An Ecological Analysis of Predictors of Hospitalizations for Primary Care Sensitive Conditions under Brazil's Family Health Strategy

by

Adriana Lein

Duke Global Health Institute
Duke University

Date:_______________________
Approved:

____
João Vissoci, Co-Chair

____
Catherine Staton, Co-Chair

____
Eric Green

A thesis submitted in partial
fulfillment of the requirements for the degree
of Master of Science in the Duke Global Health Institute
in the Graduate School of
Duke University

2017

ABSTRACT

An Ecological Analysis of Predictors of Hospitalizations for Primary Care Sensitive

Conditions in Brazil's Unified Health System

by

Adriana Lein

Duke Global Health Institute
Duke University

Date:________________________
Approved:

____
João Vissoci, Co-Chair

____
Catherine Staton, Co-Chair

____
Eric Green

____

An abstract of a thesis submitted in partial
fulfillment of the requirements for the degree
of Master of Science in the Duke Global Health Institute
in the Graduate School of
Duke University

2017

Abstract

Background: Primary care sensitive conditions (PCSC), a classification of illnesses that includes noncommunicable diseases (NCDs) and maternal health complications, are considered preventable through appropriate care management and interventions at the primary care (PC) level. Consistent with trends in global disease burden, PCSC are a significant contributor to avoidable hospitalizations in low and middle income countries (LMIC), which carries profound social and economic consequences. Rates of hospitalizations for primary care sensitive conditions (HPCSC) have been found to be associated with the level of infrastructure of health services delivery, health system, and socioeconomic context. This study concentrates on the Brazilian state of Minas Gerais to evaluate the current profile of HPCSC and their predictors under the universal PC program, the Family Health Strategy (FHS).

Methods: This is an ecological study based on: 1) data of PC infrastructure from 560 municipalities, collected from 2012-2013 through the *Programa Nacional de Melhoria do Acesso e da Qualidade da Atenção Básica* (PMAQ-AB), 2) data on rates of HPCSC available in the Hospital Information System of the Unified Health System, and 3) data on health system and socioeconomic indicators from the Brazilian Ministry of Health and the Brazilian Institute for Geography and Statistics, respectively. For the analysis, 7 groups of PCSC specifically targeted under the FHS were considered. 24 structure and process indicators were selected from the PMAQ-AB database and a principal component analysis with factor interpretability was performed, utilizing the theoretical rationale of the *Starfield Model of Primary Care*, to reduce and describe data dimensionality. Principal component scores were averaged by municipality, and assessed as predictors of HPCSC across municipalities in multiple regression models both individually and progressively adjusting for health system and socioeconomic variables as groups.

Results: From January-December 2012, municipalities in our sample experienced 12,078 HPCSC due to the 7 conditions chosen, with an aggregate age-adjusted rate of 112.15 per 10,000 inhabitants. The NCDs of congestive heart failure, cerebrovascular diseases, and diabetes mellitus collectively accounted for 87.56% of all hospitalizations. The best-fitting principal component model of infrastructure data consisted of 3 components that corresponded to the level of adequacy of care comprehensiveness, continuity, and coordination. In the fully-adjusted models, the strongest predictors of HPCSC per 10,000 were continuity (β= 12.44) for heart failure, comprehensiveness (β= -3.09) for cerebrovascular diseases, continuity (β= 1.45) for diabetes, continuity (β= .92) for skin and subcutaneous tissue infections, comprehensives e (β=.99) for female pelvic inflammatory diseases, and continuity (β=.74) for prenatal and postpartum conditions.

Conclusions: NCDs heavily influence incidences of avoidable hospitalizations in Minas Gerais, Brazil. Yet, our findings suggest that the community-based care models of the FHS may have the potential to mitigate the role of social vulnerability in influencing

health outcomes. This project offers a model for quantifying the quality of PC infrastructure and more research is needed to validate its use in LMIC, as well as to further understand the strength and directionality of the relationship between health center, health system, and socioeconomic predictors of HPCSC.

Dedication

To Ana Flávia, for the next chapters we will write together.

Contents

List of Tables

List of Figures

Acknowledgements

I would like to thank Duke University's Dr. João Vissoci and Dr. Catherine Staton for your invaluable support, mentorship, and the opportunities to develop as a researcher. I would also like to thank Thiago Rocha and Dante Almeida of the Federal University of Minas Gerais for your guidance during the project's fieldwork component and statistical training provided.

1. Introduction

Primary care sensitive conditions (PCSC), illnesses or complications considered avoidable through appropriate primary care (PC) level interventions, such as screenings to assess risk factors for disease or patient education to promote behavior modifications, remain significant contributors to global mortality and morbidity [1]. In *The Global Burden of Disease Study 2013*, cardiovascular and circulatory diseases, two PCSC, ranked second among leading causes of age-standardized mortality, contributing to 23.48 deaths per 10,000 people [2]. Worldwide, approximately 82% of premature deaths from noncommunicable diseases (NCDs) occur in low and middle income countries (LMIC), and as many as 80% of these 13 million deaths are considered preventable by targeting risk factors at the PC level [3]. Hospitalizations for primary care sensitive conditions (HPCSC) are an accepted outcome indicator of the quality of PC preventative services [4-6]. Literature from high income countries has found disparities in the burden of HPCSC associated with the quality of service delivery in health centers, namely structure and process dimensions, and population-level predictors related to health system resources and socioeconomic demographics [6-12]. However, more research is needed in LMIC to better understand predictors of HPCSC and the relationship between predictors at the levels of health centers, health systems, and socioeconomic contexts.

In Brazil, targeting PCSC was made a priority in reforms of the Family Health Strategy (FHS) in 2006 to include measures focused on disease prevention and health promotion through household visits by community health workers and considerations of social vulnerability [13-14]. As Brazil's main PC policy, the FHS has successfully expanded access to health services through a community-based approach that assigns multidisciplinary family health teams to operate out of primary care units (PCU) assigned to geographic boundaries, known as micro-regions of health [13-14]. The FHS was developed with the objective of addressing regional and socioeconomic disparities in health outcomes and has been particularly instrumental in increasing PC coverage in the less-developed Northeast region and rural areas [15]. As of 2016, the FHS is active in approximately 98% of Brazil's 5,570 municipalities (5,463) and covers 63.85% of the total population [16]. In 2008, The Ministry of Health released a list of 20 classifications of PCSC, corresponding to 74 diagnoses [17]. These classifications guide epidemiological surveillance efforts and HPCSC are recorded in the Hospital Information System [17]. Nationally, Brazil experiences 142 HPCSC per 10,000 inhabitants, constituting approximately 27% of total hospitalizations [18].

1.1 Primary care in the Unified Health System

The Unified Health System (SUS) is an administrative entity that serves as the principal steward for Brazil's public and private health systems and has provided a universal healthcare scheme for the population since 1990. SUS is the sole health care provider for an estimated 75-79% of the population, with the remaining segment having access to individual or employer purchased private plans [19-20]. In the two decades following its implementation, SUS has undergone a series of reforms, the most instrumental of which being the decentralization of health system management to states and municipalities [20-21]. The delivery of health services within SUS is organized under a three-level integrative model consisting of primary, specialized, and high complexity care [21]. An emphasis on PC has been the hallmark strategy utilized by SUS to support universal health care access, achieved through the FHS [19-21].

1.2 Health center predictors

PC is a main platform for health services delivery in LMIC and often marks patients' initial and only contact with the health systems; in the case of Brazil, this is realized through community-based PCU [22-23]. Literature on quality of care at the level of health centers favors the Donabedian model that conceptualizes quality as a function of the structure and process dimensions of service delivery [24-25]. The structure dimension encompasses physical infrastructure, including facility conditions and accessibility, and the adequateness and availability of equipment, technology, and medications. The process dimension denotes the technical actions of physicians and care providers to promote health, from patient education and prevention of disease, to diagnosis, treatment, and follow-up [26].

One study of 615 Brazilian municipalities with more than 50,000 inhabitants observed a significant negative association between the quantity of medical equipment per capita (electrocardiogram and endoscopic technologies) and HPCSC, when adjusting for socioeconomic variables and physician supply [27]. However, the association did not remain significant for all types of medical equipment assessed nor for all regions of Brazil [27]. Studies of this nature are scarce given the lack of systematized data on structure and process dimensions of service delivery at the level of health centers prior to the inception of the *Programa Nacional de Melhoria do Acesso e da Qualidade da Atenção Básica* (PMAQ-AB) in 2012 [28]. PMAQ-AB is an ongoing external diagnostic census of PCU undertaken by the Ministry of Health that aims to evaluate structure and process dimensions of quality to incentivize adherence to care protocols and inform policy changes [28]. Thus, there is a need to both identify predictors of HPCSC at the level of health centers and examine their relationship to broader health system and socioeconomic factors.

