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Graphical Abstract

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DOI: 10.1016/j.xinn.2020.04.013

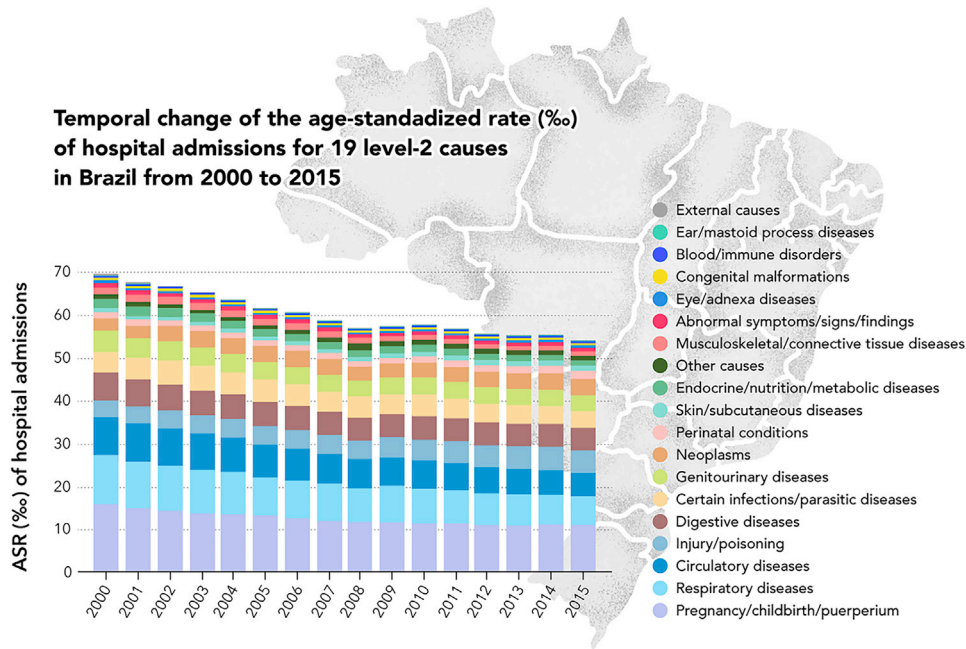
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Published Online: May 21, 2020

Received: June 2, 2019

Accepted: October 26, 2019



Public Summary

- Hospital admission rate and length of hospital stay have declined since 2000
- Healthcare costs of hospital admissions have increased since 2000
- Infants and the elderly had the highest admission rate, especially due to pneumonia
- Injury and maternal conditions were the primary causes in adult males and females
- Greatest healthcare burden occurred in the south of Brazil



Trends in Hospital Admission Rates and Associated Direct Healthcare Costs in Brazil: A Nationwide Retrospective Study between 2000 and 2015

Qi Zhao,¹ Micheline S.Z.S. Coelho,² Shanshan Li,¹ Paulo H.N. Saldiva,² Michael J. Abramson,¹ Rachel R. Huxley,³ and Yuming Guo^{1,*}

BACKGROUND

In Brazil, the increase in non-fatal events presents a new, unprecedented challenge for the free and universally accessible public healthcare system (SUS), the size and nature of which has yet to be reliably quantified. We examined the change in all-cause and cause-specific SUS hospital admissions during 2000 to 2015.

MATERIALS AND METHODS

Data on hospital admissions across 1,816 cities were collected from the Brazilian Unified Health System. The age-standardized rates of hospital admissions, the associated healthcare costs, and length of hospital stay were quantified. Stratum analyses were performed by age, sex, region, and cause-specific categories.

RESULTS

Hospital admission rates decreased by 10.2‰ per decade to 54.2‰ in 2015. For admissions in 2015, healthcare costs per patient equaled US\$353 (an increase of \$23.5/year since 2000) with an average length of hospital stay of 5 days (a decline of 0.04 days/year since 2000). Circulatory diseases incurred the greatest financial costs. Children and the elderly were most susceptible, especially for pneumonia. Injury and poisoning were the primary reason for admission in adult males, whereas maternal and other female-specific conditions were the highest burden in females. The burden of hospital admission was highest in the south and lowest in the north and northeast.

DISCUSSION

Although hospital admission rates and length of stay have decreased in Brazil since 2000, the decline has been offset by an increase in direct healthcare costs. Age-, sex-, and region-specific features of the disease burden should be factored into future plans for healthcare expenditure in Brazil.

Introduction

Brazil is the world's fifth most populous country with an estimated population of over 207 million people.¹ Between 2000 and 2012 Brazil had one of the

DOI:[https://doi.org/10.1016/](https://doi.org/10.1016/j.xinn.2020.04.013)

[j.xinn.2020.04.013](https://doi.org/10.1016/j.xinn.2020.04.013)

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Published Online: May 21, 2020

Received: June 2, 2019

Accepted: October 26, 2019

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fastest-growing economies in the world, with an annual (compound) GDP growth rate of over 10%.² It currently has the ninth largest economy but suffers from profound income disparity: 4% of the population subsist on less than US\$1.9 a day.^{3,4} Brazil's rapid economic development is reflected by equally significant health gains in the first two decades of the 21st century: mortality rates in the under-fives has more than halved and life expectancy has increased by 7 years in both men and women.^{5,6} A major contributing factor to Brazil's significant achievements in public health has been its Unified Health System (SUS), a public-private arrangement established in 1990.⁷ SUS provides universal free access to health services to all the Brazilian population funded largely by the government through tax revenue.⁸ Additional private health cover, which is beyond the means of the majority of the Brazilian population, has limited uptake.⁹

Increased life expectancy, however, has brought with it new challenges to Brazil's healthcare system, in the form of a growing demand from an aging population: between 2000 and 2015, the proportion of individuals over the age of 65 years in Brazil increased from 6% to 8%,¹⁰ during which time the years of life lost decreased by 4%, but this was more than outweighed by the years lost due to disability, which rose by more than 27%.¹¹ This phenomenon is not unique to Brazil but is representative of other major emerging economies such as India and China, the populations of which are experiencing major socioeconomic transitions.^{12,13}

Accurately quantifying the rate of hospital admissions associated with specific diseases and conditions, and its distribution, across the population is integral for efficient allocation of healthcare resources. This is particularly true for countries such as Brazil, which are transitioning from a healthcare system dominated by communicable diseases to one in which the demands of non-communicable illnesses are emerging.¹⁴ Most previous studies that have attempted to examine the burden of disease in Brazil have been confined to individual diseases in specific regions of the country,¹⁵⁻¹⁷

with no published data on rates of all-cause and cause-specific non-fatal health outcomes nationwide.

This study examines the geographic and demographic and temporal variations in the burden of hospital admissions through the SUS in Brazil between 2000 and 2015, including an analysis of hospital admission rates, length of stay, and direct healthcare costs due to different causes of disease. By providing a comprehensive evaluation of the changing nature of healthcare demands of the Brazilian population, we aim to provide policy-makers with the necessary information to help optimize the future allocation of resources within Brazil's healthcare system.

Results

In total, data from 1,816 out of 5,570 cities, covering 78.5% of the national population, contributed to this study (Table S1). The coverage of local population by the 1,816 cities ranged from 27% in the north to 87% in the southeast. As shown, the 1,816 cities had slightly higher GDP per capita and lower proportion of the elderly (≥ 60 years old) than the cities not included due to incomplete electronic records. Between 2000 and 2015, there were 148,069,974 hospital admissions due to 305 diseases or health-related issues with direct healthcare costs totaling \$59,939,359,097 after adjustment for the inflation rate.

