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Research Article

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Contents

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Abstract

BACKGROUND
Age misreporting affects population estimates at older ages. In Brazil, every citizen must be registered and show an identity document to vaccinate against COVID-19. This requirement to present proof of age provides a unique opportunity for measuring the oldest-old population using novel administrative data.

OBJECTIVES
To offer critically assessed estimates of the Brazilian population aged 80 and older based on data from the vaccination registration system (VRS). To uncover discrepancies between the number of vaccinated oldest-old people and the projections used to estimate target populations for COVID-19 vaccination.

METHODS
We calculate data quality indicators based on data from the VRS – namely, 100+/80+ and 90+/80+ population proportions, sex ratios, and the Myers blended index – and compare them to those based on data on target populations from Brazilian censuses and demographic projections, and from Sweden – a country with high-quality data. We also estimate vaccination coverage ratios using population projections adjusted to excess deaths as the denominators.

RESULTS
Requiring documentation reduces age heaping, age exaggeration, and sex ratios marginally. However, it cannot solve the problem of the misreporting of birth dates due to the absence of long-standing birth registration systems in Brazil, particularly in the

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northern and central regions. In addition, we find a mismatch between the projected populations and numbers of vaccinated people across regions.

CONCLUSIONS
Despite improvements in data quality in Brazil, we are still not confident about the accuracy of age reporting among the oldest old in the less advantaged Brazilian regions. The postponement of the 2020 census reduced the ability of authorities to define the target populations for vaccinations against COVID-19 and other diseases.

CONTRIBUTIONS
This is the first study to compare population estimates for the oldest old in administrative data and census data in Brazil. Age misreporting resulted in discrepancies that may have compromised the efficacy of the COVID-19 vaccination campaign.

1. Introduction

Age is a fundamental characteristic in population studies. In countries with poor-quality data, the misreporting of age has many critical implications. The reported number of elderly people is usually implausibly high in such countries, distorting mortality estimation at older ages. In addition, biased estimates of population age distributions affect public and non-public planning efforts that seek to target specific population subgroups.

The degree of age misreporting varies across data sources, countries, population subgroups, and periods (Coale and Kisker 1986; Dechter and Preston 1991; Elo and Preston 1994; Preston, Elo, and Stewart 1999; Newman 2018; Ouedraogo 2020). Research has attributed age misreporting to factors such as delayed birth registration, memory recall problems, proxy reporting, and low numeracy and literacy. To mitigate the risk of age misstatement, most household surveys and administrative records have replaced the question about the individual's age in completed years with a question about the individual's birth date. However, the absence of long-standing birth registration systems in some places can make it challenging for people living in those areas – particularly older adults of low socioeconomic status – to recall their actual birth dates.

In Brazil, demographic data are not free of age misreporting. Although age heaping has become less common, there is growing evidence of age exaggeration at older ages. Studies show that the number of centenarians reported in censuses and death certificates is implausibly high (Gomes and Turra 2009; Nepomuceno and Turra 2020). In addition, because of age misreporting in population and death data, mortality rates at the oldest ages appear to be lower in Brazil than in countries where the data quality is good (Turra 2012; di Lego, Turra, and Cesar 2017; Nepomuceno and Turra 2020). Earlier analyses have detected similar misreporting patterns in other Latin American countries, although the age at which the distortions begin may vary across populations (Dechter and Preston 1991; Rosenwaike and Preston 1984; Grushka 1996; Glei et al. 2021).

To determine the correct ages of adults whose ages seem to have been misreported, demographers have used historical census data to track events and reports from the first years of the life of these individuals (Preston et al. 1996). Unfortunately, historical census microdata are missing for many places, including Brazil. Alternatively, researchers have used statistical and demographic methods to adjust current population and death counts based on model age patterns (Carrier and Farrag 1959; Siegel and Swanson 2004; Helleringer et al. 2019; Palloni, Beltrán-Sánchez, and Pinto 2021). To identify the most appropriate methodological solution, researchers must assess the extent of age misreporting in the available data. Since more data generally means more information, the introduction of any new database that keeps birth date records can improve our knowledge about age misreporting in countries with poor data quality.

During a global public health crisis, such as the COVID-19 pandemic, the demand for information increases, and there are opportunities for building new databases. In Brazil, the start of the vaccination campaign marked the beginning of the collection of new administrative data. The National Plan for Operationalization of the Vaccine against COVID-19, implemented by the federal government, specified many priority groups, including individuals aged 60 and older (Brasil 2021b). The Brazilian government used various data sources to estimate target populations based on the prioritization criteria. According to official documents, 77,279,644 individuals were prioritized when vaccination started in Brazil. Of these individuals, 30,197,052 were aged 60 and older. Every citizen who wanted to be vaccinated had to be registered in the Ministry of Health (MoH) data system and show an identity document.