1.3 Health system predictors

At the level of the health system, the indicator of population insurance coverage has been found to be a predictor of HPCSC [29-30]. In Brazil, studies show varied results as to the association between FHS coverage and HPCSC. A study of all 26 states and federal district of Brasília found a significant negative association between FHS coverage and HPCSC in 38.4% of the analyzed units, suggesting that latent variables may be influencing the association [18]. The relationship between physician supply, most commonly measured in terms of physicians per capita, and HPCSC has also been assessed without finding a significant association [7-8]. Distinct from the quantity of physicians per capita, the proportion of primary care physicians out of all physicians in a geographic area has been found to be significantly negatively associated with HPCSC [31]. Further, one study from Brazil found a significant positive association between investment in PC and HPCSC [32]. Existing literature tends to be biased towards urban areas or capital cities, underscoring the need for studies involving smaller and more rural municipalities whose different demographic profiles pose challenges for health systems [27, 33].

1.4 Socioeconomic predictors

Socioeconomic status has been identified to be a predictor of HPCSC [9-10, 34]. Previous studies conducted in Brazil and internationally provide evidence of lower socioeconomic status being associated with higher rates of HPCSC [9-10, 34-35]. The components of socioeconomic status of education and income at the level of cities, districts, and patients have been found to be independent predictors of HPCSC [9-10,34]. A study in the Southern city of Porto Alegre found a significant negative association between years of patient education and rates of HPCSC [35].

Similarly, the largest scale study to date in Brazil of data from 60 million public sector hospitalizations spanning 5,564 municipalities found municipality literacy rates to be a significant negative predictor of changes in HPCSC [36]. International literature also documents a significant negative association between income and HPCSC at the level of cities and districts [36]. Studies from high-income countries have concluded that a lower mean household income is significantly associated with higher rates of HPCSC [8-10]. In high income countries, Gross Domestic Product (GDP) per capita has also been found to be significantly negatively associated with HPCSC in the case of NCDs [37].

1.5 Study aims

This study aims to: 1) identify the current burden and profile of HPCSC in Minas Gerais, Brazil, 2) measure and describe the formed latent structure of PC infrastructure data, and 3) evaluate the association between PC data, health system variables, and socioeconomic variables and rates of HPCSC.

2. Methods

This ecological study examines the relationship between health center, health system, and socioeconomic predictors of HPCSC in the Brazilian state of Minas Gerais. Municipalities (n=560) are the unit of analysis. Municipalities are an appropriate unit of analysis for identifying predictors in variations of rates of HPCSC as SUS designates PC administration to municipalities [21]. Thus, the operation of PCU occurs within the health system and socioeconomic contexts of municipalities.

2.1 Setting

This project is set in Minas Gerais, a state in the Southeast region of Brazil with a population estimated at 20,997,560 as of 2016 [38]. Collaboration for this project is undertaken with the School of Economic Sciences of the Federal University of Minas Gerais. Minas Gerais has the third largest GDP of Brazilian states behind Rio de Janeiro and São Paulo [39]. The 853 municipalities of Minas Gerais constitute 15.5% of total municipalities in Brazil. Most research on population health outcomes in Brazil has been confined to metropolitan areas with populations of 50,000 or greater, overlooking the situations of less populated municipalities [27]. Yet, less populated and rural areas experience distinct challenges in Brazil, including greater rates of extreme poverty and lack of human resources and infrastructure for health, that render their study particularly important to highlight gaps in coverage to inform a more responsive health system [39]. Minas Gerais is appropriate setting for an ecological study as 786 (92%) of its total municipalities have less than 50,000 inhabitants, although they have a collective population of 8,439,520 [40]. Thus, research in Minas Gerais has the potential to contribute much needed understanding on predictors of HPCSC in currently underserved populations.

2.2 Procedures

2.2.1 Selection of municipalities

All municipalities in the state of Minas Gerais with at least one PCU that participated in Modules 1 and 2 of the first cycle of PMAQ-AB (2012-2013) of the Brazilian Ministry of Health were eligible for inclusion in the study. Inclusion was also contingent upon complete responses to chosen structure and process variables, as incomplete information was determined to be missing not at random and therefore imputation strategies were likely to introduce biased estimates [41]. Municipalities with only smaller neighborhood posts and specialized posts were excluded to maintain internal validity. From these criteria 593 municipalities were selected, containing a total of 2,044 PCU.

2.2.2 Data sources

Variables related to health center infrastructure were extracted from the PMAQ-AB database, through a systematic approach used for the development of quality indicators in PC known as the RAND appropriateness method [42]. The RAND method is a combination of expert opinion and a literature review to reach consensus based on predetermined criteria [41]. Utilizing the *Core Dimensions of Primary Care*, three researchers from Duke University and the Federal University of Minas Gerais independently selected indicators from the PMAQ-AB External Evaluation Manual from Module 1 (structure) and Module 2 (process) [43-44]. Indicators that were agreed upon by all three researchers where then chosen for inclusion. In total, a consensus was reached around 24 infrastructure variables (10 structure and 14 process). The PMAQ-AB data collection instrument relies on Likert-type scale items (Yes= 1, No=2, or Always =1, Sometimes = 2, Never =3), and resulting scores are interpreted within Brazil as measures of inadequacy of infrastructure [44]. Thus, a higher score denotes a higher level of inadequacy of infrastructure.

Based on a review of international literature on predictors of HPCSC published in English, Portuguese, and Spanish, the indicators of FHS coverage, the percentage of physicians in primary care, and PC investment per municipality were selected to correspond to the health system, and indicators of GDP, the illiteracy rate, unemployment rate, and individual monthly household income per were selected to correspond to the socioeconomic context. Although physician supply per capita is the most common metric used in the literature, under the Brazilian health care network, physician supply is heavily skewed towards urban areas where hospitals and other specialized health centers, whether public or private, are concentrated [45]. However, the FHS was intended to increase PC coverage in rural and less developed areas where a greater proportion of the population relies upon the public system, and the percentage of physicians in primary care is a more telling measure of the composition of a municipality's health system that is appropriate for our research objectives [15].

Variables selected for the health system and socioeconomic contexts were downloaded from seven publically-accessible databases of the Brazilian Ministry of Health and the Brazilian Institute for Geography and Statistics (**Figure 1**). Data were retrieved online, downloaded as comma-separated value (csv) files, and transferred to RStudio Version 0.99.893 for management and analysis.

Data on the outcome variable of HPCSC were downloaded from the Hospital Information System of SUS (*Sistema de Informações Hospitalares do SUS*). The Brazilian government utilizes a classification system of 20 groups of diseases considered to be PCSC adapted from the ICD-10 and maintains records of public hospitalizations due to PCSC [17]. Data on hospitalizations that occurred in the state of Minas Gerais from January-December 2012 were downloaded. Data were available per month and downloadable as database container (dbc) files. Data were then converted to database (dbf) files and transferred to RStudio, Version 0.99.893 using the package csapAIH designed to aggregate data on HPCSC from the Hospital Information System by year. HPCSC corresponding to 7 groups of conditions were selected **(Figure 2**) as they align with the target areas of the health promotion and prevention efforts of the FHS [44]. These HPCSC were then aggregated by group, municipality of patient's residence, and the age categories of 15-49 and 50+, as is common in the literature from within Brazil [46]. Pediatric PCSC are addressed in separate programs of the FHS and were therefore outside the scope of this study [44]. HPCSC were then standardized to adjust for population and municipality age structure using the direct standardization approach [47].

Indicator	**Source**	**Year**
Family health strategy coverage	Brazilian Ministry of Health	2012
Investment in primary care	Brazilian Ministry of Health	2012
Percentage of physicians in primary care	Brazilian Ministry of Health	2012
Gross domestic product (per capita)	Brazilian Institute for Geography and Statistics	2010
Illiteracy rate	Brazilian Institute for Geography and Statistics	2010
Individual monthly income (per capita)	Brazilian Institute for Geography and Statistics	2010
Unemployment rate	Brazilian Institute for Geography and Statistics	2010

Figure 1: Data sources for health system and socioeconomic predictors[1][2][3][4][5][6][7]

[1] Departamento de Atenção Básica. (2016). Histórico de Cobertura da Saúde da Família. Brasília. Retrieved from http://dab.saude.gov.br/portaldab

[2] Sala de Apoio à Gestão Estratégica. (2016). Receitas Estaduais/Municipais. Retrieved from http://sage.saude.gov.br/

[3] Departamento de Atenção Básica. (2016). Histórico de Cobertura da Saúde da Família. Brasília. Retrieved from http://dab.saude.gov.br/portaldab

[4] Atlas do Desenvolvimento Humano no Brasil. (2013). Retrieved from http://www.atlasbrasil.org.br/2013/

[5] Ibid.

