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COVID-19 EXCESS MORTALITY IN PARAIBA AND THE MOST AFFECTED COUNTIES

JOAO PESSOA

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Dissertation submitted for the degree of Master to the Postgraduate Program in Decision Models and Health, Center of Exact Sciences and Nature, Federal University of Paraiba.

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Joao Pessoa, February 25th, 2022

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ABSTRACT

The impact of COVID-19 pandemic in terms of number of deaths varied widely across the territories of Brazil with a significant number of deaths underreported. In this sense, the mortality statistics investigation focusing on subsequent analysis that triggering specific chain of events, could draw attention to the reliability of mortality information, scope, and severity of exceed deaths and real impact of pandemic. The present study aimed to analyze the magnitude and temporal course of excess mortality associated with the COVID-19 pandemic in 2020 in Paraiba state and its most affected municipalities. The following methodological steps were performed: comparative analysis of quality of the Brazilian mortality data sources; investigation of the quality of mortality statistics: analysis of the coverage by General Growth Balance method application, analysis of deaths registration completeness by redistribution of ill-defined causes and redistribution of garbage codes; and excess deaths estimation for 2020 in Paraiba based on weekly 2015-2019 time-series. The results of the study evidenced contradicted information released by five official Brazilian mortality data sources not only in terms of volume of COVID-19 deaths, but in interpretation of specific events such as time lag, pandemic picks, and weekly distribution of deaths. The data quality correction after coverage and completeness analysis showed significant increasing of deaths volume in Paraiba and its municipalities for 2020. The study showed clear evidence of statistically significant excess mortality due all-causes, natural causes and respiratory diseases in Paraiba 2020 with disclosure of direct and indirect impact of pandemic, specific demographic characteristics and weekly distribution of deaths. Due to the gaps in a scientific knowledge about excess mortality and the quality of mortality statistics under unprecedented circumstances in Paraiba during pandemic 2020, this study could benefit towards improvement of vital statistics in the state and contribute to better understanding of real pandemic impact to future policy making.

Keywords: COVID-19, Excess mortality, Quality of mortality data, Respiratory infectious diseases, Pandemic

RESUMO

O impacto da pandemia de COVID-19 em termos de número de mortes variou amplamente nos territórios do Brasil, com um significativo número de mortes sub-registradas. Nesse sentido, a investigação das estatísticas de mortalidade com foco em análises posteriores, que desencadearam as cadeias específicas de eventos, chamam a atenção para a confiabilidade das informações de mortalidade, alcance e gravidade das mortes excedentes e sobre o real impacto da pandemia. O presente estudo teve como objetivo analisar a magnitude e o curso temporal do excesso de mortalidade associado à pandemia de COVID-19 em 2020 no estado da Paraíba e seus municípios mais afetados. As seguintes etapas metodológicas foram realizadas: análise comparativa da qualidade das fontes de dados brasileira sobre mortalidade; investigação da qualidade dos dados de mortalidade: análise da cobertura pela aplicação do método Balanço Geral de Crescimento, análise da completitude do registro de óbitos por redistribuição de causas mal definidas e redistribuição de códigos garbage; estimativa do excesso de óbitos para 2020 na Paraíba com base em dados semanais da série temporal de 2015-2019. Os resultados do estudo evidenciaram informações contraditórias divulgadas pelas cinco fontes oficiais de dados de mortalidade brasileiras não apenas em termos de volume de óbitos por COVID-19, mas também na interpretação de eventos específicos, como o *timelag*, os picos da pandemia e a distribuição semanal dos óbitos. A correção da qualidade dos dados, após análise da cobertura e completude, mostrou aumento significativo do volume de óbitos na Paraíba e seus municípios para 2020. O estudo mostrou evidências claras de excesso de mortalidade estatisticamente significativo por todas as causas, causas naturais e doenças respiratórias na Paraíba em 2020, impacto direito e indireto da pandemia, características demográficas específicas e distribuição semanal dos óbitos. Devido às lacunas no conhecimento científico sobre o excesso de mortalidade e a qualidade das estatísticas de mortalidade nestas circunstâncias inéditas na Paraíba devido a pandemia em 2020, este estudo contribui para a melhoria das estatísticas vitais no estado, bem como para uma melhor compreensão do real impacto da pandemia para a elaboração de políticas futuras.

