a patient's absence from the treatment center for a minimum of 30 days after the return date indicated by his or her health professional. TB treatment outcomes (including mortality) are reported to and updated in the SINAN database by health professionals at the health unit where treatment occurs.

Health professionals at primary health units where suspected TB patients are first encountered report all new TB cases to SINAN using a standardized case notification form. These suspected cases are prospectively followed until the case is considered closed with one of the following outcomes: cure, abandonment, death from TB, death from other cause, transfer, or missing outcome.

In Brazil, DOT is implemented in accordance with WHO recommendations, [8] by the country's primary health system (Sistema Único de Saúde - SUS). The patient appears at the treatment center a minimum of three times each week during the first two months of treatment, or has the same frequency of home visits by community health workers. (7) The Brazilian Ministry of Health's policy is that all TB cases (new and reactivation TB) should receive DOT. In practice, health professionals use DOT for patients perceived as being at greatest risk of treatment failure. The decision to observe treatment at-home or at the health-post is made by the health professional in consultation with the patient. This policy also alludes to the importance of making this decision given existing limitations in infrastructure or availability of human resources (e.g. if there are enough employees to observe, or if a health unit is geographically proximal to the patient). (7) In Brazil, provision of food and transportation vouchers for those enrolled in DOT is at the discretion of individual health professionals and encouraged by the Ministry of Health when a professional believes it will enhance treatment adherence. (9)



We assessed differences in the demographic and socioeconomic characteristics of TB cases in AGSN and non-AGSN areas using the Mantel-Haenszel (MH) chi-squared test and Students T-test where appropriate. We calculated relative risks (RR) with the Mantel-Haenszel (MH) chi-squared test for treatment outcomes (e.g. death, cure rate, abandonment, transfer, etc.) in those who did or did not undergo DOT to compare treatment outcomes of TB cases on DOT versus treatment outcomes of TB cases not on DOT.

After this crude analysis, multivariable logistic regression models were developed to adjust for other factors that may have influenced the relationship between DOT, AGSN residence, and TB treatment outcomes: cure (table 3), abandonment (table 4) and death from TB (table 5). Those who transferred elsewhere for treatment (590, 8.9%) or were missing treatment outcome data (688, 10.4%) were excluded from all models, leaving 5,266 (80.7%) eligible TB cases. Potential confounding variables were included if they were related to TB treatment outcome. Those available in SINAN include: age, sex, HIV status, alcoholism, diabetes, relapse (a TB case that was previously declared cured), and disease severity (extrapulmonary v. pulmonary), in addition to DOT status, and residence in an AGSN. (10-12) Models were created in a forward stepwise process, maintaining covariates in the final models with a p-value < 0.20. Dummy variables were created to test for interaction between age and sex, as well as DOT and residence in a slum. We evaluated the hypothesis that DOT treatment varies in effectiveness between AGSN and non-AGSN TB cases. (13,14)

The Ethics Committee at the Federal University of Espírito Santo approved this study. Cases were geocoded by Brazilian personnel, and at the time of analysis by Berkeley personnel, data were completely de-identified. For this reason, approval from the Committee for Protection of Human Subjects (CPHS) at Berkeley was not necessary.

### **3.3. Results**

In 2010, there were 1,807 TB cases among residents of AGSN areas (0.13% of the total AGSN population, 27.4% of 2010 Rio TB cases), and 4,794 cases among residents of non-AGSN areas of Rio de Janeiro (0.10% of the total non-AGSN population, 76.2% of 2010 Rio TB cases) that were reported to SINAN (Table 1). Of 6,601 total TB cases, 2,317 (35.1%) were in women. The mean age of all patients with TB was 38.7 years (standard deviation: 16.5).

Of the 1,807 cases living in AGSN areas, 638 (35.2%) were on DOT while 1,234 (26.2%) TB patients living in non-AGSN areas were on DOT. Among TB patients living in AGSN areas, 963 (56.7%) patients were cured, while 2,622 (57.8%) TB patients living outside of AGSN areas were cured (Table 2). Of 1,807 AGSN TB patients, 325 (19.1%) abandoned treatment, and 746 (16.5%) non-AGSN TB patients did so (Table 2). Of the AGSN TB patients, 32 (1.9%) died from other causes while 68 (4.0%) died from TB. Of the non-AGSN cases, 128 (2.8%) died from other causes while 199 (4.4%) died from TB. Among AGSN TB

cases, 17 (2.7%) on DOT and 83 (7.8%) not on DOT died of all causes, while among non-AGSN cases 52 (4.2%) not on DOT and 275 (8.4%) on DOT died of all causes.

Unadjusted bivariate analyses indicated that those living in AGSN and on DOT were 1.66 (95% confidence interval (CI): 1.45-1.91) times as likely to be cured and had 0.20 (95% CI: 0.08-0.46) times the risk of death compared to those not on DOT in AGSN. Outside of AGSN, those on DOT had 1.15 (95% CI: 1.04-1.27) times the probability of cure and 0.54 (95% CI: 0.38-0.76) times the risk of death compared to those not on DOT. Of those on DOT in AGSN, 118 (18.5%) abandoned treatment, while 265 (21.5%) non-AGSN patients did so. The MH chi-squared test statistic suggested that there was effect modification by AGSN for cure, abandonment, death from TB, and death from other causes. Those who transferred to another municipality for TB treatment or who were missing their treatment outcome were not more likely to be residents of an AGSN.

Holding other factors constant (age, sex, HIV/AIDS and clinical disease presentation - pulmonary v. extrapulmonary), TB cases residing in AGSN areas were less likely to be cured (0.77, 95% CI: 0.63-0.95) than TB cases living outside of AGSN areas (Table 3). TB cases on DOT and living outside of AGSN were 1.16 times as likely to be cured (95% CI: 0.95-1.42) as TB cases not on DOT living outside of AGSN. If the TB case was a resident of an AGSN area and on DOT, the chance of cure increased to 1.67 (95% CI: 1.17-2.40) compared to TB cases that were not residents of AGSN and not on DOT.

The risk of treatment abandonment was similarly influenced by DOT and the TB case's location of residence. Controlling for sex, age, clinical disease severity, and HIV/AIDS, we found that TB patients residing in an AGSN were 1.33 times more likely to abandon treatment (95% CI: 1.05-1.67) (Table 4) than TB patients not residing in an AGSN. Being on DOT did not have a statistically significant effect on risk of abandonment (1.15; 95% CI: 0.92-1.43). TB cases residing in an AGSN area and on DOT had 0.61 times the risk of abandonment (95% CI: 0.41-0.90) compared to TB cases not in AGSN and not on DOT.

Similarly, the relationship between a TB case being on DOT and dying from TB was also modified by whether or not the case resided in an AGSN area (Table 5). When controlling for age, clinical disease severity and HIV/AIDS, being on DOT decreased risk of death from TB by a factor of 0.39 (95% CI: 0.23-0.67). Being a resident of an AGSN did not significantly increase the risk of death from TB (1.23, 95% CI: 0.85, 1.78). Being on DOT and residing in an AGSN area reduced the risk of death from TB by a factor of 0.1 (95% CI: 0.01, 0.77) compared to not being on DOT and not residing in an AGSN.

### **3.4. Discussion**

Slum-defining characteristics, such as overcrowding, poor access to



healthcare, and poverty are associated with worse TB treatment completion and disease outcomes. (15, 16) Here, we found that administering DOT to TB patients that live in informal settlements (AGSN) lowered a TB cases' risk of treatment abandonment, or death from TB, and increased their chance of being cured. The Brazilian NTCP makes explicit its prioritization of DOT in vulnerable populations, but has yet to do this in slums. The differential effectiveness of DOT inside and outside of AGSN in Rio de Janeiro highlighted here, lends support to the hypothesis that residents of slums should be considered a vulnerable population when considering DOT as a treatment strategy for TB.

In Rio de Janeiro in 2010, DOT coverage was higher among AGSN TB cases (35.2%) than in non-AGSN TB cases (26.2%). Cure rates, however, remained low in both communities. The TB cure rates inside (56.7%) and outside of AGSN (57.8%) were nearly identical, and roughly the same as the 2010 Brazilian average (61.9%), which is well below the Millennium Development Goal of 85% cure. (1) However, patients on DOT residing in AGSN areas had better outcomes than patients on DOT that lived outside of AGSN areas. Within AGSN areas, TB cases were 1.67 (95% CI: 1.17-2.40) times more likely to be cured if on DOT, compared to cases not on DOT and not living in AGSN areas. In AGSN, the proportion of deaths due to TB was 4.3 times higher among those who were not on DOT, while it was 2.3 times higher in the non-AGSN population not on DOT (Table 2).