[6] Ibid.

[7] Ibid.

Group	**Diagnosis**	**ICD-10**
Hypertension	Hypertensive heart disease Essential hypertension	I11 I10
Congestive heart failure	Heart failure Pulmonary edema	I50 J81
Cerebrovascular diseases	Cerebrovascular diseases	I63-I67, I69, G45, G46
Diabetes mellitus	With coma or ketoacidosis No specific complications With complications (renal, ophthalmologic, neurological, circulatory, peripheral, other, multiple, unspecified)	E10.0-E10.1, E11.0-E11.1, E12.0-E12.1, E13.0-E13.1, E14.0-E14.1 E10.9, E11.9 E12.9, E13.9, E14.9 E10.2-E10.8, E11.2-E11.8, E12.2-E12.8, E13.2-E13.8, E14.2-E14.8
Skin and subcutaneous tissue infections	Skin abscesses, furuncles, and carbuncles Cellulitis Impetigo Acute lymphadenitis Urinary tract infection	L02 L03 L01 L04 N39.0
Female pelvic inflammatory diseases	Salpingitis Uterine inflammatory disease (except cervix) Cervical inflammatory disease Other female pelvic inflammatory diseases Other inflammatory conditions of the vagina and vulva Diseases of the Bartholin glands	N70 N71 N72 N73 N76 N75
Prenatal and postnatal conditions	Urinary tract infection during pregnancy Congenital syphilis Congenital rubella syndrome	O23 A50 P35.0

Figure 2: Brazilian Ministry of Health classification list for primary care sensitive conditions targeted in the Family Health Strategy[8]

[8] Alfradique, M. E., Bonolo Pde, F., Dourado, I., Lima-Costa, M. F., Macinko, J., Mendonca, C. S., . . . Turci, M. A. (2009). [Ambulatory care sensitive hospitalizations: elaboration of Brazilian list as a tool for measuring health system performance (Project ICSAP--Brazil)]. *Cadernos De Saúde Pública, 25*(6), 1337-1349

2.4 Data analysis

Descriptive statistics of the mean, standard deviation, minimum, quartile 1, median, quartile 3, and maximum were used to assess municipality characteristics and HPCSC. Variables related to the infrastructure of health centers were analyzed through a principal component analysis (PCA) to generate regression scores. An oblique rotation was chosen, due to the intercorrelation of structure and process dimensions [49]. PCA is a formative statistical modeling technique to reduce the dimensionality of data through identifying linear combinations (components) that maximize the variation explained [50]. PCA is a preferred method for exploratory analysis with variables that are highly correlated [51]. Four independent, exploratory models were tested, and the number of components to retain was decided based on the parallel analysis, scree test, eigenvalues >1, and cumulative variance explained by the model and its interpretability, as supported by best practices [52-53].

Multiple regression models were then used to test the association of health center, health system, and socioeconomic variables. Health center, health system, and socioeconomic variables were added to the models as groups. For each of the seven PCSC, three nested models were tested consisting of 1) health center predictors, 2) health center and health system predictors, and 3) health center, health systems, and socioeconomic predictors. The justification for the addition of groups of predictors in this order comes from an adaptation of the Bronfenbrenner Ecological Systems Model to population health, with health centers located at the microsystem, the health system located at the mesosystem, and the socioeconomic context located at the macrosystem [54].

3. Results

3.1 Municipality characteristics

A complete case analysis was performed on 560 municipalities. The municipalities had a mean population of approximately 24,100 inhabitants and ranged in population from 1,210-604,000 inhabitants. The mean GDP per capita of analyzed municipalities was $6,226.34 USD, ranging from $1,260.99 USD-$100,949.51 USD, and the mean individual monthly income per capita was $179.57 USD, ranging from $53.96 USD-$359.27 USD. **Table 1** contains the socioeconomic characteristics of municipalities represented in the study.

Table 1: Socioeconomic characteristics of municipalities (n=560)

Variable	*Mean*	*Standard deviation*	*Minimum*	*Q1*	*Median*	*Q3*	*Maximum*
Gross domestic product (USD per capita)	6,226.34	6,616.77	1,260.99	2,512.67	4,510.17	7,762.88	100,949.51
Individual monthly household income (USD per capita)	179.57	65.36	53.96	120.39	181.37	225.60	359.27
Illiteracy rate (%)	11.36	7.35	3.40	5.50	8.40	16.60	37.20
Unemployment rate (%)	6.80	2.68	0.48	4.99	6.62	8.69	17.84

Of the health system characteristics selected for the analysis, municipalities had a mean FHS coverage of 81.92%, ranging from 0% to 100%. Only 3 (0.5%) municipalities had no (0%) FHS coverage. Municipalities had a mean per capita investment in PC of $34.03 USD, ranging from $0.13 USD to $2,731.12. **Table 2** displays the health system characteristics of municipalities represented in the study.

Table 2: Health system characteristics of municipalities (n=560)

Variable	*Mean*	*Standard deviation*	*Minimum*	*Q1*	*Median*	*Q3*	*Maximum*
Family Health Strategy coverage (%)	81.92	22.06	0.00	62.84	95.47	100.00	100.00
Investment in primary care (USD per capita)	34.03	78.29	0.13	11.50	23.87	39.01	2,731.12
Physicians in primary care (%)	50.10	24.70	8.58	29.13	48.42	70.48	100.00

3.2 Health center infrastructure

Of the four independent models tested, the best-fitting retained 3 components and explained 61% of the cumulative variation in the data structure. All indicators loaded onto components with values of ≥ .40. Factor interpretability was applied to construct the final model, utilizing the theoretical rationale of the *Starfield Model of Primary Care* to describe underlying constructs [55]. *The Starfield Model* is frequently used to examine “essential components” of primary care, defining quality in primary care as a function of first contact, comprehensiveness, coordination, and continuity of services [55]. First contact refers to the PC provider's capacity to facilitate patient entry into the health system and is dependent upon accessibility and patient intake services for new needs. Comprehensiveness is defined as the availability of services at the PC level that are integrated across the spectrum from health promotion to treatment and includes both physical and mental health. Coordination indicates communication and collaboration with more advanced levels of care to provide referrals, transfer medical records, and follow-up. Continuity is the extent to which longitudinal services are provided to manage patient care [56].

Given that the structure of the Brazilian public health care network assigns PCU to be the designated site for care-seeking to other levels of the health system, the best-fitting model reflected convergence between first contact and coordination, which was labeled as coordination [21]. **Table 3** shows the complete breakdown of indicators and their categorization under the components of comprehensiveness, continuity, and coordination.

Table 3: Factor loadings of principal component analysis of infrastructure variables (n=2,001)

VARIABLE	*COMPREHENSIVENESS*	*CONTINUITY*	*COORDINATION*
Physician consultations		0.82	
Nurse consultations		0.62	
Patient check-in		0.99	
Wound care		0.93	
On-site procedures		0.70	
Vaccination administration		0.81	
Additional services		0.52	
Access for spontaneous demand			0.59
Patient needs evaluated			0.64
Referrals to other levels of care			0.44
Frequency of professional training with specialists			0.80
Frequency of specialists on-site			0.77
Women's health services	0.85		
Family planning	0.80		
Prenatal and postnatal care	0.78		
Men's health services	0.71		
Geriatric services	0.80		
Nutrition counseling	0.79		
Prevention and treatment of hypertension	0.89		
Prevention and treatment of diabetes	0.92		
Chronic disease self-care support groups	0.83		
Communication/education for sexual and reproductive health	0.78		
Group education for infectious disease per demand	0.83		
Prevention and treatment for drug and alcohol abuse	0.61		
Proportion of variance	0.33	0.51	0.61

3.3 Burden of hospitalizations

In total, 12,078 HPCSC due to the seven conditions targeted by the FHS were recorded in the Hospital Information System of the Unified Health System from January-December 2012. 4,496 (37.22%) of reported hospitalizations were due to heart failure, and 3,014 (24.95%) were due to cerebrovascular diseases. The NCDs of heart failure, cerebrovascular diseases, diabetes and hypertension together accounted for 10,576 (87.56%) HPCSC. The aggregate age-adjusted hospitalization rate for all municipalities was found to be 112.15 per 10,000 inhabitants. **Table 4** details the mean adjusted rates of HPCSC per 10,000 inhabitants by condition.