The requirement that an individual had to show proof-of-age documentation when seeking to vaccinate against COVID-19 has provided researchers with a unique opportunity to measure the elderly population in Brazil, as it led to the creation of a new database. It is unclear how much age exaggeration persists when age distribution is measured using administrative records like those from the National Vaccination Plan in Brazil. We hypothesize that requiring individuals to present identity documents can mitigate age misreporting that can occur when response errors are made due to memory recall problems, proxy reporting, or low numeracy and literacy levels. However, we recognize that this requirement cannot solve the problem of individuals providing the wrong birth date because their birth registration was incorrect. Therefore, we expect that while the age distributions reported in the COVID-19 vaccination database are not perfect, they are more accurate than those reported in the official population census and population estimates based on data sources that are more vulnerable to reporting errors.

This article has two main objectives. The first is to offer new, critically assessed estimates of the oldest members of the Brazilian population: men and women aged 80 years and older. To do so, we calculate different demographic indicators using data from the vaccination registration system. We then compare these indicators to those derived from the target population estimates of the National Vaccination Plan, censuses and population projections for Brazil, and indicators for Sweden, a country with high-quality population data. Since age misreporting is associated with socioeconomic conditions, we look at the results for Brazil broken down by region.

The second objective is to uncover potential discrepancies between the number of the oldest-old people in Brazil who have been vaccinated and official estimates used by the Brazilian public health authorities to calculate target populations. During the COVID-19 pandemic, the Brazilian Census Bureau (IBGE) postponed the collection of the 2020 census data to 2022. Thus, the vaccination campaign and other planning programs that needed population counts had to rely on population projections. However, demographic projections are not definitive, as they can reflect errors in the projection methodology and input data. The most recent projections for Brazil are based on baseline demographic data that date back to the 2010 census. Data errors, including age misreporting, may have decreased as new cohorts have reached higher ages. Conversely, the vaccination records reflect the current demographic conditions and the use of documentation that provides proof of age. Thus, we expect to find discrepancies between the numbers of the oldest-old individuals who were targeted and those who were vaccinated. Since the quality of the demographic data varies across Brazilian regions, consistency in the numbers of targeted individuals and vaccinated subgroups may differ by region, and this could compromise the vaccination campaign's efficacy and speed.

2. Materials

2.1 Vaccination data

For our analysis, we drew upon data from the Brazilian Ministry of Health's open microdata registers for the national COVID-19 vaccination campaign (Brasil 2021a). We used vaccination registers that were compiled from the official start of the campaign (January 18, 2021) to March 14, 2022. The database includes anonymized information on individuals who received first, second, third, fourth, or single doses of any COVID-19 vaccine. It also includes information on each vaccinated person's age, date of birth, sex, race, type of dose, vaccination group (e.g., health worker, age group), city/state of vaccination, and city/state of residence, and the name and developer of the vaccine the individual received. Although some of the individuals in our sample may have died between the beginning of the vaccination campaign in January 2021 and March 14, 2022, we cannot identify who they are. To minimize the mortality effect and to make the estimates based on the vaccination records more comparable to the population projections, we estimated the vaccinated population as of July 1, 2021.

The initial database comprises 387,750,333 records. We considered only those aged 80 and older who received the first or a single dose of any COVID-19 vaccine in Brazil and its regions by sex and single age. Thus, we limited the database to 4,630,733 individuals. Of this total, 215,262 records appear more than once for unique anonymized patients (92.1% of the records appear twice, 3.7% appear three times, and 4.3% appear four times or more). We fixed these issues by keeping the record with the earliest vaccination date for each unique patient identity. After we cleaned multiple records, the database consisted of 4,518,183 records (97.56% of the original number). We excluded records that had missing sex information (18; 0.0004%) and vaccination dates before January 18, 2021 (431; 0.0954%). There were also records with December 30, 1899, birthdates (which would make the individuals 121 years old) in the missing (49; 0.0011%) and health care worker vaccination categories (2,892; 0.064%). We believe this is the system default for dealing with cases with unknown birth dates and excluded these records from our database, as we assume they are not those of centenarians. The excluded sets intersect. Consequently, the total number of excluded cases (because the person had missing sex information, had a vaccination date before January 18, 2021, belonged to a missing vaccination category, or was a health care worker born on December 30, 1899) is just 3,385 (0.075%). Last, another 33,655 (0.74%) records had a missing state of residence. We corrected them by obtaining the state of residence from information on the state of vaccination, which had no missing values. Our final database consists of 4,514,798 individuals aged 80 years and older, including 2,796,476 females and 1,718,322 males.

2.2 Population estimates

We compared records for the vaccinated population with estimates for the Brazilian and Swedish populations aged 80 years and older. The Brazilian estimates include (1) the target population for COVID-19 vaccination as defined by the MoH (Brasil 2021b); (2) population projections prepared by the Brazilian Institute of Geography and Statistics (IBGE 2018); (3) population projections from the United Nations (United Nations 2019)[4]; and (4) Brazilian censuses from 1980 to 2010 (Minnesota Population Center

[4] We use the 2019 version instead of the 2022 version of the UN projections because the latter was published after our article was completed. While the UN population estimates for older adults differ between the two versions, they do not alter our primary conclusions.