Although treatment abandonment was higher in AGSN compared to non-AGSN TB cases, abandonment among those on DOT was less likely if the TB patient lived in an AGSN area (18.5%) when compared to TB patients that did not live in AGSN areas (21.5%). The higher rate of treatment abandonment among those on DOT may be biased by the program's design, as it is strongly encouraged as a treatment option for those considered at risk for abandoning treatment.

Importantly, the provision of food and transport vouchers is not noted in the SINAN database (a practice encouraged to reduce abandonment). A 2015 survey of health professionals from five different regions in Brazil (not including the city of Rio de Janeiro) indicated that only 51% and 20.5% of surveyed clinics had access to food and transport vouchers, respectively. It is possible that these vouchers are more frequently given to TB cases that reside in slums to discourage abandonment while on DOT, but we cannot evaluate this bias due to the absence of these data in SINAN. (9)

Almost 5% (289, 4.4%) of the SINAN database is lacking data on DOT. In contrast to the observational data presented here, a 2015 Cochrane meta-analysis of DOT randomized control trials found questionable improvements in TB outcome, highlighting the need to indicate where DOT is administered (home or health facility) and who observes treatment (family member v. health professional). (17) Completing these missing data, including the 10% of cases that were missing data on treatment outcome, and simultaneously augmenting

the SINAN database by including location of DOT, and who is observing treatment could further clarify how DOT works.

Of more concern is the fraction of data that are missing for other important covariates. Almost a quarter of the 2010 TB cases (25.6%) did not have their HIV status recorded in SINAN despite the fact that HIV status was the most important risk factor for cure, risk, or abandonment. Health professionals must continue to make efforts to identify all HIV-positive TB patients and reliably report TB cases' HIV-status to SINAN.

There are several possible explanations for the apparent greater impact of DOT on TB cases in AGSN. The program is overseen by SUS's community-based health program, in which residents of the community where the health post is located serve as community-health workers. The familiarity of these agents with patients and their communities could have contributed to the differential success of DOT in AGSN areas. The quality of DOT coverage, therefore, may differ between the two populations.

This analysis is based on data from the surveillance system SINAN, which has a high case-detection rate, but that relies on cases being reported.[1] A 2008 study in Rio de Janeiro indicated that roughly half of the TB deaths in the city were not reported to SINAN. (18) This was likely due to the severity of the disease when it was diagnosed (i.e. patients who died and were included in the mortality database but not in SINAN were already at an advanced stage of disease when admitted to the hospital and died before they were reported to SINAN). Inclusion of data from the city's mortality database in this analysis would have increased the number of deaths, but likely would not have influenced the differential influence of DOT in AGSN.

Case reporting and reliability of the database must be enhanced so that the effectiveness of DOT can be thoroughly evaluated. The differential effect of DOT on TB cases residing in AGSN areas should be confirmed in future analyses as the quality of data reporting in SINAN continues to improve. These findings suggest that DOT should be more thoroughly implemented both inside and outside of slums. The relatively greater effectiveness of DOT within slums further emphasizes the importance of identifying which TB cases reside in slums.

### **3.5. Conclusions**

There were no notable differences in treatment between AGSN and non-AGSN TB cases in Rio de Janeiro. TB treatment outcomes were worse among TB cases not on DOT, with DOT demonstrating the greatest impact on cure rates in vulnerable AGSN communities. Our results suggest an effect of DOT on mortality as well. The Brazilian NTCP's success with DOT in the AGSN communities of Rio de Janeiro offers an established model for improving TB care in vulnerable slum populations in other global megacities.

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### 3.7 Tables

	Total n (%)	Slum n (%) AGSN	Non-slum n (%) Non-AGSN	p-value*
Number of cases	6601 (100.0)	1807 (27.4)	4794 (72.6)	-
Median age in years (IQR)	37 (26, 50)	38 (37, 51)	33 (23, 47)	-
Sex (% female)	2317 (35.1)	1666 (34.8)	651 (36.0)	0.313
Site of TB				
Pulmonary	5412 (82.0)	1515 (83.8)	3897 (81.3)	0.02
Extrapulmonary	867 (13.1)	218 (12.1)	649 (13.5)	0.11
Pulmonary and extrapulmonary	322 (4.9)	74 (4.1)	248 (5.2)	0.07
HIV/AIDS status				
Positive	792 (12.0)	204 (11.3)	588 (12.3)	0.23
Unknown	1692 (25.6)	457 (25.3)	1235 (25.8)	
Case category				
New case	5173 (78.4)	1362 (75.4)	3811 (79.5)	< 0.001
Relapse after previous treatment completion	483 (7.3)	167 (9.2)	316 (6.6)	<0.001
Relapse after loss to follow-up in previous treatment	545 (8.3)	177 (9.8)	368 (7.7)	0.01
Unknown	73 (1.1)	16 (0.89)	57 (1.2)	0.29
Transfer to other municipality	327 (5.0)	85 (4.7)	242 (5.1)	0.57
Tuberculin skin test result				
Not reactive (0-4 mm)	266 (4.0)	57 (3.2)	209 (4.4)	0.03
Weak reaction (5-9 mm)	101 (1.5)	33 (1.8)	68 (1.4)	0.23
Strong reaction (≥10 mm)	638 (9.7)	175 (9.7)	463 (9.7)	0.97
Not performed	5590 (84.7)	1542 (85.3)	4048 (84.4)	0.37
Acid-fast bacilli smear at diagnosis				
Positive	3228 (48.9)	959 (53.1)	2269 (47.3)	< 0.01 <sup>§</sup>
Negative	1551 (23.5)	368 (20.4)	1183 (24.7)	
Not performed	1822 (27.6)	480 (26.6)	1342 (28.0)	
On DOT at diagnosis				
Yes; completed full course	1892 (28.7)	636 (35.2)	1256 (26.2)	<0.01 <sup>†</sup>
Yes; did not complete full course	10 (0.2)	10 (0.6)	-	
No	4410 (66.8)	1081 (59.8)	3329 (69.4)	
Unknown	289 (4.4)	80 (4.4)	209 (4.4)	
Treatment changed due to intolerance or failure				
Yes	45 (0.7)	17 (0.9)	28 (0.6)	0.12
No/not recorded	6556 (99.3)	1709 (99.1)	4766 (99.4)	
All contacts indicated at diagnosis examined at follow-up				
Yes	3349 (51.2)	855 (47.8)	2494 (52.5)	<0.01
No	3195 (48.8)	935 (52.2)	2260 (47.5)	
Median days (IQR) from diagnosis until notification	0 (0, 14)	0 (0, 14)	1 (0, 14)	-
Median days (IQR) from diagnosis until initiation of treatment	0 (0, 0)	0 (0, 0)	0 (0, 1)	-
Median days (IQR) from initiation of treatment until change of treatment due to adverse reaction	175 (77, 238)	182 (79.5, 237.5)	149 (76, 244)	-
Median days (IQR) from diagnosis until end of follow-up	187 (145, 219)	187 (146, 218)	189 (145, 221)	-

IQR = interquartile range, 25<sup>th</sup> and 75<sup>th</sup> percentile

\* p-value comparing selected characteristics between cases in slums and non-slums

<sup>§</sup> Comparing positive versus negative AFB smear diagnosis

<sup>†</sup> Comparing all those assigned to DOT (regardless of completion)

**Table 1:** Clinical and treatment characteristics of residents with tuberculosis living in slum (*aglomerados subnormais* – AGSN) and non-slum (non-AGSN) areas, Rio de Janeiro, Brazil, 2010

	Slum (AGSN)			Non-slum (non-AGSN)			RR <sup>§</sup>	95% CI	p-value <sup>†</sup>
	Total	DOT (%) Yes	No	Total	DOT (%) Yes	No			
Missing outcome	174 (10.2)	39 (6.1)	135 (12.7)	462 (10.2)	98 (7.9)	364 (11.0)	0.77	0.64-0.92	0.06
Cure	963 (56.7)	430 (67.4)	533 (50.1)	2622 (57.8)	758 (61.4)	1864 (56.5)	1.15	1.04-1.27	< 0.01
Abandonment	325 (19.1)	118 (18.5)	207 (19.5)	746 (16.5)	265 (21.5)	481 (14.6)	1.37	1.23-1.53	< 0.01
Death TB	68 (4.0)	8 (1.3)	60 (5.6)	199 (4.4)	28 (2.3)	171 (5.2)	0.54	0.38-0.76	0.03
Death other	32 (1.9)	9 (1.4)	23 (2.2)	128 (2.8)	24 (1.9)	104 (3.2)	0.65	0.45-0.95	0.92
Transfer out	140 (8.2)	34 (5.3)	106 (10.0)	378 (8.3)	61 (4.9)	317 (9.6)	0.60	0.47-0.75	0.82

There were 88 (4.4%) cases in AGSN and 219 (4.4%) outside of AGSN where the case's DOT status was unknown.