Causes Excluding Mental and Behavioral Disorders and Diseases of the Nervous System

Hospital Admissions due to Level 1 Causes

Between 2000 and 2015, there were more than 136 million hospital admissions due to level 1 causes (Table S2). Cause-specific rates of hospital admissions by age groups are shown in Figure 1. The age-standardized rate (ASR) of hospital admissions decreased by 10.2‰ per decade from 69.8‰ in 2000 to 54.2‰ in 2015. For females, the ASR was higher at baseline but declined at a faster rate (14.4‰ per decade) than in males (5.8‰ per decade). ASRs for non-communicable diseases (NCDs)

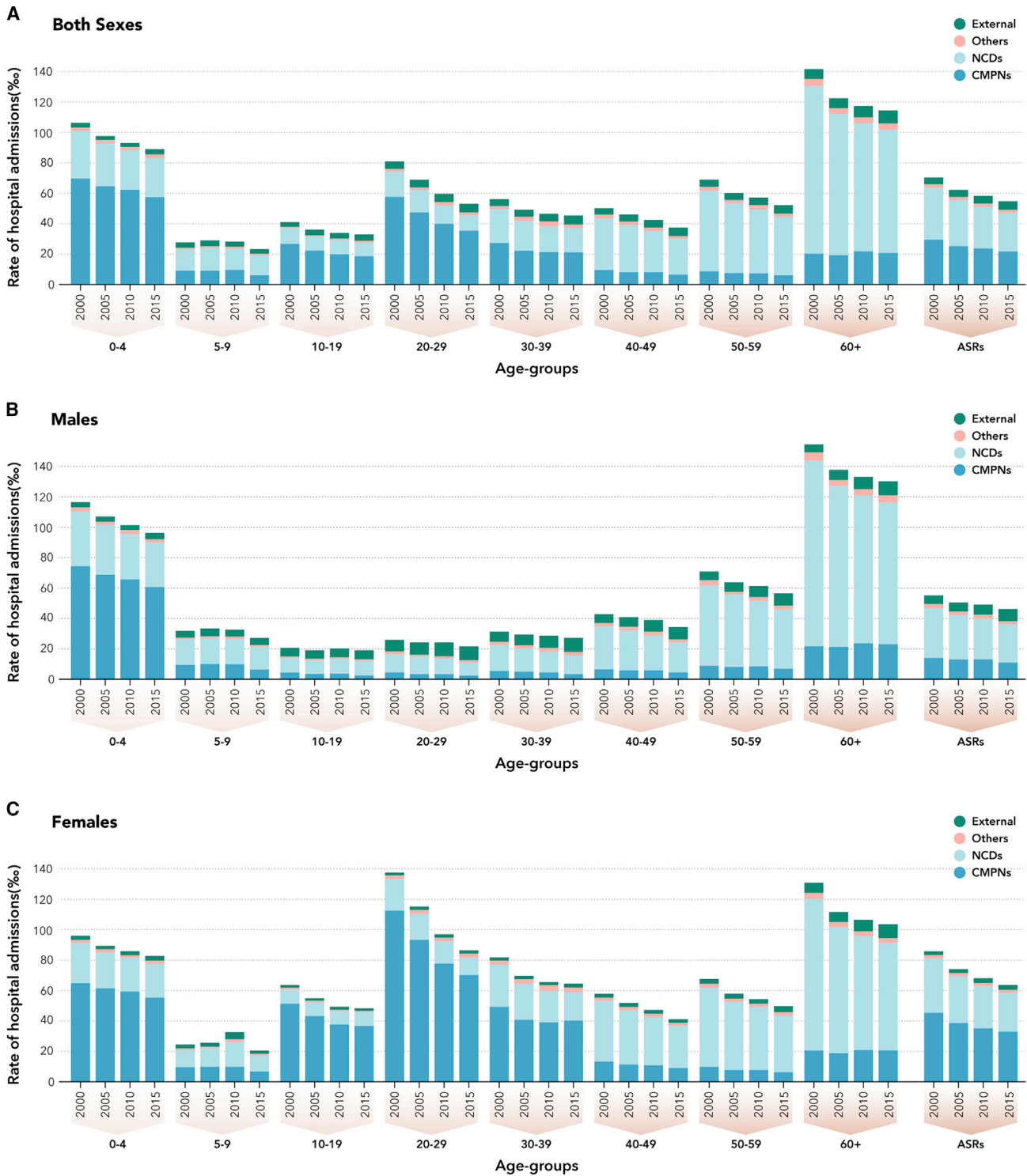


Figure 1 Rates of Hospital Admissions due to Specific Causes (Level 1) by Sex and Age Groups during 2000 to 2015 Excluding M&N Diseases

(A) For both sexes, (B) for males, and (C) for females. CMPNs refer to communicable, maternal, perinatal, and nutritional conditions. NCDs, non-communicable diseases; External, external causes; Others, other conditions. ASRs are provided.

and communicable, maternal, perinatal, and nutritional conditions (CMPNs) both decreased by 26% while ASRs

The rates of hospital admissions were four and five times higher for children aged 0–4 years (primarily from CMPNs) and those older than 59 years (primarily

from NCDs), respectively, compared with those aged 5–19 years (the age group with the lowest rate of admissions).

For patients hospitalized between 2000 and 2015, the total length of hospital stay was 825 million days with direct hospital costs totaling \$55 billion, with 90% attributable to NCDs and CMPNs. At the individual patient level, the mean direct healthcare costs per admission in 2015 equaled \$353, with an average length of stay of 5 days in hospital. At the population level, this is equivalent to an average healthcare expenditure for each resident of \$18.9 and 0.3 health days. Between 2000 and 2015, the costs per patient increased at a rate of \$23.5/year after adjustment for the inflation whereas the length of stay per patient decreased by 0.04 days/year. As a result, the healthcare expenditure for each resident increased by \$1.08/year, with NCDs accounting for 60% of the increase.

Hospital Admissions due to Level 2 Causes

Figure 2 summarizes the top ten level 2 causes of hospital admissions, accounting for approximately 90% of cases during 2000 to 2015 (see Table S3 for details of all 19 level 2 causes). The chief leading cause of admissions for males in 2015 was from injury and poisoning, with the ASR increasing 36% since 2000 to 7.4‰. Females were admitted to hospital primarily due to causes related to pregnancy, childbirth, and the puerperium (ASR in 2015: 21.7‰), although the ASR had decreased by one-third since 2000. For both males and females, admissions for respiratory, circulatory, and digestive diseases were ranked 2 to 4 in 2015. However, the ASRs of these diseases have declined by 17%–44% since 2000. Other leading causes of hospital admissions, for which there were notable increases in ASR over the same time period, were neoplasms, diseases of the skin and subcutaneous tissue (for males), perinatal conditions, and injury and poisoning (for females). For patients hospitalized in 2015, the top ten level 2 causes resulted in an average of \$357.7 direct healthcare cost and 5.2 days of hospital stay per patient, equating to \$17.1 and 0.25 days per Brazilian resident. Infants admitted to

hospital for perinatal conditions cost the most (\$777.5 and 10.0 days per patient). However, diseases of the circulatory system generated the largest burden for the Brazilian population compared with all other causes (\$3.9 and 0.04 days per resident).

Figure 3 shows the rates of the top ten level 2 causes by age groups in 2015 and the percentage change since 2000. For both sexes, respiratory and circulatory diseases were the primary causes of hospital admissions for children aged 0–9 years and those aged ≥ 50 years, respectively. Males aged 10–49 years were admitted to hospital mainly due to injury and poisoning, while for females, pregnancy, childbirth and the puerperium, and neoplasms were the most common causes. Hospital admission rates for skin problems and neoplasms increased for both sexes between 2000 and 2015, in particular in those aged 0–19 years and those ≥ 50 years. In comparison, the greatest increase in the rate of injury and poisoning occurred in those aged 20–49 years. Rates of hospital admissions due to circulatory and respiratory diseases showed the most substantial declines across most age groups and sex groups compared with other diseases.