2020). The Brazilian population estimates are presented according to different age configurations: five-year age groups (target population, IBGE, and UN projections) and single years of age (census data). The definition of the last open-ended age group also varies. It is 90 and older for the target population and the IBGE projections, and it is 100 and older in the census data and the UN projections. In most data sources (census data, IBGE projections, and UN projections), the population data are disaggregated by sex. In some (census data and IBGE projections), the population data are broken down by region. The data for Sweden were drawn from the Human Mortality Database (2021). We used Swedish raw data for the 1992–2019 period that include population by sex and single year of age up to 110 and older.

The IBGE and the United Nations prepared the population projections before the COVID-19 pandemic started. Thus, we subtracted the estimated number of excess deaths caused by the pandemic – between July 1, 2020, and July 1, 2021 – from the original figures. The Conselho Nacional de Secretários de Saúde (CONASS) has estimated different distributions of excess deaths in Brazil, including the proportions by age group, sex, and region of residence, and absolute numbers by epidemiological week and region of residence. Since the oldest age group used in the CONASS (2021) is 60 and older, we assumed that the relative estimates also apply to the 80 and older age group. After combining the various distributions, we calculated the proportions of excess deaths for men and women aged 80 and older living in Brazil and in its five regions between July 1, 2020, and July 1, 2021. We then multiplied the estimated proportions of excess deaths by the number of implicit deaths in each corresponding subgroup of the population projections. The result is the number of individuals subtracted from the projected population numbers for July 1, 2021, which includes the impact of the COVID-19 pandemic.

2.3 Measures

To address the first objective of the article, we tabulated population numbers by age group, sex, and Brazilian region (North, Northeast, Midwest, Southeast, and South). We then calculated the age proportions at older ages (100+/80+ and 90+/80+) and compared them across the different data sources. Next, we estimated the blended Myers index (Myers 1954; Siegel and Swanson 2004) to measure levels of age heaping for ages 80 to 99 in the vaccination records and the 1980–2010 Brazilian censuses by sex and by region. Moreover, since men are more likely to misreport age than women in Brazil (Nepomuceno and Turra 2020), we calculated the sex ratios by single age. We compared the sex ratios for the vaccinated individuals across the Brazilian regions with those estimated based on data from the 2010 census in Brazil and Sweden. Finally, to better understand Brazil's regional distribution of errors, conditional on mortality levels, we plotted the age proportions at older ages for the vaccinated population and Sweden against life expectancy at age 50 (e(50)) (IBGE 2018; Human Mortality Database 2021).

For the study's second objective, we estimated vaccination coverage ratios using IBGE population projections as the denominators, adjusted for excess deaths. We calculated the coverage ratios by sex and age group (80–84, 85–89, 90+) across Brazil's five regions. The R code and the data to reproduce the analysis are available at: https://github.com/demographyandme/covid-19-datasus-vacina.