<sup>§</sup> Relative risk (RR) estimating crude risk of outcome in patients on DOT compared to patients not on DOT in slum versus non-slum neighborhood.

<sup>†</sup> P-values assessing for effect measure modification of AGSN census tracts on the relationship between DOT and respective outcome with the Mantel-Haenszel chi-square test.

**Table 2:** Treatment outcomes of patients with tuberculosis receiving and not receiving directly observed treatment (DOT), separated by census tract of residence: slum (*aglomerados subnormais* - AGSN) and non-slum (non-AGSN), Rio de Janeiro, Brazil, 2010.

	Odds ratio	Standard error	95% confidence interval
On directly observed treatment (DOT)	1.16	0.12	0.95, 1.42
Residence in a slum (AGSN*) area	0.77	0.08	0.63, 0.95
Sex (reference female)	0.73	0.06	0.62, 0.85
Age in years	1.01	0.002	1.00, 1.01
Extrapulmonary clinical disease	2.07	0.23	1.66, 2.59
HIV/AIDS	0.23	0.02	0.19, 0.28
DOT * AGSN (interaction term)	1.67	0.31	1.17, 2.40

N: 3797,  $R^2 = 0.061$

\*AGSN = aglomerados subnormais

**Table 3:** Logistic regression model predicting risk of cure after treatment for tuberculosis in Rio de Janeiro, Brazil, 2010.

	Odds ratio	Standard error	95% confidence interval
On directly observed treatment (DOT)	1.15	0.13	0.92, 1.43
Residence in a slum (AGSN*) area	1.33	0.16	1.05, 1.67
Sex (reference female)	1.41	0.13	1.18, 1.69
Age in years	0.98	0.003	0.97, 0.98
Extrapulmonary clinical disease	0.44	0.06	0.33, 0.57
HIV/AIDS	1.97	0.23	1.56, 2.48
DOT * AGSN (interaction term)	0.61	0.12	0.41, 0.90

N: 3797,  $R^2 = 0.047$

\*AGSN = aglomerados subnormais

**Table 4:** Logistic regression model predicting risk of abandoning treatment for tuberculosis in Rio de Janeiro, Brazil, 2010.



	Odds ratio	Standard error	95% confidence interval
On directly observed treatment (DOT)	0.39	0.11	0.23, 0.67
Residence in a slum (AGSN*) area	1.23	0.23	0.85, 1.78
Age in years	1.03	0.01	1.02, 1.04
Extrapulmonary clinical disease	0.64	0.13	0.43, 0.95
HIV/AIDS	8.79	1.45	6.35, 12.16
DOT * AGSN (interaction term)	0.10	0.10	0.01, 0.77

N: 3797,  $R^2 = 0.175$

\*AGSN = aglomerados subnormais

**Table 5:** Logistic regression model predicting risk of death from tuberculosis among all TB cases in Rio de Janeiro, Brazil, 2010.

## **Chapter 4: Differences in the Prevalences of Select Non-communicable Diseases and Risk Factors for Select Non-communicable Diseases Between Slum Dwellers and the General Population in a Large Urban Area in Brazil**

### **4.1. Introduction**

In the past 25 years, non-communicable diseases (NCD) have displaced communicable diseases as the principal cause of illness globally. In 1990, NCD accounted for 42.5% of global disability-adjusted life years (DALY), whereas in 2013 they accounted for 58.5% of global DALY. (1,2) In 2011, the United Nations Human Settlements Program (UN-Habitat) estimated that approximately 863 million people lived in urban slums in low- and middle-income countries. (3) Slums are operationally defined as urban areas with overcrowding, poor sanitation infrastructure, limited access to safe water and poor structural quality of housing. (4) Access to healthcare, which has a substantial impact on NCD outcomes, is also less available in urban slums. (5) Further, residents of slums are also exposed to high levels of outdoor air pollution (cardiopulmonary disease), stressful living conditions (ischaemic heart disease), and limited city planning (fewer areas for exercise). (6, 7) These slum-defining phenomena synergistically interact to cause more NCD and their sequelae in slum populations when compared to residents of the same city that do not live in slums. (6) Because of the persistence of many environmental risk factors for communicable diseases in slums, residents of slums now suffer a dual burden of communicable disease and NCD.

Health surveys often do not describe health disparities between populations living in the same geographic area, such as within the same city. Existing surveys of NCD and NCD risk factors in slums tend to focus on individual NCDs, such as diabetes, hypertension, or overweight/obesity. (7-17) Further, most studies done in urban areas do not disaggregate the population's health data by slum and non-slum status to allow for detection of intra-urban health disparities, or even identify participants for sampling from slums. (7-17) If they do sample from these areas, researchers do not disaggregate and fail to describe this differential burden of disease.

Brazil is the largest country in South America, with an estimated 45.7 million (28.0%) of its residents residing in slums. (18) It has undergone a substantial demographic (and epidemiologic) transition over the past 30 years, with increases in both the prevalence and incidence of NCD. (1, 19-21) Previous studies have not compared the burden of disease among Brazilians living in slums to that in the general population. Here we report the findings of a survey of the prevalence of NCD and NCD risk factors among adults living in an urban slum in Salvador, Brazil and compare those prevalences with the prevalence of NCD and NCD risk factors in the general population of the same city. While this is not the same as comparisons with exclusively non-slum residents (a lack of disaggregated data make this comparison impossible), disparities in disease

burden between these two populations could reveal evidence for effect modification by residence in a slum or not, and provide observational evidence to support studies explicitly designed to compare slum populations with non-slum populations.

## **4.2. Methods**

### **4.2.1. Study Site**

In 2010, Salvador had the third largest population in Brazil (2,676,606 inhabitants), and the greatest proportion of its residents (33%) living in slums. (22) In 2003, the Centro de Pesquisas Gonçalo Moniz, Fundação Oswaldo Cruz (CPqGM- Fiocruz) established a study site in Pau da Lima, a slum community in Salvador, to conduct surveillance for acute febrile illnesses and cohort studies of leptospirosis. Of the city's estimated 882,204 slum residents, 76,532 (8.7%) reside within the Pau da Lima study site. (23, 24) Pau da Lima meets both the United Nations', and the Brazilian Census Bureau's criteria for an urban slum. (4, 22)

### **4.2.2. Data Collection and Recruitment**

In 2010, during enrollment of individuals from randomly selected households for a leptospirosis survey, (23-26) researchers collaborated with the Pau da Lima Residents Association (RA) to conduct screening for diabetes mellitus (DM), hypertension, dyslipidemia, overweight, obesity, and smoking as a benefit to participants in the leptospirosis survey. All participants eighteen and older were invited to visit the RA, while fasting, for NCD screening. At the RA they were interviewed using a standardized questionnaire, collecting information concerning self-reported height, weight, previous medical diagnoses of hypertension, diabetes mellitus, dyslipidemia, and current smoking status. Blood samples were collected in plain and sodium fluoride tubes and on the same day were transported under refrigeration to the Faculty of Pharmacy at the Federal University of Bahia, where plasma glucose, triglycerides, and cholesterol were measured.

Collaborating with the community's Health District Office, researchers arranged appointments with physicians at the local health facility for those with abnormal laboratory results, a prior diagnosis of hypertension but not on treatment, or a body mass index (BMI) greater than 25 kg/m<sup>2</sup>.