Hospital Admissions due to Level 3 Causes

Figure 4 compares the top ten causes of hospital admissions for level 3 causes by sex between 2000 and 2015 (see Table S3 for details of all 288 diseases or health issues excluding mental and behavioral disorders and diseases of the nervous system [M&N diseases]). Admissions due to pneumonia dominated level 3 admissions in both sexes over the past 16 years. Gastrointestinal infections disappeared from the list of most common hospital admission causes. However, admissions for other bacterial diseases increased from the top 25 to the top nine. In 2015, the ten leading causes for males comprised three forms of injuries and two forms of heart disease, whereas four of the leading causes of admissions for females were associated with delivery and abortion.

Children and the elderly of both sexes were most likely to be admitted for pneumonia (Figure 5). Fractures of

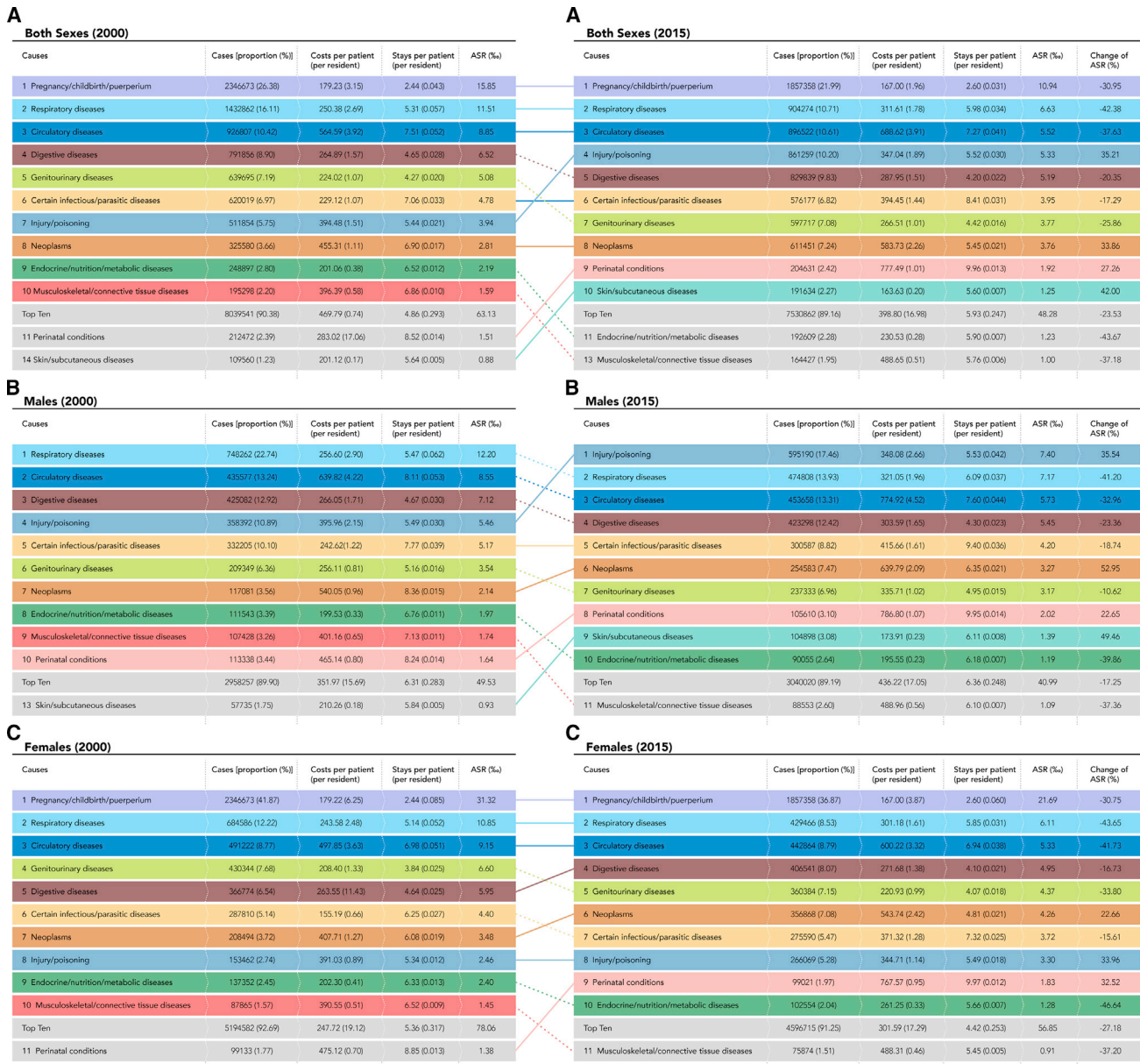


Figure 2 Top Ten Causes of Hospital Admissions (Level 2) by Sex during 2000 to 2015 Excluding M&N Diseases (A) For both sexes, (B) for males, and (C) for females. Ranks were sorted by the ASR. Proportion of cases is the proportion in all hospital admission cases. Costs and length of hospital stay per resident for both sexes, males and females, are calculated based on the number of populations within the specific groups. For the summaries of the top ten causes, costs and length of hospital stays per patient were the mean values, costs and length of hospital stays per resident were the aggregated values, and ASRs were the aggregated values.

other limb bones were the primary cause of hospital admissions for males aged 10–59 years. In females, the main cause of hospital admission varied by age groups: spontaneous delivery for those aged 10–39 years; leiomyoma of the uterus for those aged 40–49 years; and cholelithiasis/cholecystitis for those aged 50–59 years.

City-Specific Burden

Figure S1 shows the city-specific ASRs of hospital admissions occurring in 2015 and the associated costs and length of stay, and the change since 2000 for both sexes (see Figures S2–S11 for details of the ten leading level 2 causes). The ASR was highest in the south (70.2%) but lowest in the northeast (62.6%). Between 2000 and

A Both Sexes

Age group	1	2	3	4	5	6	7	8	9	10
0-4 years	Respiratory (29.99)	Perinatal (21.71)	Infection (12.29)	Digestive (4.61)	Genitourinary (3.87)	Congenital (3.30)	Injury (3.29)	Skin (2.28)	Endocrine (1.43)	Neoplasm (1.39)
5-9 years	Respiratory (6.44)	Injury (3.26)	Infection (3.10)	Digestive (2.99)	Genitourinary (2.01)	Neoplasm (1.02)	Skin (0.98)	Coongenital (0.80)	Endocrine (0.50)	Other (0.46)
10-19 years	Pregnancy (16.01)	Injury (4.06)	Digestive (2.43)	Genitourinary (2.01)	Respiratory (1.94)	Infection (1.73)	Neoplasm (0.94)	Skin (0.72)	Muscular (0.51)	Other (0.45)
20-29 years	Pregnancy (32.70)	Injury (5.61)	Digestive (3.14)	Genitourinary (2.60)	Infection (1.62)	Respiratory (1.34)	Other (1.25)	Neoplasm (0.92)	Circulatory (0.85)	Skin (0.72)
30-39 years	Pregnancy (17.86)	Injury (5.72)	Digestive (4.59)	Genitourinary (3.26)	Neoplasm (2.20)	Infection (2.14)	Other (2.08)	Circulatory (2.05)	Respiratory (1.58)	Muscular (0.97)
40-49 years	Digestive (5.71)	Injury (5.34)	Neoplasm (4.90)	Circulatory (4.57)	Genitourinary (3.78)	Infection (2.57)	Pregnancy (2.32)	Respiratory (2.12)	Muscular (1.28)	Other (1.14)
50-59 years	Circulatory (10.37)	Digestive (7.87)	Neoplasm (7.36)	Injury (5.80)	Genitourinary (4.45)	Respiratory (4.00)	Infection (3.53)	Muscular (1.83)	Endocrine (1.75)	Skin (1.55)
≥ 60 years	Circulatory (27.84)	Respiratory (16.51)	Neoplasm (13.13)	Digestive (11.93)	Genitourinary (9.10)	Injury (8.90)	Infection (8.78)	Endocrine (4.74)	Eye (2.92)	Skin (2.60)