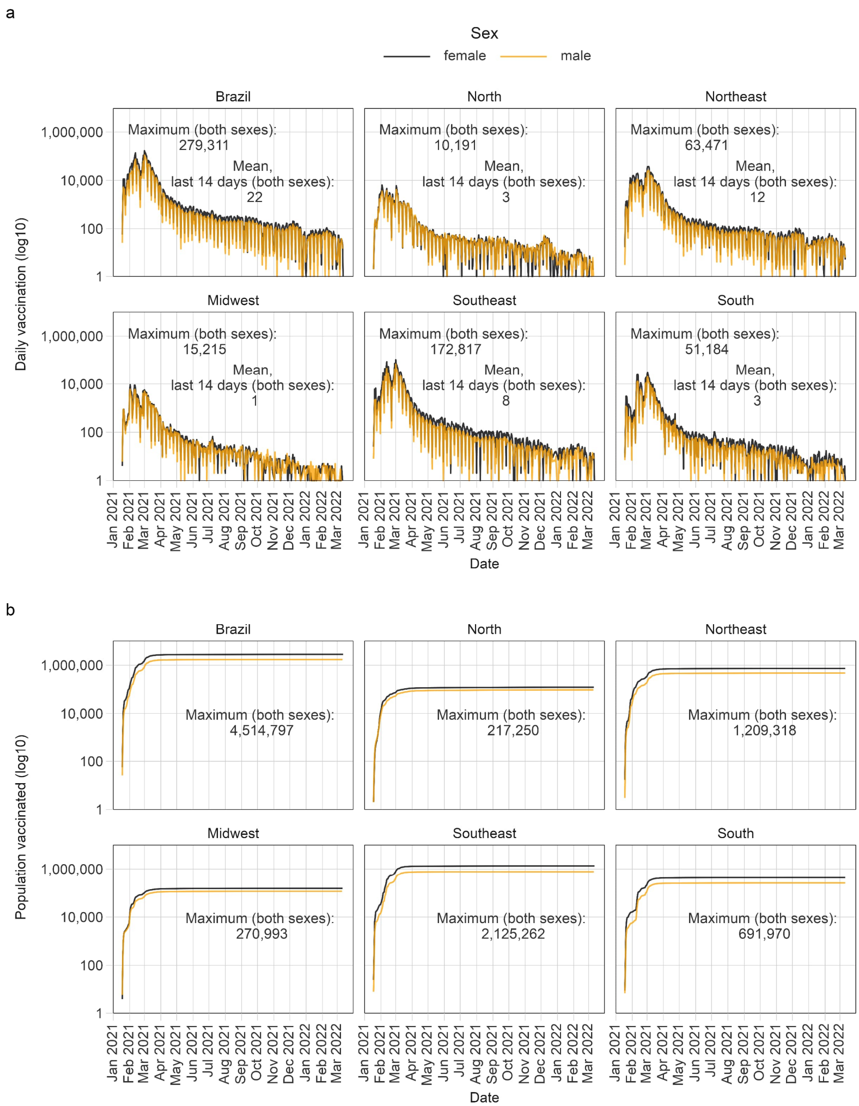
3. Results

3.1 Age-sex distributions in the vaccination records

Brazil's national COVID-19 vaccination campaign started in January 2021 with efforts to vaccinate the oldest groups and is still under way. Figure 1 shows the evolution of the daily vaccination count and the vaccinated population over age 80 in Brazil and its regions. The results are only for the first dose or a single dose. We display the results on a log scale since they vary substantially in size across the country. The patterns of daily vaccination rates and the vaccinated population are similar across the regions. Fluctuations in the number of daily vaccinations are due to differences in numbers on the weekends. The highest numbers of daily vaccinations were at the beginning of March 2021, at around 280,000. Between March 7, 2022, and March 12, 2022 – the last week before our database cutoff date – the daily growth rates for the vaccinated population were nearly stable, oscillating at around 0.0015%. Therefore, we anticipate that the number of records will undergo only slight variations in future versions of the database.

Table 1 compares the age proportions at older ages for the vaccinated population and the Brazilian population for 2021 as estimated by different sources. In the official estimates, the proportion of individuals aged 90 and older (90+/80+) is either 0.201 (MoH) or 0.181 (IBGE). By contrast, the proportion in the UN estimates is much lower (0.163), which suggests that the age distribution is younger than that reported in the official Brazilian figures. In the vaccination records, the proportion is 0.175 and is thus lower than the measures calculated based on the MoH and IBGE projections. Therefore, while the proof-of-age requirement has not eliminated age exaggeration among the vaccinated, it has probably occurred on a smaller scale than in the other Brazilian data. However, the differences between the vaccination records and the UN estimates increase at the oldest ages, as the proportion of centenarians in the vaccination records is twice as high as that in the UN projections.

Figure 1: Daily vaccination counts and the population vaccinated with a first or a single dose (log10). Men and women aged 80 and older. Brazil and its regions



Source: Prepared by the authors based on Brasil (2021a).

Table 1: Population age distributions at ages 80 and older by sex. Brazil. Selected data sources

Open-ended age groups, proportion and absolute values by sex	Vaccine records as of March 14, 2022, age adjusted to July 1, 2021	Population estimates				
		MoH target estimates	IBGE rev. 2018		United Nations Population Division rev. 2019	
			Original projections as of June 12, 2021	Adjusted to excess deaths	Original projections as of June 12, 2021	Adjusted to excess deaths
Proportion 90+/80+						
Both sexes	0.175	0.201	0.185	0.181	0.167	0.163
Women	0.190	-	0.202	0.198	0.184	0.180
Men	0.150	-	0.158	0.153	0.138	0.134
Proportion 100+/80+						
Both sexes	0.010	-	-	-	0.005	0.005
Women	0.011	-	-	-	0.006	0.006
Men	0.007	-	-	-	0.004	0.003
80+						
Both sexes	4,514,798	4,441,046	4,617,408	4,469,078	4,375,134	4,239,494
Women	2,796,476	-	2,862,715	2,783,524	2,738,251	2,665,197
Men	1,718,322	-	1,754,693	1,685,554	1,636,883	1,574,296
90+						
Both sexes	788,048	893,873	856,211	809,543	730,167	689,864
Women	531,005	-	578,698	551,016	503,996	479,107
Men	257,043	-	277,513	258,527	226,171	210,757
100+						
Both sexes	44,159	-	-	-	23,804	21,194
Women	31,420	-	-	-	17,502	15,694
Men	12,739	-	-	-	6,302	5,501

Source: Prepared by the authors based on Brasil (2021a), Brasil (2021b), CONASS (2021), IBGE (2018), and United Nations (2019).