### **4.2.3. Clinical Definitions**

The BMI of all participants was calculated and categorized according to World Health Organization (WHO) guidelines as underweight (BMI < 18.5 kg/m<sup>2</sup>), normal weight (BMI ≥ 18.5 and < 25 kg/m<sup>2</sup>), overweight (BMI ≥ 25 and < 30 kg/m<sup>2</sup>), or obese (BMI ≥ 30 kg/m<sup>2</sup>), (27) Participants reported whether or not they were active smokers at the time of the interview. In this study, diabetes mellitus was defined as a one-time measured fasting plasma glucose greater than 200

mg/dl or a self-reported previous diagnosis of diabetes mellitus by a medical professional. (28) A prior diagnosis of hypertension was defined based on self-report.

Levels of low-density lipoprotein cholesterol (LDL-cholesterol), high-density lipoprotein cholesterol (HDL-cholesterol) and triglycerides were used to calculate total cholesterol per the Adult Treatment Panel (ATP) III report criteria. Dyslipidemia was defined as an LDL-cholesterol greater than 160 mg/dl, a total cholesterol above 240 mg/dl, or a self-reported previous diagnosis by a medical professional. (29)

#### **4.2.4. NCD Survey of Salvador**

To investigate how the prevalences of NCD and NCD risk factors in the Pau da Lima slum population differed from the prevalence of NCD and NCD risk factors in the overall population of Salvador we compared the prevalences of NCD among residents of Pau da Lima with the prevalences of NCDs among all residents of Salvador who participated in the 2010 Vigitel survey. This annual telephone survey interviews at least 2,000 adults (18 and older) in every Brazilian state capital. The Ministry of Health has used Vigitel since 2006 to monitor NCD in Brazil. (30) Sampling for Vigitel begins with the random selection of 5,000 landlines per city and theoretically include Pau da Lima and other slums. After screening for businesses, vacant homes, and inactive numbers, each number is called up to ten times, with interviewers randomly selecting an individual in each household, until 2,000 people are interviewed. A standardized questionnaire is used to record respondents' self-reports of previous medical diagnoses of NCD (DM, hypertension, and, as of 2013, dyslipidemia) and self-reported weight, height, and data used to evaluate risk and protective factors for NCDs. (31) Age, sex, height, weight, diabetes mellitus, hypertension, and smoking data were extracted for Salvador from the 2010 survey. (32) Vigitel began to collect data for dyslipidemia in 2013. As a result, 2013 data were used for comparisons in the present study. (33)

#### **4.2.5. Statistical Analyses**

All analyses were performed in Stata version 12.1 (Statacorp, College Station, USA). Pearson's chi-squared test was used to assess for differences between leptospirosis cohort members who did and did not participate in NCD screening. This was done to assess for possible selection bias between those who participated in the randomly selected leptospirosis study and those who chose to participate in the NCD survey. Overall, age-, and sex-specific prevalences for the surveyed Pau da Lima population and the Vigitel survey were calculated as the proportion of participants who fulfilled clinical criteria for each condition. Measurements of glucose, triglycerides, cholesterol, and creatinine for those not fasting at least nine hours prior to blood draw were excluded from analyses. (29) One participant with invalid records of height and weight was also excluded. For the surveyed population in Pau da Lima and the surveyed

population of Salvador, 95% confidence intervals (CI) of unadjusted prevalences were estimated by non-parametric bootstrap; one thousand bootstrap samples were used to estimate the standard error.

Prevalences of DM, hypertension, overweight, obesity, smoking and dyslipidemia from both the Vigitel survey and the Pau da Lima survey were age- and sex-standardized to the age and sex distributions of the city of Salvador that were reported in the 2010 Census to allow direct comparisons. (22) Sex-specific prevalences of these NCD were age-standardized, and the age-specific prevalences of all conditions were sex-standardized. The standard errors and 95% CI of adjusted rates were calculated with Keyfitz's method. (34) All comparisons between Vigitel participants and Pau da Lima in the text refer to comparisons of adjusted rates.

#### **4.2.6. Human Subject Protection**

The ethics committee at the Oswaldo Cruz Foundation, the Brazilian National Committee for Ethics in Research, and the Yale Human Research Protection Program all approved the leptospirosis cohort study. All participants provided written informed consent. The NCD and NCD risk factor survey data were not initially collected for research purposes, but as a service requested by community leaders and delivered by researchers at the Oswaldo Cruz Foundation. However, a 2014 protocol was approved by the ethics committee at the Oswaldo Cruz Foundation, granting a waiver for informed consent for the present use of these data.

The UC Berkeley Committee for the Protection of Human Subjects (CPHS) granted a waiver for the present study, as study data were completely de-identified for analysis and Berkeley personnel had no role in collection or maintenance of these data.

### **4.3. Results**

#### **4.3.1. Demographic Characteristics and Comparison of Surveyed Populations**

Of 2,331 participants in the leptospirosis cohort, 792 (34.0%) participated in the NCD survey. Those who chose to participate in the NCD survey were similar to the non-participants from the leptospirosis cohort in terms of race and education, yet had more women, were older, and significantly wealthier ( $p < 0.05$ ) (Table 1). Among the NCD survey population, 511 (64.5%) were women, with a mean age of 38.7 years.

#### **4.3.2. Prevalence of non-communicable diseases and risk factors**

Seven hundred and seventy three (97.6%) people had data available on all conditions (hypertension, DM, overweight/obesity, cholesterol, and smoking). The total number of participants varies by NCD and NCD risk factor because

some participants either did not know their status, or refused to report information on that NCD or NCD risk factor (19, 2.4%).

#### *4.3.2.1. Diabetes mellitus*

Of the 783 participants in Pau da Lima reporting information on DM or with a laboratory test result (98.9% of 792 total), 69 (8.8%) reported having previously received a diagnosis of DM (56, 81.1%), or had a measured FPG above 200 mg/dl at time of survey (13, 18.8%) (Table 2). The age- and sex-adjusted prevalence of DM was greater among residents of Pau da Lima (10.1%) than in the general population of the city of Salvador (5.2%) (Figure 1, Table 3).

#### *4.3.2.2. Hypertension*

Of the 792 participants in Pau da Lima, 189 (23.8%) reported having received a previous diagnosis of hypertension (Table 2). The age- and sex-adjusted prevalence of hypertension was roughly the same among residents of Pau da Lima (23.6%) as in the general population of Salvador (22.9%) (Figure 1, Table 3). Although women in Pau da Lima had a higher age-adjusted prevalence of hypertension (29.3%) than women in the general population (25.6%). The prevalences of hypertension were also higher among those aged 40-59 years (PDL: 35.2%; Vigitel: 30.9%) and those older than 60 years (PDL: 62.1%; Vigitel: 55.5%) who also lived in Pau da Lima than among individuals of the same age in Salvador.

#### *4.3.2.3. Dyslipidemia*

Of 781 participants living in Pau da Lima reporting information on dyslipidemia, 183 (23.4%) had dyslipidemia (Table 2). After age- and sex-adjustment, the 2013 prevalence of dyslipidemia in the whole city of Salvador was the same as the prevalence of dyslipidemia in Pau da Lima in 2010 (PDL: 21.4%; Vigitel: 21.5%) (Figure 1, Table 3).

#### *4.3.2.4. Overweight and obese*

Of 790 participants living in Pau da Lima who reported their height and weight, 387 (49.0%) were overweight or obese, and 137 (17.3%) were obese (Table 2). After adjustment, the adjusted prevalence of overweight and obesity was 46.5% among residents of Pau da Lima, compared to 40.6% among residents of Salvador. After age- and sex-adjustment, fifteen percent (15.2%) of the population in Pau da Lima was obese, compared to only 11.1% of the population of Salvador (Figure 1, Table 3). The prevalences of overweight/obesity and obesity were higher among women living in Pau da Lima than among women in the general population of Salvador. The age-adjusted prevalence of overweight/obesity among men in Pau da Lima (42.8%) was the same as the age-adjusted prevalence of overweight/obesity among men in the city of Salvador (44.1%).

In Pau da Lima, the prevalence of overweight or obesity, and obesity was higher among women (52.0% BMI  $\geq$  25, and 20.2% BMI  $\geq$  30) than among men (42.8% BMI  $\geq$  25 and 11.3% BMI  $\geq$  30). (Figure 1, Sup Table 1).