Table 4: Mean age-adjusted rate of hospitalizations Family Health Strategy targeted primary care sensitive conditions (per 10,000 inhabitants)

Condition	Mean rate (per 10,000)	Standard deviation
Hypertension	5.21	0.0098
Congestive heart failure	36.82	0.0523
Cerebrovascular diseases	27.89	0.0382
Diabetes mellitus	16.54	0.0219
Skin and subcutaneous tissue infections	11.30	0.0166
Female pelvic inflammatory diseases	6.90	0.0158
Prenatal and postnatal conditions	7.49	0.0138

3.4 Multiple regression models

Multiple regression models were run independently for the seven categories of HPCSC selected. For each category of variables three models were tested consisting of 1) health center predictors, 2) health center and health system predictors, and 3) health center, health system, and socioeconomic predictors. Coefficients and p-values were rounded to the nearest thousandth or nearest non-zero value for reporting. For all PCSC, the model fully adjusted for health center, health system, and socioeconomic predictors performed the best seen in the resulting change in adjusted R^2 from the addition of each category of variables. The level of the inadequacy of continuity infrastructure, FHS coverage, and mean household income were the only predictors significant across all fully-adjusted models for the 7 PCSC. The percentage of physicians in primary care was significant in 6 of the fully-adjusted models. **Tables 5-11** present the results of the multiple regression models by each PCSC.

Table 5: Multiple regression models of health center, health system, and socioeconomic predictors of hospitalizations due to hypertension

	Infrastructure Model 1		*Infrastructure + Health System Model 2*		*Infrastructure + Health System+ Socioeconomic Context Model 3*	
Predictor	β (SE)	P	β (SE)	P	β (SE)	P
Comprehensiveness	-.5016 (.2735)	.0668	.4043 (.2538)	.1113	-.1748 (.2539)	.4913
Continuity	2.0559 (.2471)	<.0001***	2.0729 (.2539)	<.0001***	2.078 (.2561)	<.0001***
Coordination	0.8655 (.2531)	.0006***	.6522 (.2347)	.0055**	.5455 (.2320)	.0188*
Coverage			-.0666 (.0117)	<.0001***	-.0732 (.0119)	<.0001***

Investment			.0004 (.0008)	.6214	.00006 (.0008)	.9416
Physicians			-.1001 (.0106)	<.0001***	-.1304 (.0135)	<.0001***
GDP					-.00001 (.00001)	.1869
Illiteracy					-.0529 (.0484)	.2744
Income					-.0069 (.0021)	<.0001***
Unemployment					.4206 (.0780)	<.0001***
R^2	.0317		.1707		.1957	
Change in R^2 (F)				<.0001***		<.0001***

For hospitalizations due to hypertension, inadequacy of continuity and coordination were significant in model 1, and only continuity remained significant in the fully-adjusted model 3. The health system predictors of FHS coverage and the percentage of physicians in PC were significant in model 2 and remained significant in the fully-adjusted model in which income and the unemployment rate were also significant. In the fully-adjusted model, an increase in inadequacy of continuity was significantly associated with 2.0780 more hospitalizations, an increase in inadequacy of coordination was significantly associated with 0.5444 more hospitalizations, an increase in FHS coverage was significantly associated with 0.0732 fewer hospitalizations, an increase of the percentage of physicians in PC was associated with 0.1304 fewer hospitalizations, an increase in monthly household income was associated with 0.00069 fewer hospitalizations, and an increase in the unemployment rate was associated with 0.4206 more hospitalizations/10,000 inhabitants.

Table 6: Multiple regression models of health center, health system, and socioeconomic predictors of hospitalizations due to heart failure

	Infrastructure Model 1		*Infrastructure + Health System Model 2*		*Infrastructure + Health System+ Socioeconomic Context Model 3*	
Predictor	*β (SE)*	*P*	*β (SE)*	*P*	*β (SE)*	*P*
Comprehensiveness	-4.6350 (1.4940)	.0020**	-3.8350 (1.2220)	.0017**	-3.5270 (1.2170)	.0038 **
Continuity	11.0090 (1.4970)	<.0001***	11.1400 (1.2220)	<.0001***	12.4400 (1.2270)	<.0001***
Coordination	3.9790 (1.3830)	.0041**	2.1950 (1.1300)	.5222	1.8320 (1.1110)	.0995
Coverage			-.5532 (.0565)	<.0001***	-.4990 (.0571)	<.0001***
Investment			-.0005 (.0040)	.8979	-.0020 (.0039)	.6060
Physicians			-.8247 (.0509)	<.0001***	-.7122 (.0648)	<.0001***
GDP					-.0003 (.0001)	<.0001***
Illiteracy					.9325 (.2319)	<.0001***
Income					.0620 (.0100)	<.0001***
Unemployment					2.4630 (.3726)	<.0001***
R^2	.0304		.3553		.3807	
Change in R^2 (F)				<.0001***		<.0001***

For hospitalizations due to heart failure, inadequacy of comprehensiveness, continuity, and coordination infrastructure were significant in model 1, and comprehensiveness and continuity remained significant in the fully-adjusted model 3. In model 2, the health system predictors of FHS coverage and the percentage of physicians in PC were also significant. In the fully-adjusted model, an increase in inadequacy of comprehensiveness was significantly associated with 3.5270 fewer hospitalizations, an increase in inadequacy of continuity was significantly associated with 12.4400 more hospitalizations, an increase in FHS coverage was significantly associated with 0.4990 fewer hospitalizations, an increase in the percentage of physicians in PC was significantly associated with 0.7112 fewer hospitalizations, an increase in GDP was significantly associated with 0.0003 fewer hospitalizations, an increase in the illiteracy rate was significantly associated with 0.9325 more hospitalizations, and increase in income was associated with 0.0620 more hospitalizations, and an increase in the unemployment rate was significantly associated with 2.4630 more hospitalizations/10,000 inhabitants.

Table 7: Multiple regression models of health center, health system, and socioeconomic predictors of hospitalizations due to cerebrovascular diseases

	Infrastructure Model 1		*Infrastructure + Health System Model 2*		*Infrastructure + Health System+ Socioeconomic Context Model 3*	
Predictor	*β (SE)*	*P*	*β (SE)*	*P*	*β (SE)*	*P*
Comprehensiveness	-3.5724 (1.1047)	.0012**	-2.5523 (.7986)	.0014**	-3.0870 (.7799)	<.0001***
Continuity	2.3893 (1.1071)	.0314*	2.2917 (.7990)	.0042**	1.8300 (.7865)	.0201*
Coordination	2.4771 (1.0223)	.0155*	.7313 (.7386)	.3222	.7512 (.7125)	.2919
Coverage			-.6858 (.0369)	<.0001***	-.5984 (.0366)	<.0001***
Investment			-.0013 (.0026)	.6289	-.0017 (.0025)	.5018
Physicians			-.5598 (.0333)	<.0001***	-.3170 (.0415)	<.0001***
GDP					.00001 (.0001)	.8486
Illiteracy					.3868 (.1487)	.0093
Income					.0576	<.0001***
Unemployment					2.5560 (.2395)	<.0001***
R^2	.0070		.4839		.5232	
Change in R^2 (F)				<.0001***		<.0001***

For hospitalizations due to cerebrovascular diseases, inadequacy of comprehensiveness and continuity were significant in model 1, and remained significant in the fully-adjusted model 3. In model 2, the health system predictors of FHS coverage and the percentage of physicians in PC were also significant. In the fully-adjusted model, an increase in inadequacy of comprehensiveness was significantly associated with 3.0870 fewer hospitalizations, an increase in inadequacy of continuity was significantly associated with 1.8300 more hospitalizations, and increase in FHS coverage was significantly associated with 0.5984 less hospitalizations, an increase in the percentage of physicians in PC was significantly associated with 0.3170 fewer hospitalizations , an increase in income was significantly associated with 0.0576 more hospitalizations, and an increase in unemployment was significantly associated with 2.5560 more hospitalizations/10,000 inhabitants.