B Males

Age group	1	2	3	4	5	6	7	8	9	10
0-4 years	Respiratory (32.93)	Perinatal (21.91)	Infection (12.82)	Digestive (5.69)	Genitourinary (4.41)	Congenital (3.97)	Injury (3.75)	Skin (2.43)	Endocrine (1.49)	Neoplasm (1.48)
5-9 years	Respiratory (6.88)	Injury (4.26)	Digestive (3.45)	Infection (3.23)	Genitourinary (2.82)	Neoplasm (1.10)	Skin (1.06)	Coongenital (1.06)	Other (0.58)	Endocrine (0.54)
10-19 years	Injury (6.30)	Digestive (2.55)	Respiratory (1.93)	Infection (1.71)	Genitourinary (1.52)	Neoplasm (0.98)	Skin (0.83)	Muscular (0.62)	Other (0.59)	Congenital (0.52)
20-29 years	Injury (9.00)	Digestive (2.70)	Infection (1.66)	Respiratory (1.37)	Genitourinary (1.18)	Other (0.94)	Muscular (0.91)	Skin (0.88)	Circulatory (0.74)	Neoplasm (0.70)
30-39 years	Injury (8.97)	Digestive (4.05)	Infection (2.38)	Other (1.78)	Circulatory (1.75)	Respiratory (1.68)	Genitourinary (1.67)	Muscular (1.23)	Neoplasm (1.05)	Skin (0.99)
40-49 years	Injury (8.05)	Digestive (5.78)	Circulatory (4.34)	Infection (2.97)	Respiratory (2.27)	Neoplasm (2.27)	Genitourinary (2.17)	Muscular (1.45)	Other (1.42)	Skin (1.17)
50-59 years	Circulatory (11.73)	Digestive (8.72)	Injury (7.91)	Neoplasm (6.31)	Respiratory (4.33)	Infection (4.07)	Genitourinary (3.69)	Endocrine (1.86)	Muscular (1.82)	Skin (1.76)
≥ 60 years	Circulatory (32.45)	Respiratory (18.49)	Neoplasm (15.61)	Digestive (14.45)	Genitourinary (10.78)	Infection (9.60)	Injury (9.16)	Endocrine (4.95)	Ab symptoms (3.00)	Skin (2.93)

C Females

Age group	1	2	3	4	5	6	7	8	9	10
0-4 years	Respiratory (26.91)	Perinatal (21.51)	Infection (11.73)	Digestive (3.48)	Genitourinary (3.31)	Injury (2.81)	Congenital (2.60)	Skin (2.13)	Endocrine (1.37)	Neoplasm (1.29)
5-9 years	Respiratory (5.98)	Infection (2.97)	Digestive (2.51)	Injury (2.22)	Genitourinary (1.17)	Neoplasm (0.92)	Skin (0.90)	Congenital (0.54)	Endocrine (0.47)	Ab symptoms (0.37)
10-19 years	Pregnancy (32.61)	Genitourinary (2.53)	Digestive (2.30)	Respiratory (1.95)	Infection (1.75)	Injury (1.73)	Neoplasm (0.90)	Skin (0.61)	Endocrine (0.43)	Muscular (0.41)
20-29 years	Pregnancy (65.90)	Genitourinary (4.04)	Digestive (3.60)	Injury (2.18)	Infection (1.59)	Other (1.57)	Respiratory (1.31)	Neoplasm (1.13)	Circulatory (0.97)	Skin (0.55)
30-39 years	Pregnancy (35.56)	Digestive (5.12)	Genitourinary (4.83)	Neoplasm (3.34)	Injury (2.50)	Other (2.37)	Circulatory (2.35)	Infection (1.90)	Respiratory (1.49)	Skin (0.74)
40-49 years	Neoplasm (7.43)	Digestive (5.65)	Genitourinary (5.32)	Circulatory (4.79)	Pregnancy (4.56)	Injury (2.73)	Infection (2.19)	Respiratory (1.96)	Muscular (1.11)	Endocrine (0.94)
50-59 years	Circulatory (9.12)	Neoplasm (8.33)	Digestive (7.09)	Genitourinary (5.15)	Injury (3.86)	Respiratory (3.69)	Infection (3.03)	Muscular (1.83)	Endocrine (1.65)	Skin (1.36)
≥ 60 years	Circulatory (24.23)	Respiratory (14.96)	Neoplasm (11.19)	Digestive (9.95)	Injury (8.70)	Infection (8.14)	Genitourinary (7.78)	Endocrine (4.57)	Eye (3.01)	Skin (2.34)

Percentage change in raw rates of hospital admissions (%) between 2000 and 2015
 ● -65.64, -49.88 ● -49.87, -36.48 ● -36.47, -23.96 ● -23.95, -11.56 ● -11.55, 4.45
 ● 4.46, 20.17 ● 20.18, 36.29 ● 36.30, 51.06 ● 51.07, 73.76 ● 73.77, 114.35

Figure 3 Top Ten Causes of Hospital Admissions (Level 2) by Age Groups during 2000 to 2015 Excluding M&N Diseases (A) For both sexes, (B) for males, and (C) for females. Raw rates of hospital admissions in 2015 are provided in parentheses. Percentage changes of rates since 2000 are colored by value ranges. Ab symptoms refers to symptoms, signs, and abnormal clinical and laboratory findings not elsewhere classified. Circulatory refers to diseases of the circulatory system. Congenital refers to congenital malformations, deformations, and chromosomal abnormalities. Digestive refers to diseases of the digestive (legend continued on next page)

2015, the largest decrease in ASR occurred in the north-east of Brazil (−26%) while the smallest reduction was observed in the north of the country (−9%). Both health-care expenditure per resident and increase in expenditure were highest in southern Brazil (\$25.2 in 2015 with \$1.6 annual increase) and lowest in the north (\$12.1 in 2015 with \$0.6 annual increase). On average, every resident in the south stayed 0.29 days in hospital (2015) compared with 0.24 days for those living in northeastern Brazil.

M&N Diseases

There were 11.8 million hospital admissions due to M&N diseases during 2000 to 2015, accounting for 8.0% of all cases, 8.7% of costs, and 72.5% of hospital stays. The estimated number of missing records in 2015 accounted for 9.9% of hospital admissions due to M&N diseases. Diseases of the nervous system, and mental and behavioral disorders, resulted in costs per patient of approximately \$375 and \$231, respectively. The corresponding lengths of stay in hospital were 11.8 and 37.6 days, respectively (Table S4). The ASRs of M&N diseases for males were nearly twice as high as those for females (Figure S12). Males aged 5–9 years and females ≥ 60 years were most likely to be admitted for diseases of the nervous system. Males aged 20–59 years had the highest rate of hospital admissions for mental and behavioral disorders.