#### 4.3.2.5. *Smoking*

Among residents of Pau da Lima, 106 were smokers (13.4%) (Table 2). In Pau da Lima, almost one-fifth (18.2%) of men smoked, compared to only 9.9% of women (Figure 1, Table 3). After age- and sex-adjustment, a higher proportion of Pau da Lima's residents (14.5%) were smokers than in the city of Salvador (8.3%). The prevalence of smoking among men living in Pau da Lima (18.2%) was almost double the prevalence of smoking among men in the general population of Salvador (9.5%). Those aged 18-24 years in Pau da Lima smoked at roughly twice the frequency (9.4%, 25-39 years: 13.6%) of those aged 18-24 in the city of Salvador (4.8%; 25-39 years: 6.2%).

### 4.4 Discussion

In this survey of residents of an urban slum in Salvador, Brazil, we found higher age- and sex-adjusted prevalences of diabetes mellitus, smoking, and of being overweight or obese than among residents of the general population of Salvador. These high prevalences were mirrored in most age- and sex-specific estimates as well, with the largest differences in prevalence found between Pau da Lima's women and the city of Salvador as a whole: women in Pau da Lima were much more obese and overweight than the general population of Salvador. Women in Pau da Lima also had a higher prevalence of hypertension than men in Pau da Lima, or all women in the city of Salvador. The prevalence of smoking in Pau da Lima was twice the prevalence of smoking in the city of Salvador.

These results suggest that the prevalence of NCD in Pau da Lima is higher than in the city of Salvador, lending support to the hypothesis that the NCD disease profile of slum residents is different than that of the city as a whole. The higher prevalence of NCD and cardiovascular risk factors in this slum population suggest that as it continues to age, it will be at greater risk for major cardiovascular events, such as heart attack or stroke, than the general population.

Very few studies have investigated the prevalences of NCD among residents of urban slums, anywhere in the world (7-17, 35, 36). However, none of these studies compared the prevalences of these conditions in slums with their prevalences in a population that did not include slum residents. This is an important and necessary comparison that could reveal health disparities and support the development of policies that contribute to their mitigation.

In 2011, the World Health Organization estimated that 14.1% of the Brazilian population smoked, 40.0% had elevated blood pressure, and 18.8% were obese. (37) These prevalences are higher than those found in both Vigitel and the

present survey. One explanation for this is regional differences in NCD prevalences in Brazil (the WHO estimate country-wide), with the highest disease burden in the country's northeast, where this survey was done. (19) An important drawback of countrywide estimates like that provided by the WHO for Brazil is that they fail to capture or describe smaller-scale health inequalities (regional, urban vs. rural, or slum vs. non-slum). Another explanation for the differences in prevalences between the present survey and the WHO's are different survey methodologies. Vigitel is a telephone survey whereas WHO estimates are based on regression modeling techniques compiled from aggregate data provided by each country. The WHO estimates also use different age-categories than Vigitel; smoking prevalence in the WHO survey includes those 15 years and older, whereas Vigitel only included those older than 18 years. (37, 38)

Both the Vigitel and the Pau da Lima surveys relied on self-report. Self-reporting can bias disease estimates of disease prevalence. In the Vigitel survey, all of the NCD and NCD risk factors were self-reported, whereas the Pau da Lima survey combined self-report and laboratory measures for DM and dyslipidemia, relying on self-report for hypertension, smoking, overweight and obesity. We hypothesize that this would be a differential bias, with non-slum residents more accurately reporting their disease status due to their higher level of education, relatively better access to medical care, and higher health literacy rate. Several studies, including one in Brazil, reported that the accuracy of self-reported diabetes and hypertension diagnoses increases with increasing education (38 - 40). To date the relationship between accuracy of self-report and income or health literacy have not been evaluated in this way.

There are other limitations to this study. Sampling in the initial leptospirosis cohort was random by household, but participants in the present survey were expected to report to the resident's association. As a result, it is possible that the study suffered from self-selection bias, but as the Vigitel survey could also have suffered from this bias, comparisons between the two may still be valid. Our survey was only done in one community, Pau da Lima, possibility limiting its generalizability, however, a large proportion of the world's and Brazil's slum populations live in similar climates, with comparable rates of poverty, environmental degradation, and socio-political disenfranchisement. (4)

We only used one fasting plasma glucose reading to identify DM (supplementing these data with self-reported previous diagnoses). In doing so we identified 13 diabetics who reported never having been told by a physician that they were diabetic in Pau da Lima. The methods used to detect DM and dyslipidemia in our study (laboratory test and self-reported diagnosis) were not the same as those used in the Vigitel survey (self-report only). There may have been differential misclassification of DM and dyslipidemia status, (i.e. wealthier non-slum Vigitel participants were more likely to be diagnosed with an NCD than residents of Pau da Lima) because poverty and education reduce the accuracy of self-reported medical information. (41) This is in addition to poor access to healthcare in slums. The effect of these biases cannot be evaluated because



income, slum status, and evaluations of the quality of medical care are not part of the Vigitel survey.

Citywide telephone surveys, such as Vigitel, do not adequately sample from slums. Only 40% of the 764 surveyed households in Pau da Lima had landlines in 2010. Consequently, the general population of Salvador represented by this survey may not have included a representative proportion of slum residents (i.e. 33% of Salvador's population lives in slums, therefore 33% of Vigitel should be slum residents), and may have underestimated the burden of NCD in the overall population. Because we did not compare the Pau da Lima population with the non-slum population of Salvador, but with the general Salvador population (which includes residents of both slum and non-slum areas), the differences we report between the prevalences of NCD between slum and non-slum populations could have underestimated the extent of the differences in prevalences.

The difference in disease burden between the general population of Salvador (Vigitel) and Pau da Lima could be due to the differences in survey methodology discussed above, but may also be due to demographic differences between the two populations or differences in the physical geography of slum and non-slum areas. For example, residents of urban slums have limited access to healthcare, are less educated, are younger, and poorer than their non-slum dwelling urban counterparts. (42, 43) This could lead to relatively poorer health literacy and differences in diet. Further, the topography of slums, in addition to drug-related violence, particularly in Brazil, (44) limits access to health facilities, also leaving fewer safe spaces for exercise and play.

Importantly, cardiovascular risk is often measured using scales like the Framingham Risk Score, (45) as opposed to reporting the prevalences of NCD and NCD risk factors. Calculating these risk scores requires more detailed data (the Framingham Risk Score requires blood pressure in mmHg, the present survey only queried diagnoses - yes/no) and offers the opportunity to predict the long-term impact of these differences in NCD and NCD risk factors.

The disproportionate burden of NCD and NCD risk factors borne by slum residents may impose an enormous economic cost on the state, not only in terms of mounting healthcare costs from disease sequelae, but also in the form of an acute loss of labor from the low-income and informal economy when they become too sick to work or die. The informal economy comprises roughly 40% of the economy in middle- and low-income countries, where the majority of the global slum population also resides. (46, 47) A large portion of the construction, manufacturing, sales, and migrant workforces live in slum communities. (48) As the most prevalent age group in Pau da Lima, and other Brazilian slums is also the most active economically (those aged 18-60), (41) NCD sequelae may remove them from the workforce at an earlier age than their non-slum dwelling colleagues. This will exacerbate the cyclical nature of poverty in these communities because this population will be unable to support themselves or their families without work due to their illnesses. (47, 49)

Despite these drawbacks, the data presented here offer observational data describing the burden of NCD and NCD risk factors in slums. Additionally, it is one of the first studies to compare the burden of NCD in slums with a population that explicitly includes non-slum residents. If the relatively higher prevalences of NCD and NCD risk factors in this slum are confirmed by comparing disease burden in slums with an explicitly non-slum population, it would further underscore the lack of health investment in these communities and offer opportunities to reduce these differences in disease burden. Long-term severe sequelae due to these NCDs can hypothetically be prevented in non-slum populations with early, direct social interventions that facilitate access to healthy food and exercise, while also offering competitive economic opportunities. (50) While social interventions and individual behavioral-change models have been met with varying success outside of slums, without a comprehensive understanding of the extent of the problem, researchers and practitioners will be unable to implement interventions that reduce disease burden or evaluate the effectiveness of these interventions in slums. (51) As the global burden of NCDs increases along with the number of people living in slums, researchers must explicitly quantify and compare disease risk in slums with non-slum residents to understand the extent of these differences, and to contribute to policies that can improve health in slums. (4)