Next, we compare the vaccination records with census data collected in earlier decades. Table 2 shows that the degree of age heaping, measured by the Myers summary preference index (ages 80–99), was roughly halved between the 1980 and 2010 censuses across all regions. Nonetheless, in all regions, age heaping is noticeably lower in the vaccination records than in any of the earlier censuses. It is, for example, 8% (Northeast) to 37% (Southeast) lower in the vaccination records than in the 2010 census data. Since the vaccination records were collected 12 years later than the census, it is unclear whether this reduction in age heaping is simply following historical trends. However, considering that digit preference was already low in 2010, our results suggest that proof-of-age requirements may have a favorable effect. Despite the improvements in data quality, regional differences in age heaping have persisted across time and data sources. The index has been historically worse in northern and central states due to the worse socioeconomic conditions in those areas.

Table 2: Myers index (ages 80–99) and the proportion of centenarians per 100 persons 80+ (100+/80+). Brazilian regions. Vaccination records (2021) and census data (1980–2010)

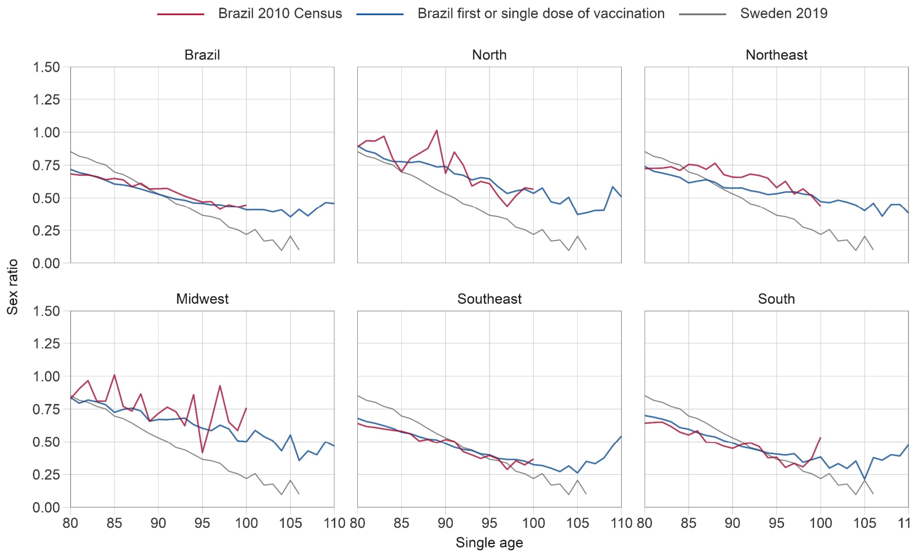
Data/Year	Regions/Measures									
	North		Northeast		Midwest		Southeast		South	
	Myers Index	100+/80+	Myers Index	100+/80+	Myers Index	100+/80+	Myers Index	100+/80+	Myers Index	100+/80+
Census Data										
1980	8.8	2.71	10.1	2.06	8.4	3.49	6.7	1.43	6.4	1.92
1991	5.0	1.97	7.0	1.42	4.9	1.73	4.8	1.14	3.1	1.23
2000	4.9	2.44	4.2	1.44	3.6	2.10	4.2	1.36	5.2	1.17
2010	4.3	1.29	3.8	1.17	4.8	0.85	3.8	0.55	3.3	0.51
Vaccination records										
2021	3.2	1.76	3.5	1.65	3.8	0.88	2.4	0.67	2.6	0.55

Source: Prepared by the authors based on Brasil (2021a) and Minnesota Population Center (2020).

The proportion of centenarians per 100 persons 80+ also declined substantially across the regions (43% to 76%) between 1980 and 2010, which confirms that there were improvements in the census data. Surprisingly, there are relatively more centenarians in the vaccination records than in the 2010 census data. In particular, when calculated from vaccination records, the 100+/80+ population proportions are 22% higher in the Southeast, 36% higher in the North, and 41% higher in the Northeast. They are about the same in the two data sources in the South and Midwest. Is age exaggeration worse in the vaccination records than in the 2010 census data? The answer is “probably not.” Age misreporting is not the only factor responsible for differences in the age distribution at the oldest ages. Mortality trends also influence the proportion of centenarians per 100 persons 80+. The United Nations estimated that Brazil’s 100+/80+ population proportion increased about two times between 2010 and 2021, primarily because of survival gains at older ages (United Nations 2019). This rate of growth is higher than the variations observed in Table 2. Therefore, the proportion of centenarians in the vaccination records would have been lower than that of the 2010 census data if mortality had not declined over the last decade.

The sex composition of the oldest-old population is also related to the quality of age reporting. If men are more prone to misreport age, sex ratios will be biased. Figure 2 shows the sex ratios calculated from the vaccination records (2021), the Brazilian census data (2010), and the Swedish data (2019). Compared to the census data, the vaccination records show smoother patterns and lower sex ratios, particularly in the North, Northeast, and Midwest. However, the sex ratios calculated for Brazil from the census data and the vaccination records decline with age at a slower pace than the sex ratios calculated for Sweden. This pattern probably reflects more intense age misreporting among Brazilian men, regardless of the data source, since it is unlikely they have relatively higher chances of surviving to older ages than Swedish men.