Discussion

This is the first study to comprehensively examine nationwide trends in cause-specific rates of hospital admissions, length of hospital stay, and direct healthcare costs in the Brazilian population since the beginning of the 21st century. Between 2000 and 2015, there were more than 148 million hospital admissions associated

with more than 300 health-related outcomes costing the public health system more than \$59 billion. The cumulative length of stay in hospital totaled more than 825 million days, roughly equivalent to the sum in life expectancies of 110,000 Brazilians in 2015.⁶

Our analysis highlights the changing nature of the burden of disease across the Brazilian population as it evolves from one dominated by communicable, maternal, perinatal, and nutritional conditions to one where NCDs are emerging as the next biggest threat to the population's health. Overall, the cumulative number of hospital admissions was roughly equivalent to that of the total population from the 1,816 cities included in the study:¹⁸ at some point during 2000 to 2015, on average each resident was admitted to hospital at least once and spent 6 days in hospital at a total direct cost of \$400. However, the pattern of hospital admissions varied by region of the country: the ASR, costs per resident, and length of stay per resident were the highest in the south of Brazil but lowest in the north and northeast. The findings were consistent with data from the previous National Health Survey of 2013, which showed that the highest prevalence of a broad range of chronic diseases was in the south of the country.¹⁹ This is most likely explained by differences in population density and socioeconomic disparities across Brazil, with the south over-represented by the most socioeconomically disadvantaged groups and those most vulnerable to illness and injury relative to other areas of the country.

The ASR of hospital admissions declined by over one-fifth since 2000, primarily due to a decrease in admissions for maternal conditions as well as diseases of the respiratory and circulatory systems. This corresponds to a similar decline in mortality from NCDs, especially for cardiovascular and respiratory diseases.¹⁴ Patients

system. Endocrine refers to endocrine, nutritional, and metabolic diseases; Eye refers to diseases of the eye and adnexa. Genitourinary refers to diseases of the genitourinary system. Infection refers to certain infectious and parasitic diseases. Injury refers to injury, poisoning, and certain other consequences of external causes. Muscular refers to diseases of the musculoskeletal system and connective tissue. Neoplasm refers to neoplasms. Other refers to other causes. Perinatal refers to certain conditions originating in the perinatal period. Pregnancy refers to pregnancy, childbirth, and the puerperium. Respiratory refers to diseases of the respiratory system. Skin refers to diseases of the skin and subcutaneous tissue.

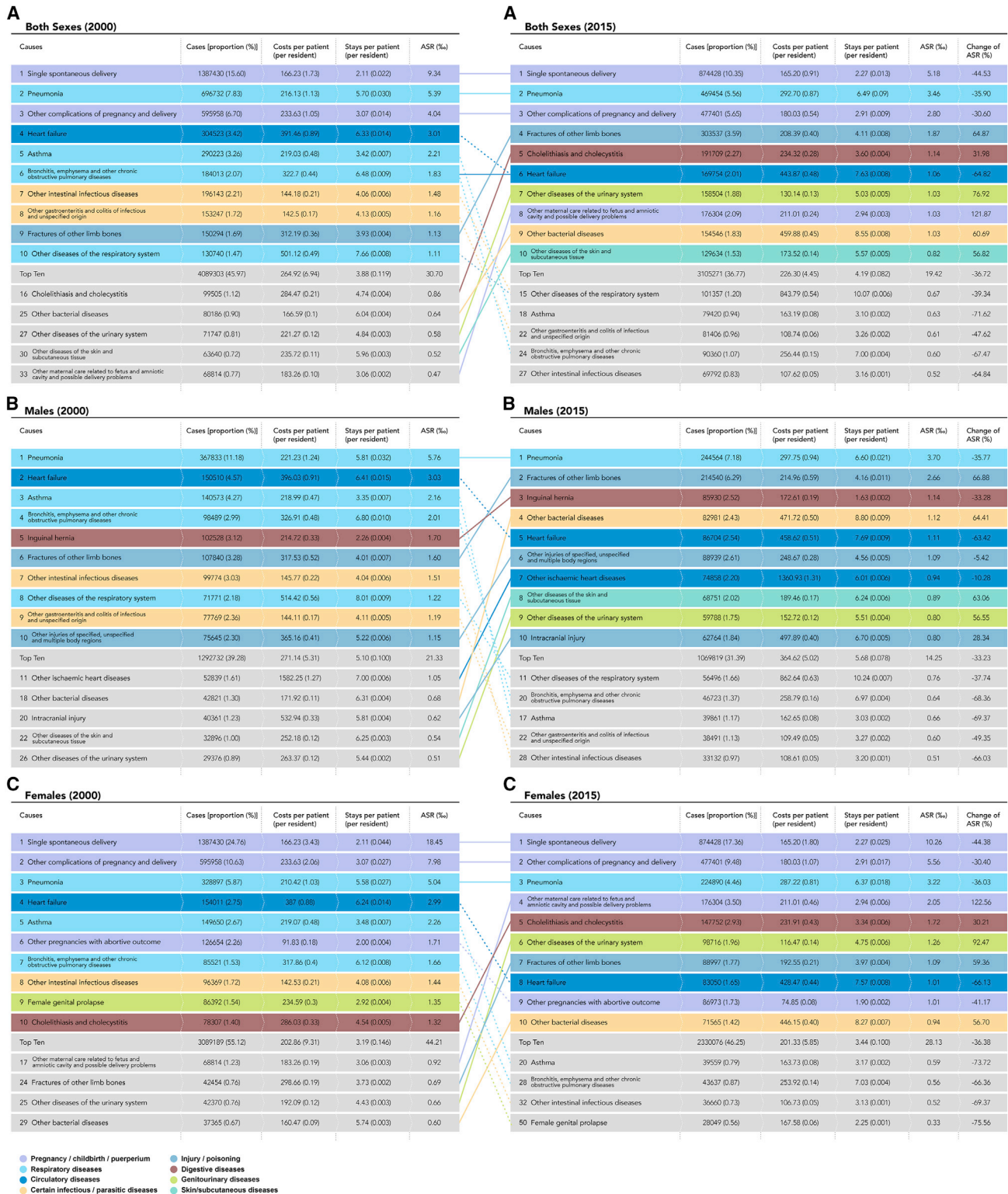


Figure 4 Top Ten Causes of Hospital Admissions (Level 3) by Sex during 2000 to 2015 Excluding M&N Diseases (A) For both sexes, (B) for males, and (C) for females. Ranks were sorted by the ASR. Proportion of cases is the proportion in all hospital admission cases. Costs and length of hospital stay per resident for both sexes, males and females, are calculated based on the number of populations within the specific groups. For the summaries of the top ten causes, costs and length of hospital stays per patient were the mean values, costs and length of hospital stays per resident were the aggregated values, and ASRs were the aggregated values.