#### 4.5. References

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		NCD Survey (n: 792)	Non-NCD survey participants from original cohort (n: 1,539)	<i>p</i> -value
Female sex (%)		511 (64.5)	911 (58.1)	< 0.01
Age group (years)	18-24	128 (16.1)	309 (19.7)	0.01
	25-39	316 (39.9)	649 (41.4)	
	40-59	287 (36.2)	506 (32.3)	
	≥60	61 (7.7)	105 (6.7)	
Race	Black	436 (55.4)	861 (55.1)	0.84
	Mixed	300 (38.2)	594 (38.0)	
	Other	51 (6.5)	107 (6.9)	
Years of schooling	0-3	156 (19.7)	273 (17.4)	0.50
	4-7	227 (28.6)	484 (30.9)	
	8-13	409 (51.6)	812 (51.8)	
Daily per-capita income in 2010 US\$	<2.00	128 (17.5)	338 (23.6)	< 0.01
	2.00-3.99	213 (29.1)	518 (36.2)	
	4.00-5.99	159 (21.8)	311 (21.7)	
	≥6.00	231 (31.6)	264 (18.5)	

**Table 1:** Demographic and social characteristics of Reis et al. (2008) cohort who participated in a non-communicable disease (NCD) survey, compared to cohort participants who did not participate in NCD survey, Pau da Lima urban slum, Salvador, Brazil, 2010.

NCD and NCD risk factors	Sex						Age							
	Total		Male		Female		18-24		25-39		40-59		≥60	
	(%)	95% CI	(%)	95% CI	(%)	95% CI	(%)	95% CI	(%)	95% CI	(%)	95% CI	(%)	95% CI
Diabetes Mellitus	8.8	6.8, 10.8	9.8	6.4, 13.2	8.3	5.9, 10.7	1.6	0, 3.5	4.8	2.4, 7.2	10.6	7.1, 14.1	36.7	24.6, 48.7
Hypertension	23.8	20.8, 28.2	19.9	15.3, 24.6	26.0	22.3, 29.8	2.3	0.0, 4.7	14.2	10.3, 18.2	35.9	30.2, 41.6	62.3	49.8, 74.8
Dyslipidemia*	23.4	20.4, 26.5	17.2	12.8, 21.6	26.8	22.9, 30.7	6.3	2.2, 10.5	14.7	10.7, 18.7	33.1	27.8, 38.4	59.0	46.8, 71.3
Overweight or obese**	49.0	45.5, 52.5	43.4	37.6, 49.2	52.1	47.8, 56.5	23.5	13.8, 33.2	51.0	44.0, 58.1	60.1	54.0, 67.6	48.7	33.1, 64.4
Obese***	17.3	14.8, 19.9	10.7	7.2, 14.2	21.0	17.8, 24.2	5.9	0.3, 11.4	13.4	8.7, 18.1	12.4	7.7, 17.1	12.8	2.4, 23.2
Active smoker	13.4	11.1, 15.7	18.1	13.7, 22.6	10.8	8.2, 13.5	8.6	3.8, 13.4	12.7	8.9, 16.4	16.7	12.3-21.1	11.5	3.3-19.6

\* Dyslipidemia estimates from 2013 used, not reported in Vigitel until 2013.

\*\* Overweight or obese defined as a BMI  $\geq$  25kg/m<sup>2</sup>.

\*\*\* Obese defined as a BMI  $\geq$  30kg/m<sup>2</sup>.

**Table 2:** Unadjusted total, sex-, and age-specific prevalences of non-communicable diseases (NCD) and NCD risk factors in Pau da Lima, Salvador, Brazil, 2010



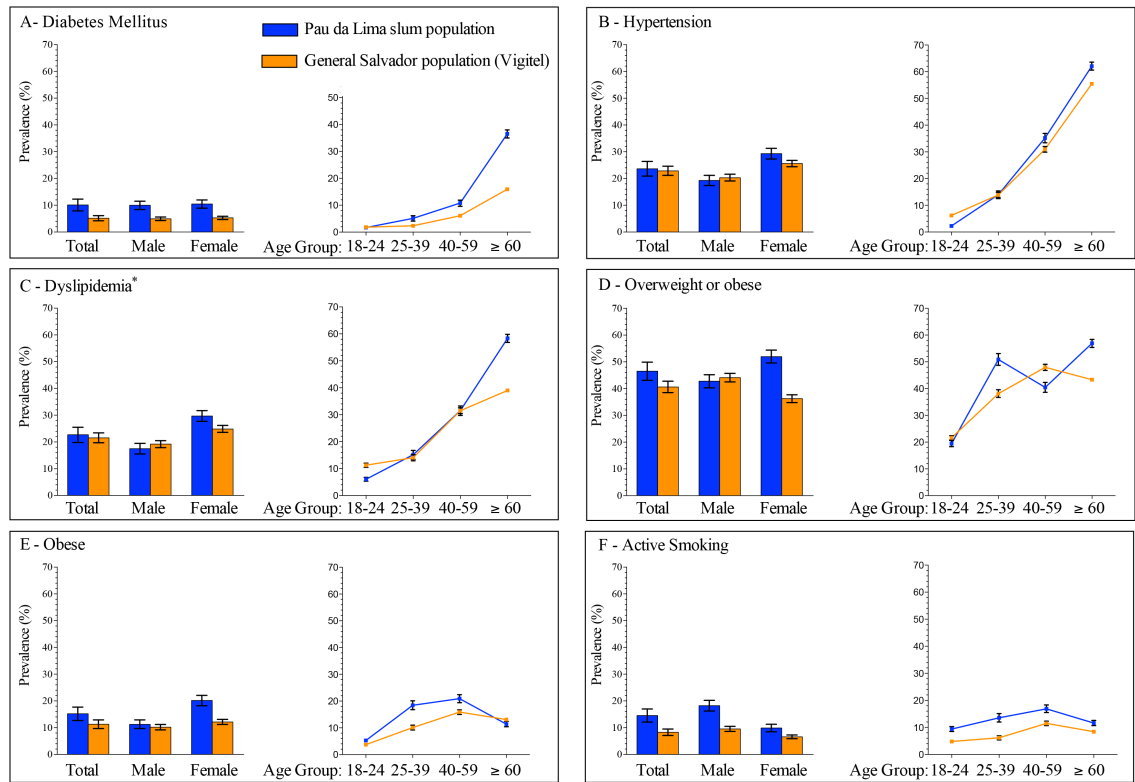
NCD and NCD risk factors	Population	Total		Sex		Age									
		(% )	95% CI	Male (%)	Female (%)	18-24		25-39		40-59		≥60 (%)			
						(%)	95% CI	(%)	95% CI	(%)	95% CI		(%)	95% CI	
Diabetes Mellitus	Pau da Lima	10.1	7.9, 12.3	10.0	8.4, 11.5	10.45	8.9, 12.0	1.7	1.3, 2.1	5.1	4.1, 6.1	10.8	9.6, 11.9	36.5	35.0, 38.0
	Vigitel	5.2	4.2, 6.1	5.0	4.3, 5.6	5.3	4.7, 5.9	1.8	1.6, 2.1	2.4	1.9, 2.8	6.1	5.5, 6.7	15.9	15.5, 16.4
Hypertension	Pau da Lima	23.6	20.9, 26.4	19.3	17.4, 21.2	29.3	27.3, 31.3	2.3	1.9, 2.7	13.9	12.5, 15.4	35.2	33.4, 36.9	62.1	60.6, 63.6
	Vigitel	22.9	21.2, 24.6	20.3	19.1, 21.6	25.6	24.4, 26.8	6.2	5.7, 6.7	13.9	12.9, 14.9	30.9	29.9, 32.0	55.5	54.8, 56.1
Dyslipidemia*	Pau da Lima	22.7	19.8, 25.5	17.5	15.5, 19.5	29.7	27.7, 31.7	6.0	5.3, 6.7	15.1	13.4, 16.7	31.5	29.7, 33.2	58.3	56.8, 59.8
	Vigitel	21.5	19.7, 23.4	19.2	17.9, 20.5	24.9	23.6, 26.2	11.3	10.5, 12	14.1	12.9, 15.2	31.5	30.4, 32.6	39.0	38.5, 39.6
Overweight or obesity**	Pau da Lima	46.5	43.1, 49.9	42.8	40.3, 45.2	52.0	49.6, 54.4	19.4	18.3, 20.6	50.9	48.7, 53.1	40.5	38.6, 42.3	56.9	55.4, 58.4
	Vigitel	40.6	38.5, 42.8	44.1	42.5, 45.7	36.3	34.8, 37.7	21.6	20.8, 22.4	38.1	36.7, 39.6	47.9	46.8, 49.1	43.3	42.7, 44
Obesity***	Pau da Lima	15.2	12.7, 17.7	11.3	9.7, 12.9	20.2	18.2, 22.1	5.3	4.6, 5.9	18.4	16.8, 20.1	20.9	19.4, 22.4	11.4	10.4, 12.4
	Vigitel	11.1	9.3, 12.9	10.2	9.2, 11.2	12.1	11.2, 13.1	3.7	3.3, 4.1	10.1	9.2, 11	15.9	15.0, 16.7	13.1	12.7, 13.5
Active smoker	Pau da Lima	14.5	12.1, 17	18.2	16.2, 20.2	9.9	8.5, 11.3	9.4	8.5, 10.3	13.6	12, 15.1	16.9	15.5, 18.3	11.6	10.6, 12.6
	Vigitel	8.3	7.1, 9.5	9.5	8.6, 10.5	6.6	5.9, 7.3	4.8	4.4, 5.2	6.2	5.4, 6.9	11.5	10.7, 12.3	8.4	8.1, 8.8