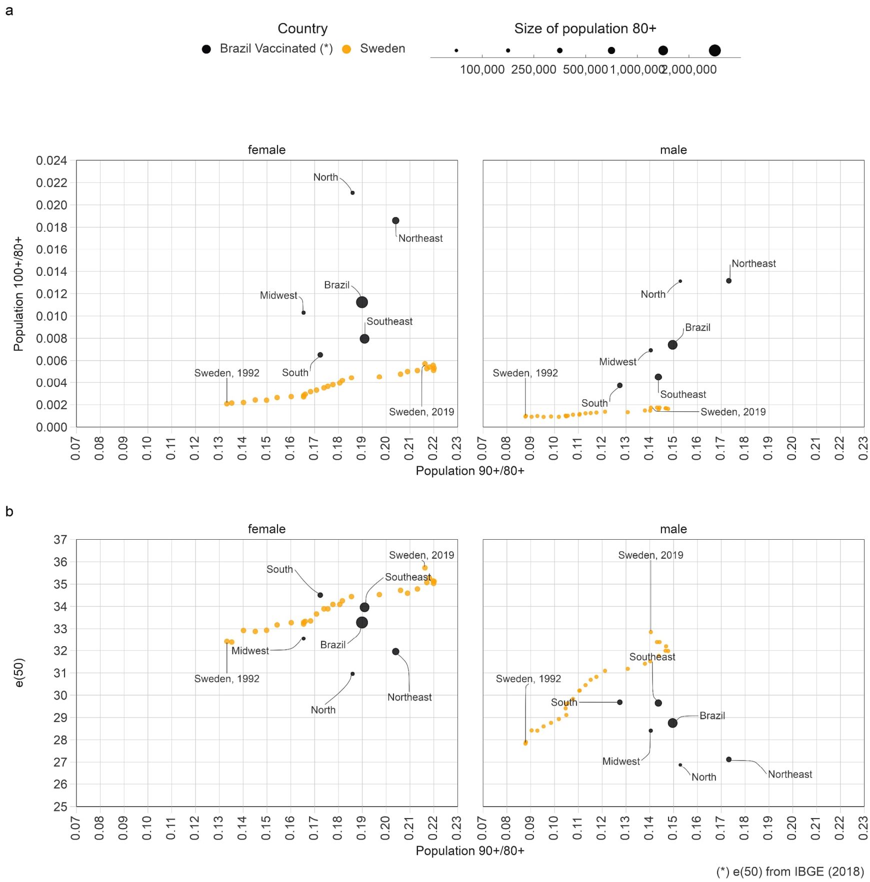
Figure 2: Sex ratios by single year of age. Brazil and its regions (2010 census data and 2021 vaccination records) and Sweden (2019)



Source: Prepared by the authors, based on Brasil (2021a), Minnesota Population Center (2020), and Human Mortality Database (2021).

It is not surprising that age exaggeration, age heaping, and fluctuations in sex ratios are more evident in Brazil's northern, northeastern, and midwestern states. The lower-quality data reflect the registration costs, longer geographical distances to register offices, and larger shares of the population living in rural areas and with low SES in those regions (Hakkert 1996). Therefore, even when documents establishing proof of age are required, these regional patterns of errors persist. Figure 3 examines this aspect in more detail by displaying the 90+/80+ proportions compared to the 100+/80+ proportions and life expectancy at age 50 ($e(50)$) for Sweden and the five Brazilian regions as calculated from vaccination records. Nonagenarians and centenarians represent much larger shares of the oldest population in the northern and northeastern regions than in Sweden and the southern areas of Brazil. In the North, $e(50)$ would have to be about three years (women) and five years (men) higher for the proportion of nonagenarians to be comparable to that in Sweden. Furthermore, in the northern regions, the number of centenarians would have to be between four and five times lower for the age distribution to become like that in Sweden. The discrepancies are much more minor in the South and Southeast.

Figure 3: Proportion of individuals aged 90 and older (90+/80+) by the proportion of centenarians (100+/80+) and life expectancy at age 50 (*e*(50)). Men and women. Brazil and its regions (vaccination records) and Sweden



Source: Prepared by the authors, based on Brasil (2021a), IBGE (2018), and Human Mortality Database (2021).