A Both sexes

Age group	1	2	3	4	5	6	7	8	9	10
0-4 years	Pneumonia (14.5) Respiratory	O conditions (7.83) Perinatal	O respir disorders (4.54) Perinatal	F growth/malnutrition (4.57) Perinatal	A bron-chitis/ cholitis (4.11) Respiratory	Asthma (3.42) Respiratory	O gastroenteritis/colitis (3.03) Infection	O intestinal infections (2.44) Infection	O bacterial diseases (2.33) Infection	O urinary diseases (1.84) Genitourinary
5-9 years	Pneumonia (2.32) Respiratory	Fractures of O limb (1.70) Injury	C tonsils/adenooids (1.64) Respiratory	Asthma (1.33) Respiratory	Appendicidiseases (0.97) Digestive	Phimos (0.96) Genitourinary	O gastroenteritis/colitis (0.80) Infection	O intestinal infections (0.74) Infection	O bacterial diseases (0.74) Infection	O hernia (0.55) Digestive
10-19 years	Spontaneous delivery (8.74) Pregnancy	O pregnancy / delivery (3.72) Pregnancy	Fractures of O limb (1.75) Injury	O maternal care (1.30) Pregnancy	Appendicidiseases (1.11) Digestive	Pneumonia (0.65) Respiratory	O urinary diseases (0.58) Genitourinary	O injuries (0.57) Injury	Spontaneous abortion (0.51) Pregnancy	O abortions (0.50) Pregnancy
20-29 years	Spontaneous delivery (15.72) Pregnancy	O pregnancy / delivery (8.52) Pregnancy	O maternal care (3.17) Pregnancy	Fractures of O limb (2.09) Injury	O abortions (1.34) Pregnancy	Spontaneous abortion (1.15) Pregnancy	Oedema / proteinuria (1.05) Pregnancy	O injuries (0.93) Injury	Chole-lithias is /cys titis (0.83) Digestive	O puerperium /obstetric (0.82) Pregnancy
30-39 years	Spontaneous delivery (7.14) Pregnancy	O pregnancy / delivery (4.84) Pregnancy	Fractures of O limb (2.14) Injury	O maternal care (1.85) Pregnancy	Chole-lithias is /cys titis (1.47) Digestive	Contraception (1.44) Other	O abortions (1.15) Pregnancy	Spontaneous abortion (0.93) Injury	O injuries (0.93) Injury	Oedema / proteinuria (0.91) Pregnancy
40-49 years	Fractures of O limb (2.00) Injury	Chole-lithias is /cys titis (1.71) Digestive	Leiomyoma of uterus (1.43) Neoplasm	Pneumonia (1.05) Respiratory	O injuries (0.79) Injury	O skin / subcutaneous (0.78) Skin	O hernia (0.78) Digestive	Varicose Lextremities (0.74) Circulatory	Spontaneous delivery (0.70) Pregnancy	O bacterial diseases (0.69) Infection
50-59 years	Chole-lithias is /cys titis (2.19) Digestive	Fractures of O limb (4.49) Injury	Pneumonia (1.97) Respiratory	O IHDs (1.91) Circulatory	Heart failure (1.59) Circulatory	A myocardial infarction (1.27) Circulatory	O skin / subcutaneous (1.18) Skin	O bacterial diseases (1.14) Infection	Diabetes mellitus (0.72) Endocrine	Stroke (1.09) Circulatory
≥60 years	Pneumonia (9.74) Respiratory	Heart failure (4.37) Circulatory	Stroke (4.37) Circulatory	O IHDs (4.03) Circulatory	COPD (3.84) Respiratory	O urinary diseases (3.64) Genitourinary	O bacterial diseases (3.58) Infection	Diabetes mellitus (2.84) Endocrine	Sepsis (2.72) Infection	A myocardial infarction (2.44) Circulatory

B Males

Age group	1	2	3	4	5	6	7	8	9	10
0-4 years	Pneumonia (17.49) Respiratory	O conditions (7.48) Perinatal	O respir disorders (6.07) Perinatal	F growth/ malnutrition (4.57) Perinatal	F growth/ malnutrition (4.52) Perinatal	Asthma (4.04) Respiratory	O gastroenteritis/colitis (3.22) Infection	O intestinal infections (2.59) Infection	O bacterial diseases (2.44) Infection	Phimos (2.07) Genitourinary
5-9 years	Pneumonia (2.41) Respiratory	Fractures of O limb (2.30) Injury	Ph imo s is (1.87) Genitourinary	Asthma (1.87) Respiratory	Asthma (1.87) Respiratory	Appendicidiseases (1.18) Digestive	O gastroenteritis/colitis (0.82) Infection	O intestinal infections (0.77) Infection	O bacterial diseases (0.71) Infection	Inguinal hernia (0.68) Digestive
10-19 years	Fractures of O limb (2.89) Injury	Appendicidiseases (0.87) Digestive	O injuries (0.85) Injury	O maternal care (1.30) Pregnancy	Phimos (0.65) Genitourinary	Intracranial injury (0.53) Injury	O skin / subcutaneous (0.47) Skin	Specific health services (0.44) Other	O bacterial diseases (0.44) Infection	Fracture of femur (0.38) Injury
20-29 years	Fractures of O limb (3.39) Injury	O injuries (1.52) Injury	Appendicidiseases (0.85) Digestive	Fractures of O limb (2.09) Injury	O skin / subcutaneous (0.38) Skin	Specific health services (0.56) Other	Pneumonia (0.54) Respiratory	Fracture of femur (0.54) Injury	Dislocations /s grains (0.49) Injury	Injury of O organs (0.48) Injury
30-39 years	Fractures of O limb (3.40) Injury	O injuries (1.50) Injury	Contraception (1.01) Other	O maternal care (1.85) Pregnancy	Pneumonia (0.81) Respiratory	O skin/subcutaneous (0.68) Skin	Inguinal hernia (0.47) Digestive	Appendicidiseases (0.43) Digestive	O bacterial diseases (0.38) Infection	Specific health services (0.37) Other
40-49 years	Fractures of O limb (2.98) Injury	O injuries (1.26) Injury	Pneumonia (1.21) Respiratory	Pneumonia (1.05) Respiratory	O skin / subcutaneous (0.84) Skin	Intracranial injury (0.82) Injury	O bacterial diseases (0.81) Infection	O hernia (0.79) Digestive	Chole-lithias is /cys titis (0.74) Digestive	Specific health services (0.57) Other
50-59 years	Fractures of O limb (2.61) Injury	O IHDs (2.48) Circulatory	Pneumonia (2.23) Respiratory	O IHDs (1.91) Circulatory	Inguinal hernia (1.86) Digestive	A myocardial infarction (1.81) Circulatory	O bacterial diseases (1.33) Infection	O skin / subcutaneous (1.29) Skin	Stroke (1.28) Circulatory	Diabetes mellitus (1.25) Endocrine
≥60 years	Pneumonia (10.70) Respiratory	Heart failure (7.24) Circulatory	O IHDs (5.32) Circulatory	O IHDs (4.04) Circulatory	COPD (3.84) Respiratory	O urinary diseases (3.64) Genitourinary	A myocardial infarction (3.58) Circulatory	O bacterial diseases (3.42) Infection	Inguinal hernia (3.27) Digestive	Sepsis (3.00) Infection