Table 8: Multiple regression models of health center, health system, and socioeconomic predictors of hospitalizations due to diabetes

	Infrastructure Model 1		*Infrastructure + Health System Model 2*		*Infrastructure + Health System+ Socioeconomic Context Model 3*	
Predictor	*β (SE)*	*P*	*β (SE)*	*P*	*β (SE)*	*P*
Comprehensiveness	-.8271 (.6341)	.1922	.4846 (.4759)	.3087	.3417 (.4810)	.4780
Continuity	2.0740 (.6355)	.0011 **	1.3650 (.4755)	.0041 **	1.4510 (.4841)	.0028 **
Coordination	1.2578 (.5868(	.0322 *	.4654 (.4383)	.2885	.4829 (.4381)	.2705
Coverage			-.2659 (.0224)	<.0001***	-.2461 (.0230)	<.0001***
Investment			.0001 (.0001)	<.0001***	.00001 (.00001)	<.0001***
Physicians			-.2030 (.0198)	<.0001***	-.1466 (.0257)	<.0001***
GDP					.00001 (.00001)	.2459

Illiteracy					.1822 (.0920)	.0477 *
Income					.0173 (.0040)	<.0001***
Unemployment					.3435 (.1528)	0.0246 *
R^2	.0063		.4479		.4525	
Change in R^2 (F)				<.0001***		<.0001***

For hospitalizations due to diabetes, inadequacy of continuity and coordination were significant in model 1, and continuity remained significant in the fully-adjusted model 3. In model 2, the health system predictors of FHS coverage, investment in PC, and the percentage of physicians in PC were also significant. In the fully-adjusted model, an increase in inadequacy of continuity infrastructure was significantly associated with 1.451 more hospitalizations , an increase, an increase in FHS coverage was significantly associated with 0.2461 fewer hospitalizations, an increase in the percentage of physicians in PC was significantly associated with 0.1666 fewer hospitalizations, an increase in the illiteracy rate was significantly associated with associated with 0.1822 more hospitalizations, an an increase in income was significantly associated with 0.0173 more hospitalizations, and an increase in unemployment was significantly associated with 0.3435 more hospitalizations/10,000 inhabitants. Investment in PC was also significant in the fully-adjusted model; however, the magnitude of the coefficient did not indicate meaningful results.

Table 9: Multiple regression models of health center, health system, and socioeconomic predictors of hospitalizations due to skin and subcutaneous tissue infections

	Infrastructure Model 1		*Infrastructure + Health System Model 2*		*Infrastructure + Health System+ Socioeconomic Context Model 3*	
Predictor	*β (SE)*	*P*	*β (SE)*	*P*	*β (SE)*	*P*
Comprehensiveness	-2.1504 (.4790)	<.0001***	-.7321 (.3065)	.0170 *	-.5993 (.3066)	.0508
Continuity	1.5494 (.4800)	.0013 **	.6549 (.3062)	.0326 *	.9231 (.3086)	.0028 **
Coordination	.6027 (.4433)	.1741	.0581 (.2823)	.8369	-.0110 (.2793)	.9685
Coverage			-.1576 (.0144)	<.0001***	-.1541 (.0147)	<.0001***
Investment			.00001 (.00001)	<.0001***	.00001 (.00001)	<.0001***
Physicians			-.1030 (.0128)	<.0001***	-.0959 (.0164)	<.0001***
GDP					.00001 (.00001)	.6141
Illiteracy					.4420 (.0586)	<.0001***
Income					.0151 (.0025)	<.0001***
Unemployment					-.0555 (.0974)	.5690
R^2	.0124		.6013		.6126	
Change in R^2 (F)				<.0001***		<.0001***

For hospitalizations due to skin and subcutaneous tissue infectious, inadequacy of comprehensiveness and continuity infrastructure were significant in model 1, and continuity remained significant in the fully-adjusted model 3. In model 2, the health system predictors of FHS coverage, investment in PC, and the percentage of physicians in PC were also significant. In the fully-adjusted model, an increase in inadequacy of continuity infrastructure was significantly associated with 0.9232 more hospitalizations, an increase in FHS coverage was significantly associated with 0.1541 fewer hospitalizations, an increase in the percentage physicians in PC was significantly associated with 0.0959 fewer hospitalizations, an increase in the illiteracy rate was significantly associated with associated with 0.4420 more hospitalizations, an increase in income was significantly associated with 0.0151 more hospitalizations, and an increase in unemployment was significantly associated with 0.0555 fewer hospitalizations/10,000 inhabitants. Investment in PC was also significant in the fully-adjusted model; however, the magnitude of the coefficient did not indicate meaningful results.

Table 10: Multiple regression models of health center, health system, and socioeconomic predictors of hospitalizations due female pelvic inflammatory diseases

	Infrastructure Model 1		*Infrastructure + Health System Model 2*		*Infrastructure + Health System+ Socioeconomic Context Model 3*	
Predictor	*β (SE)*	*P*	*β (SE)*	*P*	*β (SE)*	*P*
Comprehensiveness	.3358 (.4574)	.4630	1.1310 (.3968)	.0044 **	.9995 (.4013)	.0128 *
Continuity	1.5474 (.4584)	.0008 ***	1.112 (.3965)	.0051 **	.8964 (.4039)	.0266 *
Coordination	.5071 (.4233)	.2311	.0138 (.3655)	09699	.0377 (.3655)	.9180
Coverage			-.2182 (.0187)	<.0001***	-.2084 (.0192)	<.0001***
Investment			.00001 (.00001)	<.0001***	00001 (.00001)	<.0001***
Physicians			-.0529 (.0165)	.0014 **	-.0166 (.0214)	.4396
GDP					00001 (.00001)	.0245 *
Illiteracy					.0623 (.0767)	.4167
Income					.0073 (.0033)	.0262 *
Unemployment					.2741 (.1274)	.0316 *
R^2	.0059		.2619		.2672	

Change in R^2 (F)		<.0001***	<.0001***

For hospitalizations due to female pelvic inflammatory diseases, inadequacy of continuity infrastructure was significant in model 1 and remained significant in the fully-adjusted model 3. In model 2, the health system predictors of FHS coverage, investment in PC and the percentage of physicians in PC were also significant. In the fully-adjusted model, an increase in inadequacy of comprehensiveness infrastructure was significantly associated with 0.9995 more hospitalizations, an increase in adequacy of continuity infrastructure was significantly associated with 0.8964 more hospitalizations, an increase in FHS coverage was significantly associated with 0.2084 fewer hospitalizations, an increase in income was significantly associated with 0.0073 more hospitalizations, and an increase in the unemployment rate was significantly associated with 0.1274 more hospitalizations/10,000 inhabitants. GDP and investment in PC were also significant in the fully-adjusted model; however, the magnitude of the coefficient did not indicate meaningful results.

Table 11: Multiple regression models of health center, health system, and socioeconomic predictors of hospitalizations due to prenatal and postpartum conditions

	Infrastructure Model 1		*Infrastructure + Health System Model 2*		*Infrastructure + Health System+ Socioeconomic Context Model 3*	
Predictor	*β (SE)*	*P*	*β (SE)*	*P*	*β (SE)*	*P*
Comprehensiveness	-.3887 (.4007)	.3320	.6173 (.2907)	.0338 *	.4208 (.2884)	0.145
Continuity	.3123 (.4016)	.4370	-.2787 (.2904)	.3373	-.7436 (.2903)	0.0105 *
Coordination	.3216 (.3708)	03860	-.1847 (.2677)	.4904	-.0989 (.2627)	0.7066
Coverage			-.1887 (.0137)	<.0001***	.1806 (.0138)	<.0001***
Investment			.00001 (.00001)	<.0001***	.00001 (.00001)	<.0001***
Physicians			-.0787 (.0121)	<.0001***	-.0406 (.0154)	0.0084 **
GDP					.00001 (.00001)	<.0001***
Illiteracy					.0721 (.0051)	0.1913
Income					.0048 (.0024)	0.0413 *
Unemployment					-.1076 (.0916)	
R^2	-.0006		.4806		0.5037	
Change in R^2 (F)				<.0001***		<.0001***

For hospitalizations due to prenatal and postpartum conditions, none of the health center predictors were significant in model 1; however, inadequacy of continuity infrastructure became significant in the fully-adjusted model 3. In model 2, the health system predictors of FHS coverage, investment in PC, and the percentage of physicians in PC were also significant. In the fully-adjusted model, an increase in inadequacy of continuity infrastructure was significantly associated with 0.7436 fewer hospitalizations, an increase in FHS coverage was significantly associated with 0.1806 more hospitalizations, an increase in the percentage of physicians in PC was significantly associated with 0.0406 fewer hospitalizations, and an increase in income was significantly associated with 0.0048 more hospitalizations/10,000 inhabitants. Investment in PC and GDP were also significant in the fully-adjusted model; however, the magnitude of the coefficient did not indicate meaningful results.

4. Discussion

This ecological study sought to measure the relationship between health center, health system, and socioeconomic predictors of HPCSC, as well as to assess the current profile of avoidable hospitalizations in Minas Gerais, Brazil. This study is distinct from previous studies in its integrative approach that evaluates predictors across various levels that influence service delivery. For this reason, our findings contribute to growing efforts to identify predictors of HPCSC and disparities of their burden across geographic areas.