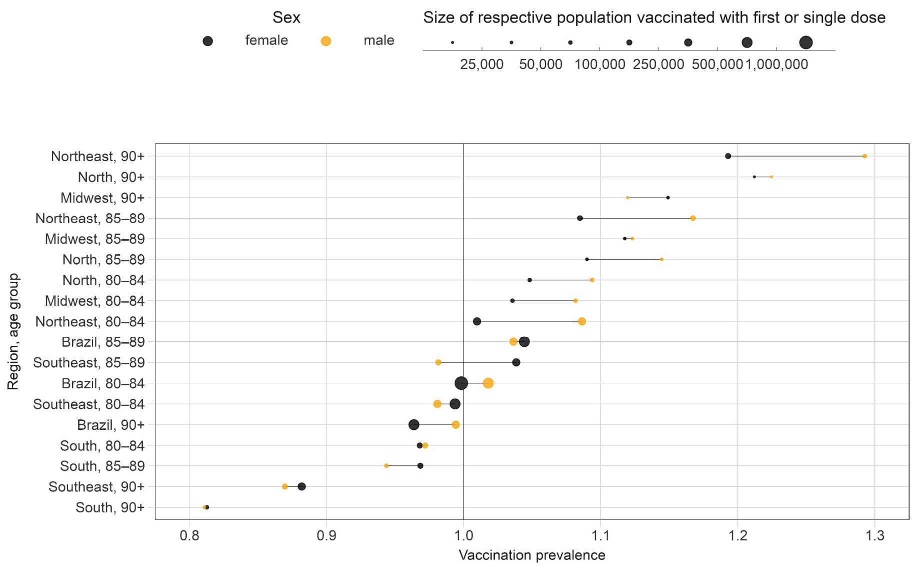
3.2 Vaccination coverage rates

So far we have shown that age reporting among the oldest old is probably slightly more accurate in the vaccination records than in official estimates and census data for Brazil. Also, despite the proof-of-age requirements for vaccination, historical and regional patterns of errors are still detectable in the vaccination records. One obvious question is how the IBGE has dealt with these issues, since accurate demographic estimates by municipalities, states, and regions are necessary to inform public policies. As shown in Table 2, data errors have declined over time as new cohorts have reached older ages. However, there is still much to learn about how age misreporting affects actual and projected population age distributions differently.

Figure 4 shows the proportion of vaccinated individuals for each region using the vaccination records as the numerator and the IBGE projections – adjusted by excess deaths due to the COVID-19 pandemic – as the denominator. The regional-age-sex pattern of differences again emerges: The ratios are higher than one in the northern, northeastern, and midwestern regions and are lower than one in the southern and southeastern regions. In addition, the discrepancies between the two data sources are more pronounced at ages 90 and older and among men, who are more susceptible to age exaggeration in Brazil. For example, in the Northeast, at ages 90 and older, the ratio is 1.293 (men) and 1.193 (women), and in the 85–89 age group it is 1.167 (men) and 1.085 (women). The corresponding ratios in the South are 0.811 and 0.813 (ages 90+) and 0.943 and 0.968 (85–89 age group).

Why are the age distributions in the northern states relatively older in the vaccination database than in the IBGE projections in the northern states? Why are they younger in the southern states? The answer depends on different factors. One may be the method the IBGE uses to adjust the mortality data before projecting the population. The IBGE does not measure and treat age-reporting issues but instead focuses on the completeness of death reporting. First, the IBGE uses indirect methods to correct the number of infant and adult deaths in Brazil, in some states in the Southeast and Midwest, and in all states in the North and Northeast, where the completeness of death records tends to be lower (IBGE 2013). Second, the IBGE compares the sum of corrected deaths by age and sex for all regions to the independently adjusted number of deaths for Brazil. To address the larger number of corrected deaths in the country than the sum of corrected deaths by region, the IBGE does not reduce the number of deaths by age and sex proportionally in all regions. This procedure is avoided because it results in implausible lower mortality rates at advanced ages in the northern, northeastern, and midwestern regions than in the southern regions. Instead, the IBGE reduces the number of deaths only in the South and Southeast to match Brazil's total number of deaths and to avoid North/South mortality crossovers (IBGE 2013). This adjustment may help explain why Figure 4 shows that the projected number of oldest-old people is larger than the number of vaccinated people in the southern regions. Addressing mortality crossovers in Brazil requires adjusting for age misreporting within each region before projecting populations at advanced ages.

Figure 4: Vaccination coverage (ratio of vaccinated and projected populations) by age group and sex. Brazil and its regions, 2021



Source: Prepared by the authors, based on Brasil (2021a), CONASS (2021), and IBGE (2018).

4. Discussion

We divided our analysis into two parts. The first part indicated only slight evidence that requiring proof-of-age documentation reduces age misreporting. We found lower levels of age heaping and age exaggeration and fewer variations in sex ratios in the vaccination records than in earlier census data and the official population estimates for Brazil. However, comparisons with older censuses may reflect historical improvement trends. Also, the requirement to present identity documents has not solved the problem that some individuals, particularly in northern and northeastern regions, are providing the wrong birth dates due to the absence of long-standing birth registration systems. There are relatively more nonagenarians and centenarians in the vaccination records than in Sweden, a country with high-quality data.