C Females

Age group	1	2	3	4	5	6	7	8	9	10
0-4 years	Pneumonia (15.25) Respiratory	O conditions (8.13) Perinatal	O respir disorders (5.02) Perinatal	F growth/ malnutrition (4.63) Perinatal	A bron-chitis/ cholitis (3.42) Respiratory	Asthma (3.15) Respiratory	O gastroenteritis/colitis (2.84) Infection	O urinary diseases (2.37) Genitourinary	O intestinal infections (2.32) Infection	O bacterial diseases (2.22) Infection
5-9 years	Pneumonia (2.22) Respiratory	C tonsils / adenooids (1.53) Respiratory	Asthma (1.19) Respiratory	Fractures of O limb (1.07) Injury	O gastroenteritis/colitis (0.78) Infection	Appendicidiseases (0.74) Digestive	O intestinal infections (0.7) Infection	O bacterial diseases (0.64) Infection	O urinary diseases (0.60) Genitourinary	O hernia (0.53) Digestive
10-19 years	Spontaneous delivery (7.54) Pregnancy	O pregnancy / delivery (2.54) Pregnancy	O maternal care (2.44) Pregnancy	Spontaneous abortion (1.03) Pregnancy	O abortions (1.03) Pregnancy	O urinary diseases (0.94) Genitourinary	Appendicidiseases (0.82) Digestive	O puerperium /obstetric (0.62) Pregnancy	Oedema / proteinuria (0.59) Pregnancy	Obstructed labour (0.3) Pregnancy
20-29 years	Spontaneous delivery (31.68) Pregnancy	O pregnancy / delivery (17.18) Pregnancy	O maternal care (6.40) Pregnancy	O abortions (2.70) Pregnancy	Spontaneous abortion (2.23) Pregnancy	Oedema / proteinuria (2.11) Pregnancy	O puerperium/obstetric (1.66) Pregnancy	Obstructed labour (1.53) Pregnancy	Chole-lithias is /cys titis (1.48) Digestive	Contraception (1.16) Other
30-39 years	Spontaneous delivery (14.26) Pregnancy	O pregnancy / delivery (9.65) Pregnancy	O maternal care (3.68) Pregnancy	Chole-lithias is /cys titis (2.42) Digestive	O abortions (2.29) Pregnancy	Contraception (1.90) Other	Spontaneous abortion (1.86) Pregnancy	Oedema / proteinuria (1.82) Pregnancy	O puerperium /obstetric (1.00) Pregnancy	Leiomyoma of uterus (0.98) Neoplasm
40-49 years	Leiomyoma of uterus (2.81) Neoplasm	Chole-lithias is /cys titis (2.42) Digestive	Spontaneous delivery (1.38) Pregnancy	O pregnancy / deliver (1.18) Pregnancy	Varicose Lextremities (1.15) Circulatory	O genitourinary tract (1.12) Genitourinary	Fractures of O limb (1.07) Injury	Malignant breast Cancer (1.02) Neoplasm	Oncoplasms (0.91) Neoplasm	Pneumonia (0.91) Respiratory
50-59 years	Chole-lithias is /cys titis (1.73) Digestive	Pneumonia (1.73) Respiratory	Fractures of O limb (1.64) Injury	Malignant breast Cancer (1.54) Neoplasm	Varicose Lextremities (1.45) Circulatory	O IHDs (1.39) Circulatory	Heart failure (1.39) Circulatory	Oncoplasms (1.09) Neoplasm	O skin / subcutaneous (1.07) Skin	Diabetes mellitus (1.02) Endocrine
≥60 years	Pneumonia (8.98) Respiratory	Heart failure (5.90) Circulatory	Stroke (3.82) Circulatory	Chole-lithias is /cys titis (3.12) Digestive	O IHDs (3.07) Circulatory	Diabetes mellitus (2.83) Endocrine	O bacterial diseases (2.74) Infection	COPD (2.70) Respiratory	O urinary diseases (2.61) Genitourinary	Fracture of femur (2.50) Injury

Percentage change in raw rates of hospital admissions (%) between 2000 and 2015
 ● -72.50, -65.65 ● -65.64, -49.88 ● -49.87, -36.48 ● -36.47, -23.96 ● -23.95, -11.56 ● -11.55, 4.45
 ● 4.46, 20.17 ● 20.18, 36.29 ● 36.30, 51.06 ● 51.07, 73.76 ● 73.77, 114.35 ● >114.35

Figure 5 Top Ten Causes of Hospital Admissions (Level 3) by Age Groups in 2015 Excluding M&N Diseases

(A) For both sexes, (B) for males, and (C) for females. Crude rates of hospital admissions in 2015 are provided in parentheses. The level 3 categories of causes are provided under the parentheses in table cells. Percentage changes of rates since 2000 are colored by value ranges. A, acute; C, chronic; O, other. F growth/malnutrition refers to slow fetal growth, fetal malnutrition and

(legend continued on next page)

with M&N diseases contributed to very limited extent to overall hospital admissions and direct costs but incurred the greatest length of stay in hospital. The marked decrease in hospital admissions is unlikely to be explained by patients choosing to access private healthcare facilities given that private health insurance coverage did not increase significantly during this period.^{19,20} Although paradoxical to the aging progress of the Brazilian population, the decline in hospital admissions, especially for cardiorespiratory diseases, probably reflects a greater success in the early detection and management of non-fatal health outcomes. In 1994 Brazil launched the Family Health Strategy (FHS), a family-based and community-oriented program under the SUS that has been demonstrated to reduce avoidable hospitalizations by over 20% in some areas.^{20,21} The FHS comprises family healthcare teams that include a general practitioner, a nurse, a nurse assistant, and between four and six community health workers, providing primary healthcare services to up to 1,000 families. The coverage of FHS has grown markedly from 4% of the Brazilian population in 1998 to 63% in 2015 (70% in rural areas).²²

Another important component of the SUS since 2011 has been the updated Brazilian People's Pharmacy Program that provides free (or heavily subsidized) medications for a range of chronic diseases including asthma, diabetes, hypertension, and osteoporosis.²³ The development of treatment and medication adherence can improve patients' survival and thus reduce the risk of hospital admissions. For example, the use of β -blockers, implant-

able cardioverter-defibrillators, and other therapeutic strategies may partly explain the decline in admissions for heart failure, which dropped from top four to top eight from 2000 to 2015. Other widespread public health programs, including the introduction of tobacco control legislation and national screening programs for diabetes and hypertension,^{14,24,25} are also likely to have had a beneficial impact on the health of the population.

In addition to maternal, cardiovascular, and respiratory diseases, admissions for certain infectious diseases, particularly gastrointestinal infections, also declined between 2000 and 2015. The exception was for other bacterial diseases, which became one of the most common level 3 admission causes over the 16 years. The contrastingly changing nature of gastrointestinal and other bacterial infections is explainable. First, gastrointestinal infections accounted for half of infectious admissions in Brazil between 2000 and 2015, and thus might have attracted a larger amount of healthcare concern than other communicable diseases. Second, other bacterial diseases mainly comprise infections associated with soil contamination and livestock breeding, paralleling the rapid growth of agricultural productivity in Brazil during the same period.²⁶

In the current study, there was little evidence of a sex difference in the rate of hospital admissions (after excluding cases due to delivery), with rates close to 46 cases per 1,000 residents in 2015 in both sexes. Although in agreement with previous studies,^{27,28} compared with

disorders related to short gestation and low birth weight. O abortions refers to other pregnancies with abortive outcome. O gastroenteritis/colitis refers to other gastroenteritis and colitis of infectious and unspecified origin. O genitourinary tract refers to other disorders of genitourinary tract. O IHDs refers to other ischemic heart diseases. O injuries refers to other injuries of specified, unspecified, and multiple body regions. O maternal care refers to other maternal care related to fetus and amniotic cavity and possible delivery problems. O pregnancy/delivery refers to other complications of pregnancy and delivery. O puerperium/obstetric refers to complications predominantly related to the puerperium and other obstetric conditions not elsewhere classified. O respir disorders refers to other respiratory disorders originating in the perinatal period. O skin/subcutaneous refers to other diseases of the skin and subcutaneous tissue. Oedema/proteinuria refers to edema, proteinuria, and hypertensive disorders in pregnancy, childbirth, and the puerperium. Phimosis refers to redundant prepuce, phimosis, and paraphimosis. Specific health services refers to persons encountering health services for specific procedures and healthcare. Spontaneous delivery refers to single spontaneous delivery. Varicose L extremities refers to varicose veins of lower extremities.

females, males had higher rates of hospital admissions for diseases of the cardiovascular and respiratory systems. Admission due to injuries was also more common in males; indeed in males aged 10–49 years, injury was the leading cause of hospital admissions with rates increasing by 35% from 2000 to 2015. Even before 2000 this was a serious public health concern in Brazil, especially among young, black, and socially disadvantaged men who are the primary victims of community violence.²⁹ The reasons are complex and multifactorial but are likely to have their origins in sociobehavioral factors such as Brazil's high crime rates and high use of alcohol and illegal drugs in this population subgroup,^{30–32} as well as poor traffic safety measures.^{33,34}

Among females, there has been a marked decline in ASRs due to single spontaneous delivery and other complications of pregnancy and delivery between 2000 and 2015. This trend may indicate a combination of factors such as improved prenatal care in combination with a fall in fertility rate: the national coverage of prenatal care improved from 81% to 99% of new mothers between 2006 and 2012, with 75% of them financed by SUS.^{35,36} The birth rate in Brazil has decreased by 31% since 2000, with the annual population growth rate falling to 0.85% in 2015.^{37,38}

The age structure of the population is a crucial consideration for population health, as it is a major determinant the epidemiological patterns of a broad range of diseases.³⁹ In the current analysis, both infants (<5 years old) and the elderly (≥ 60 years old) had the highest rates of hospital admissions but exhibited the lowest decreases in the past 16 years. It is projected that Brazil's population will shrink 0.3% annually between 2043 and 2060 and that the proportion of the population aged ≥ 60 years will double to more than one-quarter of the total population.¹⁰ As elsewhere, Brazil's aging population will present unique and economically challenging problems to the public healthcare system as life expectancy continues to increase and the proportion of the population living into old age with chronic conditions increases.