Palavras-chave: COVID-19, Excesso de mortalidade, Acurácia de dados, Doenças infecciosas respiratórias, Pandemia

LIST OF FIGURES

LIST OF TABLES

LIST OF MAPS

LIST OF ACRONYMS

ADPC	Average Daily Percentage Change
ANVISA	National Sanitary Surveillance Agency
ARPEN	National Association of Registrars of Natural Persons
CDC	Centers for Disease Control and Prevention
CI	Confidence Interval
COD	Cause of Death
COVID-19	2019 the Coronavirus Disease
CV	Coefficient of Variation
DC	Death Certificate
ETS	Exponential Triple Smoothing
FAPESQ	Research Support Foundation of the State of Paraiba
FUs	Federative Units
GBD	Global Burden of Disease
GGB	General Growth Balance
GCs	Garbage Codes
HDI	Human Development Index
HIV	Human Immunodeficiency Virus
IBGE	Brazilian Institute of Geography and Statistics
ICD	International Statistical Classification of Diseases and Related Health Problems
ICUs	Intensive Care Units
IMR	Infant Mortality Rate
IDC	Ill-Defined Causes
MAE	Mean Absolute Error
MAPE	Mean Absolute Percentage Error
MERS	Middle East Respiratory Syndrome
MHDI	Municipal Human Development Index
MSE	Mean Square Error
PAHO	Pan American Health Organization
PDSs	Physical Distancing Strategies
RNA	Ribonucleic Acid
RT-PCR	Reverse transcription–polymerase chain reaction
SARS	Severe Acute Respiratory Syndrome

SDI	Socio Demographic Index
SE	Standard Error
SES	State Department of Health
SIM	Brazilian Mortality Information System
SINASC	Live Birth Information System
SNVE	National System of Epidemiological Surveillance
SUS	Brazilian National Health System
WHO	World Health Organization

SUMMARY

1 INTRODUCTION

Initially reported in Hubei province, China, at the end of 2019 the novel coronavirus SARS-CoV-2 was fiercely spread across the countries and recognized as a pandemic of international concern (WHO, 2020a). A new disease named COVID-19 has become a massive threat and great challenge for health systems globally. Brazil, the largest and most populous country in Latin America, presented one of the most devastating pandemic scenarios among affected countries in terms of death counts since its first recorded death in March 2020 (WORLDOMETER, 2020; BRASIL, 2020a).

The COVID-19 proved to be highly transmissible, and the deadliest among all the previous coronavirus outbreaks. Presenting clinical manifestation of acute respiratory syndrome with wide range of unspecific clinical features, the disease is more severe in those with comorbidities and the elderly (ZHOU et al., 2020; CHAKRABORTY et al., 2020). In the absence of specialized medications and vaccines at the beginning of pandemic, the governments instituted public health measures such as social distancing, travel restriction, contact tracing, isolation, and others (WHO, 2020b). Despite the public health measures adopted in Brazil, COVID-19 deaths increased continuously in 2020 (BRASIL, 2020a). As the disease propagated, the health care systems have been overburdened, thereby bringing the epidemic out of control.

Several factors contributed to the devastating COVID-19 epidemic in the country (VEIGA E SILVA et al., 2020; ROCHA et al., 2021; BAQUI et al., 2020). Political changes in Brazil during the past years accompanied by economic instability, demographic changes, persistent inequality, and social problems became some of important predictors for catastrophic consequences due the COVID-19 pandemic in the country. Brazil experienced significant challenges in registration of COVID-19 cases and associated deaths (CIMMERMAN, CHEBABO, CUNHA, RODRIGUEZ-MORALES, 2020; SOUSA, TORRES, MOURA et al., 2020). Among the possible causes of reporting bias were shortage of diagnostic tests, delays in information delivery and errors in identifying of disease, especially at the beginning of pandemic.

As of July 2021, the time of this thesis conception, Brazil remained a country with the second highest mortality rate in the world (WORLDOMETER, 2020), with more than 541.000 confirmed deaths. Meanwhile, Northeast region represented the fifth part of all deaths in the country, with Paraiba reached 4th highest mortality rate in a region (BRASIL, 2020b). As pandemic was on its second year, there were also considerable progress, most notably authorization and roll out of the vaccines, as well as improvements in COVID-19 clinical management. As new SARS-CoV-2 variants continue to emerge (KOYAMA, PLATT, PARIDA, 2020), there is a need to understand if and how COVID-19 mortality changes over time.