4.1 Main Findings

4.1.1 Current burden of hospitalizations and leading causes

Our collective hospitalization rate of 112.5/10,000 inhabitants is slightly less than the national rate of approximately 142/10,000 inhabitants for all Ministry of Health designated PCSC [18]. This variation is mostly likely because our study intentionally relied on a subgroup of the seven common causes for HPCSC targeted specifically through the FHS and omitted pediatric hospitalizations (defined as <15 years of age). However, another plausible reason for the lower burden of HPCSC is that our study is comprised of small and medium-sized municipalities, rather than larger metropolitan capitals around which literature from Brazil tends to concentrate because of more advanced surveillance infrastructure and greater accessibility of data [27,33, 35]. Underreporting and errors in the Hospital Information System resulting from inadequate infrastructure and lack of cause-specific diagnostic information also disproportionately impact rural, less populated municipalities, and could potentially underestimate the burden of hospitalizations in this study [54].

Aligned with previous literature on avoidable hospitalizations in Brazil, our study found that NCDs diseases accounted for a majority (87.56%) of HPCSC. Previous studies on HPCSC from within Brazil highlight cardiovascular conditions to be the leading cause of all hospitalizations [35, 55-56]. In our sample, the calculated rate of hospitalizations due to congestive heart failure was 36.82/10,000 inhabitants, corresponding to 34% of all hospitalizations. A past study in Minas Gerais of 1,149,253 hospitalizations recorded in 2010 identified a rate of hospitalizations due to heart failure as 20.1/10,000 inhabitants [57]. However, this study retained hospitalizations for all age groups, and this inclusion of pediatric patients helps to explain the greater rate of these hospitalizations in our sample.

4.1.2 Primary care infrastructure

The results of our PCA show significant patterns in PC infrastructure that can help to define and interpret its key dimensions. All indicators selected through a combination of literature review and expert consensus loaded onto the best fitting component above the accepted threshold for loading scores of >=.40 [58]. This suggests convergence between theoretical and functional components of PC infrastructure and underscores the ongoing utility of the *Starfield Model* previously asserted in the literature

[42, 59]. Although the *Starfied Model* is used in the literature to facilitate the selection of indicators from which to quantitatively measure quality, to our knowledge, our study is the first to apply statistical methods to evaluate its applicability to capturing and interpreting significant patterns in PC infrastructure.

Continuity infrastructure remained significant across all fully-adjusted models for the 7 PCSC. In all but one of the PCSC (prenatal and postpartum conditions), the level of inadequacy of continuity infrastructure was positively associated with greater hospitalization rates. The most meaningful association was observed for heart failure, where a standardized increase in the level of inadequacy of continuity infrastructure corresponded to an estimated 12.44 more hospitalizations per 10,000 inhabitants. If expressed in terms of the mean population of municipalities in our sample, this would be the equivalent of 97.81 additional hospitalizations per municipality annually. In addition to heart failure, the conditions of hypertension and cerebrovascular diseases showed meaningful associations with the level of inadequacy of continuity infrastructure. These findings are consistent with clinical understandings of the pathologies of these conditions and best practice guidelines that recommend long-term care management for the prevention and treatment of NCDs [60-62].

Our model's construction of continuity is heavily influenced by access, including availability of physician consultations, nurse consultations, and procedures on-site. This offers a more nuanced understanding of access beyond health insurance coverage that highlights barriers at the level of health centers that are sensitive to the quantity of human resources and technology available [42]. In the context of LMIC where demand-side barriers to health access, particularly transportation and other indirect costs, influence poor health outcomes, our findings support that factors such as flexible scheduling of appointments and the ability to perform procedures on-site could successfully reduce preventable hospitalizations [63].

The component of comprehensiveness, which was significant in the fully-adjusted models for heart failure, cerebrovascular diseases, and female pelvic inflammatory disease, most closely conforms with the common definition of infrastructure in the literature [24-25]. This definition refers to equipment, supplies, and technology for service delivery. Heart failure and cerebrovascular diseases showed a significant negative association to the level inadequacy of comprehensiveness infrastructure. There were and estimated 3.54 and 3.09 fewer hospitalizations per 10,000 inhabitants, respectively, as inadequacy increases. However, it is possible that a lower hospitalization rate occurs at the expense of greater mortality, especially given that heart failure and cerebrovascular diseases often require time-sensitive diagnoses and interventions.

4.1.3 Relationship between multilevel predictors

Studies of the relationship between predictors at the level of health centers, health systems, and socioeconomic contexts are scarce, and this study contributes to filling this gap. For all seven PCSC, the models fully-adjusted for these three categories performed the best. The three NCDs of heart failure, cerebrovascular disease, and diabetes, which contributed the most to the profile of NCDs in our sample, constituted three of the four most precise models (only the model for skin infections was more precise). This ability to predict and understand trends in the burden of NCDs is especially important given projections of increased incidence in LMIC and the subsequent social and economic costs [3]. Our findings are reason to further study interventions at the level of health centers to better understand their role in potentially moderating the effects of social and economic determinants of health linked to development level.

Notably, in the cases of heart failure, cerebrovascular diseases, and diabetes the addition of health system variables produced the greatest change in the strength of the model fit. Given the likely directionality of this relationship in which actions of health systems planning result in changes at the level of individual health centers, greater investment in resources for care delivery, as well as process improvement policies should be a priority of health systems [64]. In this way, our findings contradict those from within Brazil and internationally that previously found infrastructure and health system variables to be insignificant when adjusting for socioeconomic variables [8,18,35]. More research involving smaller (<50,000 inhabitants) and rural municipalities, along with studies at the patient level that take into account multi-level predictors of HPCSC will offer additional explanations for observed relationships

4.2 Strengths and limitations

4.2.1 Reliability

All variables loaded onto the component of coordination >=.70 threshold, all variables expect nurse consultations and additional services loaded onto the continuity threshold >=.70, and only two of the variables on the component of coordination loaded >=.70. Thus, there is relatively high internal validity for the first two components, which is a strength of this study [58]. While it is possible that the model fit could be strengthened by removing those variables <.70, the purpose of our study was to examine the effects of variation in PC infrastructure rather than to validate a theoretical model. Because of this, all variables that loaded >=.40 were kept for the analysis to account for a greater range of information available at the level of health centers [58]. Our sample size of 560 municipalities is also a strength as variation in health system and socioeconomic characteristics across municipalities allowed for associated differences in PCU infrastructure and rates of HPCSC to be measured.

4.2.2 Data sources

One limitation that our study faced was its reliance on secondary data sources. Missing data from the surveys collected through the external evaluation of PMAQ-AB was common. As incomplete data were determined to be missing not at random, we were only able to include PCU for which data were complete. It is likely that missing data could be related to lack of personnel or infrastructure at the health center, and future evaluation efforts should prioritize filling in missing data gaps for these areas. Additionally, PCU are responsible for coverage areas known as a micro-regions of health that consist of approximately 1,000 households. Yet, socioeconomic and health system data are currently only available at the municipality level. Consequently, average municipality infrastructure scores are the best available estimate to capture the context in which the PCU operate, but do not capture or assess the effects of disparities between districts in the same municipality.

4.3 Implications for policy practice and future research

Unlike previous studies from within Brazil, our findings support that factors related to the strength of the health system and infrastructure in PCU have the potential to reduce preventable hospitalizations. As the FHS was designed as an overhaul of human resources and technology to deliver community-based care to under-resourced areas, our findings support that this approach may be successful to confront the growing burden of NCDs in Brazil [14]. Past studies have shown improved outcomes in maternal and child health to be associated with an increased FHS presence overtime and expanding health promotion and prevention efforts specifically focused on NCDs is an important policy action [65-66]. In LMIC, PC occupies a leading role in population health and policy should be developed to integrate care management with patientcentered interventions to mitigate the role of social economic factors, including vouchers for transportation or food, or behavioral modification programming [22-23,67]. Further, identified lessening disparities between municipalities and gaps in FHS coverage should be a priority moving forward.

More research is needed on the profile of HPCSC and their predictors in Brazil and other LMIC. Brazil is unique in the sense that universal health care, along with advanced disease surveillance infrastructure, is in place. Further research could assist in validating a model consisting of comprehensiveness, continuity, and coordination as a standard for quantifying the strength of service delivery to be used as a tool for subsequent hypotheses involving PC quality. As our study is conducted at the population-level, research at the level of patients in LMIC is also needed. Research on patients will offer needed insight into the relationship and directionality of latent variables that explain the relationship between health center infrastructure, health systems, and socioeconomic contexts, such as barriers and facilitators to care-seeking or treatment compliance.