This study has several limitations. First, we analyzed hospital admissions in 1,816 out of 5,570 cities, owing to a substantial number of missing records from 3,754 cities. The cities excluded from this study had relatively lower socioeconomic status than the cities included, which might have led to underestimation of the burden of hospital admissions for the whole Brazilian population. We could not explore this issue further due to the lack of other necessary information. However, the 1,816 cities comprised 78.5% of the national population, providing some reassurance that the results are extendable nationally. Second, data on medical records from private health insurance companies were not available for inclusion in the analysis. However, the high use of SUS and the low uptake of private insurance suggest that the current results portray an accurate and largely representative picture of hospital admissions over time in Brazil.^{20,40,41} Third, in the past decades, public health interventions (e.g., the FHS) have been developing consistently in Brazil at the level of the federal government.^{20–22} However, the implementation of these interventions may vary across regions or cities. Due to the lack of necessary information, we were unable to quantify their contributions to the declining trends of hospital admissions via time-series analysis. However, their effectiveness has been demonstrated by previous studies in Brazil.^{14,20,21,24,25} Finally, we were unable to include estimates of indirect costs associated with illness such as loss of income, provision of care by family members, and costs of any rehabilitation.

Conclusions

Since the beginning of the 21st century, Brazil has made substantial gains in several health indicators, most notably a marked increase in life expectancy. However, the rapid increase in life expectancy and Brazil's aging population presents significant and novel challenges to the country's public health system. Although rates of hospital admissions and length of stay have decreased annually since 2000, direct healthcare costs have risen. CMPNs still account for the majority of admissions, but NCDs are increasingly more common. Circulatory

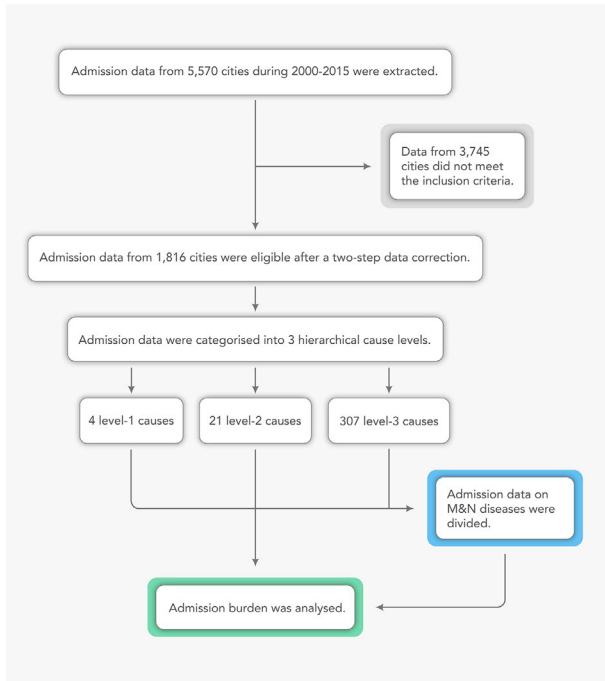


Figure 6 Flow Chart of Data Cleaning and Analysis

M&N diseases refer to mental and behavioral disorders and diseases of the nervous system.

diseases generate the largest financial burden, and M&N diseases account for the greatest number of days spent in hospital. In young males, admissions due to injury continue to remain a major public health concern. Age, sex, and regional variation in cause-specific hospital admissions suggest the need for specific tailoring of public health programs and preventive strategies in order to optimize healthcare utilization in the Brazilian public healthcare system.

Material and Methods

Data Collection

Data on nationwide hospital admissions were collected from SUS between January 1, 2000 and December 31, 2015. Variables included patient's age, sex, city of residence, reason for hospital admission (primary diagnosis), dates of admission and discharge, and hospital costs (US dollars). The primary diagnosis was coded using the 10th version of the International Classification of Diseases (ICD-10).

Annual data on city-specific population size were obtained using linear inter/extrapolation based on the Brazilian Census 2000 and 2010 datasets (<http://www.ibge.gov.br/censo/>; <http://www.censo2010.ibge.gov.br/>). The initial analysis indicated a 99% agreement between

our estimates of the national population with projections made by the Brazilian Institute of Geography and Statistics. In this study, sex-specific standardized populations were determined using the World Standard Population Distribution (2000–2025)⁴² and sex ratios taken from the Brazilian Census.

Data Analysis

Figure 6 summarizes the main steps of data cleaning and analysis. Details are given in [Supplemental Information](#). Hospital admissions were categorized using a three-level hierarchical system: level 1 comprised four categories: (1) CMPNs; (2) NCDs; (3) external causes; and (4) other conditions. Grouping of ICD-10 codes within the first three categories followed the revised tabulation list for global health estimates,^{43,44} with the remainder defined as the fourth category (Table S5). At level 2, there were 21 categories grouped according to the body systems (Table S6). Causes at level 2 were subdivided into a level 3 hierarchy according to the revised tabulation list for morbidity of ICD-10,⁴⁵ which contains 307 types of diseases or health conditions (Table S7).

Annual counts of cases, crude rates, and ASRs of hospital admissions due to all causes and cause-specific were calculated per year. The associated direct healthcare costs (US dollars) and length of stay (days) in hospital were aggregated by the year of admission, with the former adjusted for the inflation of US dollars in 2015. Direct healthcare costs and length of stay per admission, and the values per resident, were used to describe trends in the healthcare burden associated with specific causes. We calculated the annual change in ASRs, costs, and length of hospital stay using linear regression to describe the trends over the previous 16 years. Stratum analyses were performed by age-, sex-, region- and cause-specific groups. Patient age was classified into eight groups (ages 0–4, 5–9, 10–19, 20–29, 30–39, 40–49, 50–59, and ≥ 60 years), which is consistent with demographic groups of the Brazilian Census 2000 and 2010. Although some diseases are sex specific, the relevant hospitalization burdens on the whole population were still quantified and compared with other diseases in order to fully evaluate the changing nature of hospital admission in Brazil.

Hospital admission data associated with M&N diseases varied widely, particularly for the costs and length of stay. This variability resulted in model instability for describing the annual change in all-cause hospital admissions. Hence, admissions due to M&N diseases were excluded from the main analysis and reported separately.

Supplemental Information

Supplemental Information can be found online at <https://doi.org/10.1016/j.xinn.2020.04.013>.

Acknowledgments

We thank the Brazilian Ministry of Health for providing data on hospital admissions. Q.Z. was supported by a Monash Graduate Scholarship, Monash International Postgraduate Research Scholarship, and Monash Postgraduate Publications award. S.L. was supported by an Early Career Fellowship of the Australian National Health and Medical Research Council (APP1109193). Y.G. was supported by a Career Development Fellowship of the Australian National Health and Medical Research Council (APP1107107 & APP1163693). The funders of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the paper.

Declaration of Interests

The authors declare no competing interests.

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