Empirical evidence demonstrates that COVID-19 pandemic is associated with the excess mortality due its direct (infection disease) and indirect effects (shortage of health care resources, altered access to health care, patient´s comorbidity status) (CDC, 2020; BANERJEE et al., 2020; GOLDSTEIN, LEE, 2020; VESTERGAARD et al, 2020). There have been unprecedented national efforts to provide timely information on COVID-19 cases and death. Nevertheless, there were concerns regarding accuracy of real-time data, because of limitations of routine vital statistics and disease surveillance systems, and limited resources for timely diagnosis and reporting (PAHO, 2020).

1.1 Justification

Reliable and valid vital registration systems are essential for monitoring population health, measuring the impact of health interventions and developing public health policies (WHO, 2008; PAES, 2005). Brazil has made considerable progress in last three decades in improving the vital registration and disease surveillance systems (PAES, 2018; MARINHO, 2019). Nevertheless, several data quality issues remain. The most common problems faced are incomplete coverage of vital registration systems, errors in death counts, and lack of information on causes of deaths (PAES, SANTOS, COUTINHO, 2021). The quality of death registrations varies considerably by regions and states driven by regional asymmetries in social and economic development (LIMA, 2014). Additionally, there were some divergences in the way in which certain characteristics associated with vital events are investigated in Civil Registry Statistics, which lead to different results and controversies.

Since the start of the COVID-19 epidemic in Brazil, there has been a considerable public's interest in real time data on identified cases and number of deaths (VEIGA E SILVA et al., 2020). In response, various governmental and non-governmental organizations developed public COVID-19 information platforms, providing public with real-time information on reported cases and deaths. The quality of the COVID-19 mortality systems has not been assessed; thus, it remains unclear whether the co-existence of different platforms has contributed to understanding of the true death toll associated with COVID-19.

The challenges with routine mortality information systems in Northeast region (PAES, 2008; PAES, SANTOS, COUTINHO, 2021) and Paraiba (SANTOS, 2021; CARVALHO, 2018) have been well studied previously. Understanding how these data systems performed during COVID-19 pandemic is important in order to define the magnitude of the excess mortality, track changes in mortality over time, and compare across the regions or internationally (CHECCHI, ROBERTS, 2005; BEACH, CLAY, SAAVEDRA, 2020).

Excess mortality is a comprehensive measure of the pandemic impact which includes not only confirmed deaths, but also deaths that were not correctly diagnosed or reported, as well as deaths from other causes directly or indirectly related to pandemic (CDC, 2020a). There were no research studies on the excess mortality during the COVID-19 pandemic in Paraiba, one of the most affected regions of Brazil. Through rigorous assessment of quality of death data sources, the current study may contribute to the better understanding of COVID-19 mortality during the first year of the pandemic.

The thesis draws attention on COVID-19 burden during 2020, the first year of the pandemic, for several reasons:

- The initial several months of the pandemic, the health system in Paraiba was under unprecedent crisis circumstances (e.g. lack of testing, vaccines and specific treatment).
- The better understanding of excess mortality in this initial year will provide insights for any future assessments.
- The study is based on the Brazilian Mortality Information System (SIM) data: whereas complete nationally consolidated mortality data was available for period 2020. Operating mortality information for 2021 was preliminary and likely incomplete.

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1.2 Research questions

To address research gaps outlined in the previous section, this thesis set to assess quality of death registration systems, and estimate excess mortality associated with COVID-19 pandemic during 2020, the first year of the pandemic, in Paraiba and its most affected regions, namely Joao Pessoa and Grande Campina. The thesis aims to address the following research questions:

1. What was the quality of data collected by the national COVID-19 death record systems? What were coverage and completeness of COVID-19 deaths registration in 2020?
2. What were the COVID-19 mortality characteristics in 2020 in Paraiba overall?
3. What was excess mortality associated with COVID-19 pandemic in Paraiba in 2020? What was all-cause excess mortality, and excess mortality due to natural causes, and due to respiratory illness?

1.3 Objectives

Main objective: Analysis of the magnitude of excess mortality associated with COVID-19 pandemic in 2020 in Paraiba and its most affected counties.

Specific Objectives:

1. Evaluate the quality of official Brazilian COVID-19 death records databases.
2. Investigate mortality by all cause, natural causes and underlying respiratory conditions by sex and age groups.
3. Estimate excess mortality due to COVID-19 pandemic.