5. Conclusion

Our study found that in the context of Brazil's FHS, an application of the theoretical PC dimensions of comprehensiveness, continuity, and coordination is useful to quantifying and interpreting variation in health center infrastructure. The current burden of HPCS in Brazil consists mainly of the NCDS of heart failure, cerebrovascular diseases, diabetes and hypertension. For these conditions, the infrastructure dimensions of continuity and comprehensives are the most meaningful predictors of variation in rates of HPCSC across municipalities. The approaches of the FHS and similar programs that target high-risk groups through investment in human resources and technology should be further studied to better understand their potential to mitigate socioeconomic predictors of health outcomes and inform policy that is responsive to population demands. Gaps in PC services and health system disparities across municipalities need to be addressed to reduce preventable hospitalizations. Research that carries implications for PC systems strengthening is particularly significant for LMIC whose populations seek to benefit the most from community-based and integrated service delivery.

References

[1]. Billings, J., Zeitel, L., Lukomnik, J., Carey, T. S., Blank, A. E., & Newman, L. (1993). Impact of socioeconomic status on hospital use in New York City. *Health Aff (Millwood), 12*(1), 162-173.

[2]. Vos, T., Barber, R. M., Bell, B., Bertozzi-Villa, A., Biryukov, S., Bolliger, I., . . . Murray, C. J. L. Global, regional, and national incidence, prevalence, and years lived with disability for 301 acute and chronic diseases and injuries in 188 countries, 1990–2013: a systematic analysis for the Global Burden of Disease Study 2013. *The Lancet, 386*(9995), 743-800. doi:10.1016/S0140-6736(15)60692-4

[3]. World Health Organization. (2015). Noncommunicable diseases. Retrieved from http://www.who.int/mediacentre/factsheets/fs355/en/

[4]. Caminal, J., Starfield, B., Sanchez, E., Casanova, C., & Morales, M. (2004). The role of primary care in preventing ambulatory care sensitive conditions. *Eur J Public Health, 14*(3), 246-251.

[5]. Agency for Healthcare Research and Quality. (2015). Retrieved from http://www.qualityindicators.ahrq.gov/Modules/PQI_TechSpec.aspx.

[6]. Ansari , Z. (2007). The Concept and Usefulness of Ambulatory Care Sensitive Conditions as Indicators of Quality and Access to Primary Health Care. *Australian Journal of Primary Health, 13*(3), 91-110. doi:http://dx.doi.org/10.1071/PY07043

[7]. Hossain, M. M., & Laditka, J. N. (2009). Using hospitalization for ambulatory care sensitive conditions to measure access to primary health care: an application of spatial structural equation modeling. *Int J Health Geogr, 8*(1), 51. doi:10.1186/1476-072x-8-51

[8]. Magan, P., Alberquilla, A., Otero, A., & Ribera, J. M. (2011). Hospitalizations for ambulatory care sensitive conditions and quality of primary care: their relation with socioeconomic and health care variables in the Madrid regional health service (Spain). *Med Care, 49*(1), 17-23. doi:10.1097/MLR.0b013e3181ef9d13

[9]. Roos, L. L., Walld, R., Uhanova, J., & Bond, R. (2005). Physician Visits, Hospitalizations, and Socioeconomic Status: Ambulatory Care Sensitive Conditions in a Canadian Setting. *Health Services Research, 40*(4), 1167-1185. doi:10.1111/j.1475-6773.2005.00407.x

[10]. Agabiti, N., Pirani, M., Schifano, P., Cesaroni, G., Davoli, M., Bisanti, L., . . . Perucci, C. A. (2009). Income level and chronic ambulatory care sensitive conditions in adults: a multicity population-based study in Italy. *BMC Public Health, 9*(1), 457. doi:10.1186/1471-2458-9-457

[11]. Eggli, Y., Desquins, B., Seker, E., & Halfon, P. (2014). Comparing potentially avoidable hospitalization rates related to ambulatory care sensitive conditions in Switzerland: the need to refine the definition of health conditions and to adjust for population health status. *BMC Health Services Research, 14*(1), 25. doi:10.1186/1472-6963-14-25

[12]. Basu, J., Friedman, B., & Burstin, H. (2002). Primary care, HMO enrollment, and hospitalization for ambulatory care sensitive conditions: a new approach. *Med Care, 40*. doi:10.1097/00005650-200212000-00013

[13]. Harris, M., & Haines, A. (2010). Brazil's Family Health Programme. *Bmj, 341*. doi:10.1136/bmj.c4945

[14]. Macinko, J., & Harris, M. J. (2015). Brazil's family health strategy--delivering community-based primary care in a universal health system. *The New England Journal of Medicine, 372*(23), 2177-2181. doi:10.1056/NEJMp1501140

[15]. Malta, D. C., Santos, M. A. S., Stopa, S. R., Vieira, J. E. B., Melo, E. A., & Reis, A. A. C. D. (2016). Family Health Strategy Coverage in Brazil, according to the National Health Survey, 2013. *Ciencia & Saude Coletiva, 21*(2), 327-338. doi:10.1590/1413-81232015212.23602015

[16]. Departamento de Atenção Básica. (2016). Histórico de Cobertura da Saúde da Familia. Brasilia. Retrieved from http://dab.saude.gov.br/portaldab/historico_cobertura_sf.php

[17]. Alfradique, M. E., Bonolo Pde, F., Dourado, I., Lima-Costa, M. F., Macinko, J., Mendonca, C. S., . . . Turci, M. A. (2009). [Ambulatory care sensitive hospitalizations: elaboration of Brazilian list as a tool for measuring health system

performance (Project ICSAP--Brazil)]. *Cadernos De Saúde Pública, 25*(6), 1337-1349.

[18]. Ceccon, R. F., Meneghel, S. N., & Viecili, P. R. (2014). Hospitalization due to conditions sensitive to primary care and expansion of the Family Health Program in Brazil: an ecological study. *Rev Bras Epidemiol, 17*(4), 968-977.

[19]. World Health Organization. (2010). Brazil's march towards universal coverage. Retrieved from http://www.who.int/bulletin/volumes/88/9/10-020910/en/

[20]. Pierantoni, C. R., & Garcia, A. C. P. (2011). Human resources for health and decentralization policy in the Brazilian health system. *Human Resources for Health, 9*(1), 12. doi:10.1186/1478-4491-9-12

[21]. Paim, J., Travassos, C., Almeida, C., Bahia, L., & Macinko, J. The Brazilian health system: history, advances, and challenges. *The Lancet, 377*(9779), 1778-1797. doi:10.1016/S0140-6736(11)60054-8

[22]. Macinko, J., Starfield, B., & Erinosho, T. (2009). The impact of primary healthcare on population health in low- and middle-income countries. *J Ambul Care Manage, 32*(2), 150-171. doi:10.1097/JAC.0b013e3181994221

[23]. Kruk, M. E., Porignon, D., Rockers, P. C., & Van Lerberghe, W. (2010). The contribution of primary care to health and health systems in low- and middle-income countries: a critical review of major primary care initiatives. *Social Science & Medicine (1982), 70*(6), 904-911. doi:10.1016/j.socscimed.2009.11.025

[24]. Donabedian, A. (1988). The quality of care. How can it be assessed? *Jama, 260*(12), 1743-1748.

[25]. Dlugacz, Y. D. (2016). *Introduction to Health Care Quality: Theory, Methods, and Tools*: John Wiley & Sons.

[26]. Donabedian, A. (1980). *The Definition of Quality and Approaches to Its Assessment (Explorations in Quality Assessment and Monitoring , Volume 1)* (Vol. 1): Health Administration Press.

[27]. Castro, A. L., Andrade, C. L., Machado, C. V., & Lima, L. D. (2015). [Socioeconomic conditions, physician supply, and ambulatory care sensitive hospitalization in large Brazilian cities]. *Cadernos De Saúde Pública, 31*(11), 2353-2366. doi:10.1590/0102-311x00126114

[28]. Departamento de Atenção Básica. (2012). Programa Nacional de Melhoria do Acesso e da Qualidade da Atenção Básica (PMAQ). Retrieved from http://dab.saude.gov.br/portaldab/ape_pmaq.php

[29]. Saha, S., Solotaroff, R., Oster, A., & Bindman, A. B. (2007). Are preventable hospitalizations sensitive to changes in access to primary care? The case of the Oregon Health Plan. *Med Care, 45*(8), 712-719. doi:10.1097/MLR.0b013e318053717c

[30]. Bindman, A. B., Chattopadhyay, A., & Auerback, G. M. (2008). Interruptions in Medicaid coverage and risk for hospitalization for ambulatory care-sensitive conditions. *Ann Intern Med, 149*(12), 854-860.

[31]. Parchman, M. L., & Culler, S. (1994). Primary care physicians and avoidable hospitalizations. *J Fam Pract, 39*(2), 123-128.

[32]. Brasil, V. P., & Costa, J. S. D. d. (2016). Hospitalizações por condições sensíveis à atenção primária em Florianópolis, Santa Catarina - estudo ecológico de 2001 a 2011. *Epidemiologia e Serviços de Saúde, 25*, 75-84.