\* Dyslipidemia estimates from 2013 used, not reported in Vigitel until 2013.

\*\* Overweight or obesity defined as a BMI  $\geq$  25kg/m<sup>2</sup>.

\*\*\* Obesity defined as a BMI  $\geq$  30kg/m<sup>2</sup>.

**Table 3:** Age- and sex-adjusted total, sex-adjusted age-specific, and age-adjusted sex-specific prevalences of non-communicable diseases and non-communicable disease risk factors in Pau da Lima, Salvador, Brazil, 2010 and in respondents to the 2010 Vigitel telephone survey in Salvador.



**Figure 1:** Prevalences of non-communicable diseases and non-communicable disease risk factors, Salvador, Brazil, 2010.

Populations include Pau da Lima, Salvador, Brazil, 2010 and the 2010 Vigitel telephone survey of the general population of Salvador, Brazil. A) Prevalence of diabetes mellitus (self-report of previous physician diagnosis or one-time fasting plasma glucose (FPG)  $\geq 200$ ); B) prevalence of hypertension (self-reported previous medical diagnosis); C) prevalence of dyslipidemia (low-density lipoprotein cholesterol (LDL-cholesterol) greater than 160 mg/dl or total cholesterol greater than 240 mg/dl or self-reported previous physician diagnosis)\*; D) prevalence of overweight or obesity (body mass index (BMI)  $\geq 25$  kg/m<sup>2</sup>); E) prevalence of obesity (BMI  $\geq 30$  kg/m<sup>2</sup>); and F) prevalence of active smoking (self-reported). Total prevalence was adjusted for age and sex, sex-specific prevalence was adjusted for age, and age-specific prevalence was adjusted for sex. All adjustments were made to the age and sex profiles of the city of Salvador, Brazil reported in the 2010 Census.

\* Dyslipidemia estimates for the general population of Salvador are from 2013, as it was not reported in prior Vigitel surveys.

## Chapter 5 - Conclusions

### 5.1 – Summary

This dissertation sought to bring awareness to health disparities between residents of urban slums and non-slum residents and to explore methods for the comparison of disease burden between these two populations. It uses Brazil as an illustrative example of the differences in social and biological determinants of health, non-communicable disease (NCD), and treatment of a communicable disease (tuberculosis) between slums and either non-slum populations, or the general population of the same city where the sampling of the slum population was done. Taken together, the chapters demonstrate the extent of the health inequities in Brazilian slums, (systematic, avoidable health inequalities between groups of people that are socially produced). (1) The long-term effect of these inequities could have a significant economic, social, political, and cultural impact both inside and outside of slums.

This dissertation explored several different dimensions of health disparities inside and outside of Brazilian slums. The findings suggest that there are differences in the physical, socio-economic, and biological risk factors for disease inside and outside of slums (Chapter 2), as well as inequalities in NCD prevalence (Chapter 4). It also assessed the impact of an intervention (directly observed treatment for tuberculosis patients) that, if applied elsewhere could contribute to the mitigation of some of these inequalities in disease burden (Chapter 3). In sum, these chapters offer cursory and non-causal (observational) evidence to support the assertion that residents of slums bear a disproportionate burden of disease and its determinants.

However, this dissertation only describes work that has already been completed. It fails to account for ongoing primary data collection in Brazil, which I continue to oversee, and my other work describing the burden of disease in slums. (2-5) These ongoing studies include 1) a study contrasting the burden of disease due to diabetes mellitus inside and outside of urban slums in Niterói, a city in the State of Rio de Janeiro, Brazil, 2) a comparison of the antibiotic resistance profiles and molecular epidemiology of *Staphylococcus aureus* strains isolates from the nares of healthy individuals in the same population as above, and 3) a comparison of the antibiotic resistance profiles and molecular epidemiology of uropathogenic *Escherichia coli* isolates that do and do not cause recurrent urinary tract infections, again in the same populations.

Arguably of greater importance, this dissertation also fails to account for the action-oriented participatory work we do in parallel with our primary data collection. A description of the results from this work and the theoretical framework underpinning the process are currently under review for a publication in Portuguese (to be simultaneously published in English). This paper was submitted to a Brazilian journal in Portuguese, with the intention of making it

more accessible to health professionals in Brazil and also of raising the profile of a journal published by The Federal University of Fluminense (Universidade Federal Fluminense), where our Brazilian collaborators are based.

Following is brief a summary of findings from each chapter and final thoughts on the importance of conducting participatory research with slum residents, highlighting the benefits (epidemiologic, public health, and community engagement) of engaging slum communities in the research process.

## **5.2 – Comparing the Burden of Social and Spatial Determinants of Health Inside and Outside of Rio de Janeiro’s Slums**

This study was the first citywide comparison of demographic and social characteristics between slum and non-slum communities anywhere in Brazil. (6) The data for this analysis were drawn from the first systematic, nationwide census of slums worldwide, the 2010 Brazilian Census. (7) We found that 22% of residents of Rio de Janeiro lived in informal settlements, termed *aglomerados subnormais* (AGSN). In Rio in 2010, AGSN residents were younger, poorer, and had less access to safe water, sanitation, and electricity than non-AGSN residents. The data described in this chapter highlight important differences in well-described social and spatial determinants of health, setting the tone for the pursuant chapters to explore the effects of these inequalities on the health and wellbeing of slum residents.

## **5.3 – Seeking Solutions to the Unequal Burden of Communicable Diseases in the Slums of Rio**

While chapter two highlighted disparities in health determinants, Chapter 3 highlighted tuberculosis (TB) as an example of how different treatment routines are differentially effective inside and outside of Rio de Janeiro’s slums. While there have been prior studies describing the impact of disease interventions inside of slums, (8-11) to our knowledge this was the first analysis to compare the results of a treatment program, especially one as widely used as the directly observed treatment program (DOT) for TB, between residents of slum and non-slum areas of the same city. Using census tracts from the 2010 Census, we geocoded every single reported TB case in Rio de Janeiro in 2010 (excluding homeless and incarcerated populations) to slum and non-slum census tracts.

TB drugs are available free of charge to everyone diagnosed with the disease in Brazil, yet Brazil remains one of twenty-two World Health Organization’s high burden countries. (12) Many determinants of TB are social, (13) and there may be a link between the differential distribution of social and spatial health determinants in urban slums in Rio described in Chapter 2, and the results describing the effectiveness of the DOT TB program in slums presented in Chapter 3. These findings must be further examined across multiple years of data, and different cities. This is particularly important because in 2010 the

greatest TB burden in Rio de Janeiro was among those aged 20-39; (4) prime years for reproduction and economic earning potential. Continuing to disaggregate the Brazilian TB Database by slum and non-slum residents would offer more conclusive evidence that DOT can be used to improve the prospects of those diagnosed with TB in Brazilian slums. Ideally, future analyses like this will be regularly implemented into national and local disease surveillance systems.