The evidence of increasing age misstatement with old age frustrated our hope of estimating standard population age distributions using the vaccination data. The remaining methodological options to adjust for age misreporting in Brazil are limited. The gold standard age adjustment model, based on matching current data with information from early life events, proposed by Preston et al. (1996), cannot be implemented in Brazil because there are no census microdata for the decades before 1960. Another option would be to use age distributions from the wealthiest population subgroups or the southern states in Brazil, age distributions from other countries, or mathematical models as the standard. However, this would require us to assume that the biological, demographic, and socioeconomic processes intrinsic to age patterns in population models are similar to those in Brazil.

The second part of our analysis showed discrepancies between the target and the vaccinated populations by age, sex, and region. The 2020 demographic census, postponed to 2022, would have provided the best target estimates for the vaccination campaign. The use of population projections increases uncertainty because they mirror the levels of age misreporting and other types of errors from a decade ago. They also reflect the assumptions implicit in the mortality, fertility, and migration estimates. Access to accurate mortality rates is essential to project the number of people at older ages. Demographic research on population projections in Brazil has focused mainly on coverage errors, such as the completeness of death reporting. Age misreporting at the oldest ages in Brazil remains a neglected topic that should be accounted for in the official estimates.

The differences between the target and the vaccinated populations in the major geographical regions are likely to be more pronounced at the local level, as the degree of uncertainty increases for population projections for small areas. In the early stages of the COVID-19 immunization campaign, there were many media reports of vaccine shortages in Brazilian cities. There were also complaints from the population about differences in the pace of vaccination across the country. It is difficult to quantify the role of inaccurate target population estimates in the distribution of vaccines. However, when vaccination coverage is wrong, the inefficient use of resources and a lack of confidence among the population may result. Therefore assessing the accuracy of the target population estimates for immunization coverage was a global concern even before the COVID-19 pandemic (Stashko et al. 2019).

Our analysis is not free of limitations. First, the Ministry of Health gathered and distributed the vaccination records almost concurrently, increasing the chances of record errors. There have been complaints among data users, including the press, about some inconsistencies. We tried to overcome these limitations by systematically cleaning the vaccination data before using the information and comparing only relative numbers. We have run several database versions since the vaccination campaign started more than a year ago, and the results have mostly stayed the same.

A second limitation is related to vaccination coverage. Some individuals aged 80 and older may have refused to vaccinate, which would have affected our estimates. Also, some of these individuals may have been unable to move to the vaccination sites because of functional limitations and other chronic conditions. If vaccine coverage declined with age in the 80–110 age group, the 100+/80+ age proportion might have been distorted. However, we expect the oldest old to be especially likely to want to vaccinate because of their significantly higher risk of dying from COVID-19. In addition, we included data on only the first dose or a single dose of the vaccine, which safeguards our analysis from the risk of individuals skipping subsequent doses. The vaccination campaign has been in place since 2021. It started with the oldest old, and the elderly are now getting their fourth or higher doses. Thus, it is unlikely that many individuals over age 80 have not received any doses. We are also optimistic that the coverage of vaccination records at older ages is high because of how the Brazilian public health system is structured. Since the late 1980s, successive governments have sought to build a universal and decentralized system that has expanded health care services and achieved high success levels in earlier vaccination campaigns. Most vaccines are free, including five vaccines for adults and the elderly. In the last 40 years, the prevalence of vaccine-preventable diseases in Brazil has declined substantially. The main challenge has been maintaining the high vaccination coverage rates, particularly among children (Domingues et al. 2020). Estimates show that among the elderly, influenza vaccination coverage has increased, reaching about 100% in 2019 (Azambuja et al. 2020), reinforcing our confidence in the completeness of the COVID-19 vaccination records.

Another concern is the overrepresentation of the institutionalized elderly in the vaccination records relative to those in the population censuses, which may have affected some of our comparisons. However, we believe that this limitation is not severe in the context of Brazil. While the institutionalized elderly have been a priority group in the COVID-19 vaccination campaign, the proportion of the elderly population living in institutions is smaller than in wealthier countries. Estimates from the 2010 census suggest that only 0.6% of people aged 60 years and older were living in long-term care institutions. In addition, a national survey conducted between 2007 and 2009 provided a similar estimate of the number of elderly people living in institutions, thereby confirming the accuracy of census data (Camarano and Barbosa 2016).

As new birth cohorts reach older ages, age reporting will gradually become more accurate in Brazil. However, this is a long-term process. It will take some time until we are confident about the precise number of oldest-old people, particularly in the northern and midwestern areas of the country. Scholars interested in studying aging-related topics in Brazil, such as morbidity and mortality patterns at older ages, should take note of this important message.

In the meantime, any new database that includes birth date records is a precious resource for population estimates in the Brazilian context. Systematic comparisons across old and new databases offer fresh clues about discrepancies in the official figures. Moreover, these comparisons provide a critical assessment of the quality of the new databases. It is a two-way street that improves our knowledge of age and other demographic distributions. Despite the weaknesses discussed above, vaccination records represent one option for estimating the size of the oldest-old groups during the intercensal period when no better data are available.

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