[33]. Mendonça, C. S., Harzheim, E., Duncan, B. B., Nunes, L. N., & Leyh, W. (2011). Trends in hospitalizations for primary care sensitive conditions following the implementation of Family Health Teams in Belo Horizonte, Brazil. *Health Policy and Planning, 27*(4), 348-355. doi:10.1093/heapol/czr043

[34]. Basu, J., Mobley, L. R., & Thumula, V. (2014). The Small Area Predictors of Ambulatory Care Sensitive Hospitalizations: A Comparison of Changes over Time. *Social Work in Public Health, 29*(2), 176-188. doi:10.1080/19371918.2013.776316

[35]. Goncalves, M. R., Hauser, L., Prestes, I. V., Schmidt, M. I., Duncan, B. B., & Harzheim, E. (2015). Primary health care quality and hospitalizations for ambulatory care sensitive conditions in the public health system in Porto Alegre, Brazil. *Fam Pract*. doi:10.1093/fampra/cmv051

[36]. Macinko, J., de Oliveira, V. B., Turci, M. A., Guanais, F. C., Bonolo, P. F., & Lima-Costa, M. F. (2011). The Influence of Primary Care and Hospital Supply on Ambulatory Care–Sensitive Hospitalizations Among Adults in Brazil, 1999–2007. *American Journal of Public Health, 101*(10), 1963-1970. doi:10.2105/AJPH.2010.198887

[37]. Rosano, A., Peschel, P., Kugler, J., Ricciardi, W., Guasticchi, G., & van der Zee, J. (2013). Preventable hospitalization and the role of primary care: a comparison between Italy and Germany. *Journal of Public Health, 21*(5), 445-454. doi:10.1007/s10389-013-0563-x

[38]. Instituto Brasileiro de Geografia e Estatística. (2016). Minas Gerais. Retrieved from http://www.ibge.gov.br/estadosat/perfil.php?sigla=mg

[39]. Harris, M. (2016). Mais Médicos (More Doctors) Program a view from England. *Ciencia & Saude Coletiva, 21*, 2919-2923.

[40]. Atlas do Desenvolvimento Humano no Brasil. (2013). Retrieved from http://www.atlasbrasil.org.br/2013/

[41]. Wells, B. J., Chagin, K. M., Nowacki, A. S., & Kattan, M. W. (2013). Strategies for Handling Missing Data in Electronic Health Record Derived Data. *eGEMs, 1*(3), 1035. doi:10.13063/2327-9214.1035

[42]. Campbell, S., Braspenning, J., Hutchinson, A., & Marshall, M. (2002). Research methods used in developing and applying quality indicators in primary care. *Qual Saf Health Care, 11*(4), 358-364. doi:10.1136/qhc.11.4.358

[43]. Kringos, D. S., Boerma, W. G. W., Spaan, E., & Pellny, M. (2008). *Primary care evaluation in the Russian Federation. Primary care in the WHO European Region*. Copenhagen: WHO Regional Office for Europe.

[44]. Ministério de Saúde (2012). Instrumento de Avaliação Externa do Saúde Mais Perto de Você- Acesso e Qualidade

[45]. Póvoa, L., & Andrade, M. V. (2006). Distribuição geográfica dos médicos no Brasil: uma análise a partir de um modelo de escolha locacional. *Cadernos De Saúde Pública, 22*, 1555-1564.

[46]. Nedel, F. B., Facchini, L. A., Martin-Mateo, M., Vieira, L. A., & Thume, E. (2008). Family Health Program and ambulatory care-sensitive conditions in Southern Brazil. *Rev Saude Publica, 42*(6), 1041-1052.

[47]. Naing, N. N. (2000). Easy Way to Learn Standardization : Direct and Indirect Methods. *The Malaysian Journal of Medical Sciences : MJMS, 7*(1), 10-15.

[48]. Macinko, J., & Lima Costa, M. F. (2012). Access to, use of and satisfaction with health services among adults enrolled in Brazil's Family Health Strategy: evidence from the 2008 National Household Survey. *Trop Med Int Health, 17*(1), 36-42. doi:10.1111/j.1365-3156.2011.02866.x

[49]. Zhang, G., & Preacher, K. J. (2015). Factor Rotation and Standard Errors in Exploratory Factor Analysis. *Journal of Educational and Behavioral Statistics, 40*(6), 579-603. doi:10.3102/1076998615606098

[50]. Ringner, M. (2008). What is principal component analysis? *Nat Biotechnol, 26*(3), 303-304. doi:10.1038/nbt0308-303

[51]. Suhr, D. D. (2016). *Principal Component Analysis vs. Exploratory Factor Analysis*. University of Northern Colorado

[52]. Bro, R., & Smilde, A. K. (2014). Principal component analysis. *Analytical Methods, 6*(9), 2812-2831. doi:10.1039/C3AY41907J

[53]. David, C. C., & Jacobs, D. J. (2014). Principal component analysis: a method for determining the essential dynamics of proteins. *Methods Mol Biol, 1084*, 193-226. doi:10.1007/978-1-62703-658-0_11

[54]. Bronfenbrenner, U. (1979). *The Ecology of Human Development: Experiments by Nature and Design*. Cambridge, MA: Harvard University Press.

[55]. Starfield, B. (1992). Primary care. *Concept, evaluation and policy*. New York: Oxford University Press.

[56]. Starfield, B. H., Simborg, D. W., Horn, S. D., & Yourtee, S. A. (1976). Continuity and Coordination in Primary Care: Their Achievement and Utility. *Medical Care, 14*(7), 625-636.

[57]. Szwarcwald, C. L., de Frias, P. G., Júnior, P. R. B. d., da Silva de Almeida, W., & Neto, O. L. d. M. (2014). Correction of vital statistics based on a proactive search of deaths and live births: evidence from a study of the North and Northeast regions of Brazil. *Population Health Metrics, 12*, 16-16. doi:10.1186/1478-7954-12-16

[58]. Lentsck, M. H., Latorre, M. d. R. D. d. O., & Mathias, T. A. d. F. (2015). Trends in hospitalization due to cardiovascular conditions sensitive to primary health care. *Revista Brasileira de Epidemiologia, 18*, 372-384.

[59]. Ribeiro, A. L., Duncan, B. B., Brant, L. C., Lotufo, P. A., Mill, J. G., & Barreto, S. M. (2016). Cardiovascular Health in Brazil: Trends and Perspectives. *Circulation, 133*(4), 422-433. doi:10.1161/circulationaha.114.008727

[60]. Rodrigues-Bastos, R. M., Campos, E. M. S., Ribeiro, L. C., Bastos, M. G., & Bustamante-Teixeira, M. T. (2014). Hospitalizations for ambulatory care-sensitive conditions, Minas Gerais, Southeastern Brazil, 2000 and 2010. *Rev Saude Publica, 48*(6), 958-967. doi:10.1590/S0034-8910.2014048005232

[61]. Costello, A. B. & J. W. Osborne, (2005). Best Practices in Exploratory Factor Analysis: Four Recommendations for Getting the Most From Your Analysis. *Practical Assessment Research & Evaluation* 10(7): 1-9.

[62]. Hogg W, Rowan M, Russell G, Geneau R, Muldoon L: Framework for primary care organizations: the importance of a structural domain. Int J Qual Health Care 2008, 20(5):308-13.

[63]. Ensor, T., & Cooper, S. (2004). Overcoming barriers to health service access: influencing the demand side. *Health Policy and Planning, 19*(2), 69-79. doi:10.1093/heapol/czh009

[64]. Walley, J., Graham, K., Wei, X., Kain, K., & Weston, R. (2012). Getting research into practice: primary care management of noncommunicable diseases in low- and middle-income countries. *Bull World Health Organ, 90*(6), 402. doi:10.2471/blt.12.106674

[65]. Aquino, R., de Oliveira, N. F., & Barreto, M. L. (2009). Impact of the Family Health Program on Infant Mortality in Brazilian Municipalities. *American Journal of Public Health, 99*(1), 87-93. doi:10.2105/AJPH.2007.127480

[66]. Andrade, M. V., Noronha, K. V. M. d. S., Queiroz Barbosa, A. C., Souza, M. N., Calazans, J. A., Carvalho, L. R. d., . . . Silva, N. C. (2017). Family health strategy and equity in prenatal care: a population based cross-sectional study in Minas Gerais, Brazil. *International Journal for Equity in Health, 16*(1), 24. doi:10.1186/s12939-016-0503-9

[67]. Briggs, C. J., & Garner, P. (2006). Strategies for integrating primary health services in middle- and low-income countries at the point of delivery. *Cochrane Database of Systematic Reviews*(2). doi:10.1002/14651858.CD003318.pub2