#### **5.4 – Observational Evidence for a Higher Burden of Non-communicable Diseases and Non-communicable Disease Risk Factors in the Urban Slums of Salvador, Brazil**

The well-documented increase in the global burden of NCD is evident in Brazil; the NCD burden has increased by 170% since 1990. (14-15) The World Health Organization (WHO) has described the vicious cycle whereby poverty increases the incidence of NCDs, while NCDs and their risk factors exacerbate poverty. (16) Chapter 4 compared the prevalences of NCD (i.e. DM, hypertension, and dyslipidemia) and several risk factors (i.e. smoking, overweight, and obesity) among residents of an urban slum in Salvador, with those participating in a citywide survey.

The age- and sex- adjusted prevalences were similar in the two populations for hypertension, and for dyslipidemia. However, slum residents had higher age- and sex- adjusted prevalences of DM and of overweight/obesity and of obesity than participants in the citywide survey. The prevalence of smoking among slum residents was twice as high as the prevalence of smoking in the citywide survey. These results have major implications for the future healthcare burden of the NCD that result from disparities in risk factors, and the resultant sequelae from the disproportionate DM burden borne by slum residents.

Because these comparisons were done between a specific population in one slum in Salvador, and the city of Salvador as a whole, there are important limitations, some of which we describe in Chapter 4.

#### **5.5 – Final Considerations**

The observational studies described in this dissertation are not intended to demonstrate causal relationships between risk factors, disease, treatment mechanisms, and slum residence. Causal evidence for this would require the coordinated efforts of federal and local governments, the likes of which has not been done before. The informality, lack of visibility, and marginalization of slum residents render this type of study extremely difficult. Further, by definition, slum residents experience reduced access to healthcare, with their insecure residential status complicating any epidemiologic sampling frame or follow-up.

The question of whether or not slums are simply concentrated areas of urban poverty, or if residents of slums are at greater risk for disease than residents of non-slum areas can only be answered with a randomized-control trial (RCT). Obviously this would be unethical, but evaluations of randomly implemented slum-upgrading programs could help identify specific characteristics of slums that contribute to this differential disease burden. However, reducing the argument to epidemiologic causal inference may circumvent the actual problem of the fact that slum populations are, and will continue to be sicker than non-slum populations, limiting our ability to improve the health of these populations. That is to say, even if slums are concentrated areas of urban poverty, we have very little data describing the burden of disease or risk factors for disease among slum populations. How can any interventions or policies be developed if we are completely ignorant of the spectrum of disease in these communities? Slums comprise one-seventh of the global population, and without data describing the burden of risk factors for disease and the burden of disease, or by failing to disaggregate disease data by residence in slum versus non-slum areas, policy-makers and health practitioners would be unable to improve the health of these populations.

The relative wealth of Brazil (and even Rio de Janeiro) is an important consideration when describing the generalizability of these results to other slums in Brazil and other slums elsewhere in the world. Brazil was recently re-classified as an 'upper-middle income' country by the World Bank, and despite its recent economic turmoil and threats of erosion of their universal healthcare program, healthcare has been enshrined as a right in the Brazilian Constitution since its ratification in 1988. (17) Brazil's Single Health System (Sistema Único de Saúde-SUS) is implicitly designed to address the needs of slum populations. The implementation of the program in Niterói (the city which provided a model for the nationwide implementation of SUS) is such that there is a health post (the primary unit for healthcare in SUS) in most informal settlements in this city. While implementation has been sporadic and incomplete across the country (particularly in Rio de Janeiro), the fact remains that Brazil has a relatively (to poorer countries) robust health system for slum dwellers where access to healthcare is at least, theoretically, possible. Many other countries that offer 'universal' healthcare do not have this progressive slum-based implementation, let alone countries without any healthcare guarantees.

I do not argue that all slums suffer from the same health determinants or disease profiles, but, that given the results from this dissertation, what we know about slums, and the relationship between disease and poverty that national, state, and local governments, as well as their ministries' of health should consider living in a slum as a specific risk factor for disease, conducting careful epidemiologic analyses that can be used to develop targeted interventions specifically to improve the health of their slum populations.

## **5.6 Future Considerations in Slum Health Research**

The goal of research in public health is to improve the health and quality of life of populations. However, when research is done in such a way that it fails to integrate itself into the day-to-day lives of the populations involved, the researchers, as experts, appropriate the knowledge of the participants, treating them as mere data points. This corrupts results and does not encourage the development of a healthy state of being or improve health. Generally, after the dust has settled and data have been collected, researchers have offered little in return to the populations under study, aside from a vague promise of having 'contributed to scientific knowledge'. Due to their lack of access to healthcare, this form of exploitation takes on new meaning in slums. For example, contact with an epidemiologic data collector may be an individual's only contact with anyone interested in discussing his or her health and wellbeing. While most epidemiologists are not clinicians, if no mechanism exists to incorporate research findings into practice in this population, the researcher must make efforts to do so.

In making this assertion, I do not deny the very important contributions and medical advances that have been achieved by doing research in a more traditional mold, but defend the idea that the participation of social actors brings new meaning to and improves the diversity of interventions, particularly in slums. Participatory research requires stakeholders to engage in bidirectional dialogue that simultaneously enriches the research process and also increases the opportunities for positive health outcomes.

Paulo Freire argues, "...I cannot reduce these popular groups to mere objects of my research. I simply cannot understand the reality in which they live other than by understanding it with them as an additional subject of this knowledge, being for them, an understanding of previous knowledge (what happens at the level of everyday experiences), as it turns into new knowledge." (18) Relying on Freirean theory is important for the implementation of this kind of participatory research, particularly in slums.

In 2014 with this in mind, we undertook a study to evaluate the burden of DM in the urban slum of Morro do Preventório, a slum community located in the city of Niterói, Brazil. Over the course of this project, we have been committed to engaging the population. Initially we created pamphlets in Portuguese and distributed them during biweekly educational meetings, after conversations with residents about our research. However, during an interview with an elderly diabetic woman at the primary health center where we collect our data, she off-handedly mentioned that she appreciated asking her *daughter* to read the literature we distributed. Then, it hit me, "We're working with an *elderly, diabetic, slum* population." Even after working in slums for six years, I was still naïve to their reality; in Brazilian slums, most elderly residents never went to school,

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\* Original translation from the Portuguese by the author

leaving at an early age to work even if they did. Therefore, some never learned to read. In addition, diabetics, especially those with limited healthcare over an extended period of time (as is common in slums), are at greater risk for chronic end-stage eye sequelae that limit their ability to read. We had failed completely in engaging our target population. Reviewing our data, we found that 33% (n = 111) were either illiterate (33, 8.9%), or had completed less than the American equivalent of fourth grade (78, 21.0%). Beyond that, an additional 67 (18.5%) had been diagnosed with at least one degenerative eye disease (retinopathy, glaucoma, or cataracts) that rendered reading difficult or impossible.

Because we were committed to engaging our population in the research process, and hoped to produce a good that could be used to improve their health, we met with community leaders and healthcare professionals to develop a samba music video and song (audio-visual to overcome sight/literacy problems, and a samba to reach the elderly population). The resulting product was a video describing an elderly woman with pre-diabetes and how she engaged with her health professionals, neighbors, and friends (her fictional composite character had several clinical indicators that she was at risk for developing diabetes), and how she helped herself avoid DM, also spreading the message to her friends and colleagues.<sup>†</sup> We developed the message, music and recommended foods with, and based on, the realities of this particular community. The process was far from perfect, but we are committed to continuing to work with the residents, community leaders, and health professionals in this community.

Our demonstration of a commitment and responsiveness to community concerns, as well as the open, transparent and accessible channels for communication increased community engagement with our research process. Doing so has helped us identify new topics to explore (e.g. food insecurity), and nuanced hypotheses for testing, also facilitating the application of these findings to improve population health. This commitment also had overt benefits for our epidemiologic research. The next iteration of sampling (2016 Summer field season) is less biased (residents trusted us more and are more open and honest during surveying), facilitating our access to this marginalized population. Most importantly, our accountability to the populations studied has helped us understand the local context of disease and will facilitate these data's use for advocacy and policy purposes (by residents, coordinators of the city's health program, and scientists). The resulting health literacy (via participation in the research process) also holds promise for improving health outcomes in our study population. In sum, conducting research in this way in slums is absolutely essential.

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<sup>†</sup> Video available at: <https://www.youtube.com/watch?v=p80BNySqgk>



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