2 LITERATURE REVIEW

This chapter provides the background for research questions posed in this thesis. The structured literature review was conducted to understand morbidity and mortality associated with COVID-19 pandemic, globally and in Brazil, including Paraiba, methods used to assess quality of death registration systems, and approaches to estimate excess mortality. References of eligible articles from PUBMED, MEDLINE and Web of Science reference data bases were searched.

As for a new disease, the chronology of the COVID-19 pandemic, its epidemiological, clinical, public health and global impact aspects were described. The eligible articles related to the mortality informational systems and registration of vital statistics data quality, international and Brazilian rules, and procedures for accurate and timely data on cause of death (COD), were also subjects of the search. The description of historical line and organizational components of the Brazilian official vital statistics informational systems was highlighted in the review.

2.1 COVID-19 pandemic

2.1.1 Pandemic chronology, epidemiological pathway, and clinical characteristics

In the mid-December 2019, China health authorities detected few cases of an atypical pneumonia that eventually was discovered to be caused by a novel coronavirus SARS-Cov-2. Subsequent investigations discovered that the probable origin of a novel virus is related to the same family of Coronavirus that caused the severe acute respiratory syndrome (SARS) and to Respiratory Syndrome of Middle East (MERS) outbreaks during 2003 and 2012 (LU et al., 2020).

The infection was declared as an international public health emergency by the WHO on 30 January 2020 with the highest level of concern (WHO, 2020b). At that time (30 January 2020), the disease had spread to almost twenty countries, where 10,000 laboratory-confirmed cases and two hundred deaths were recorded.

By mid-March, Europe had recorded a higher number of cases than anywhere in the world, while COVID-19 cases had spread to more than 160 countries and territories involving six continents. The countries most affected by the mid- April were the United States as well as

Russia, the United Kingdom, Spain, Italy and France in Europe. As for 20th May 2020, the data collected by the WHO-Coronavirus Disease (COVID-2019) (WHO, 2020a) reports and the "Worldometers" (WORLDOMETER, 2020) databases showed more than 5,090,118 people had been infected with the virus from over 210 countries, with more than 333,000 deaths worldwide.

The epidemiological dynamics of COVID-19 has changed dramatically over the course of months. At the beginning of the outbreak, the most affected continent was Europe, however, by the mid of June 2020, the Americas, driven mainly by the United States and Brazil, have converted the region in the most affected on the planet (WORLDOMETER, 2020).

High viral load and active shedding in the upper respiratory tract that peaks during the first week of symptoms, suggests that SARS-CoV-2 is most contagious in already symptomatic subjects although some spread is likely before occurrence of symptoms (WOLFEL et al., 2020). Clinical features of COVID-19 are nonspecific and are hardly distinguishable from other causes of severe community and hospital-acquired pneumonia. While approximately 80% of cases follow a relatively mild trajectory, and has flu-like symptoms, the elderly and/or patients with comorbidities (e.g., chronic lung conditions, hypertension, diabetes, and obesity) are at risk for severe COVID-19 course with pneumonia as the typical manifestation (GUAN et al., 2020). SARS is a major complication of COVID-19 pneumonia in patients with severe disease. This develops in 20% after a median of 8 days. Mechanical ventilation is implemented in 12.3% of cases (ZHOU et al., 2020).

Deaths appear to be dominated by severe respiratory failure, fulminant myocarditis, thrombo-embolic events, and late secondary sepsis with severe single or multiorgan dysfunction (typically involving the liver and kidneys) (RUAN, 2020; SU et al., 2020). Emerging data suggest that severe COVID-19 phenotypes are associated with a significant hyper coagulopathy that correlates with disease severity (FOGARTY et al., 2020).

Direct viral infection of the endothelial cells and diffuse endothelial inflammation with a shift of the vascular equilibrium toward enhanced vasoconstriction (with subsequent organ ischemia), inflammation with an associated tissue edema, and a pro-coagulant state may constitute the main underpinnings of the severe clinical phenotypes. It is important to mention that the proportion of severe cases is highly dependent on the study population and may be related to the epidemiological behavior of the infection in each country.

2.1.2 Global emergency: social distancing, public health and economic impact

The massive global impact of COVID-19 epidemic is hard to estimate. As of May 24th, 2021, were confirmed more than 167 million cases and almost 3,5 million of deaths due COVID-19 around the world (WORLDOMETER, 2020). With many nations and regions declaring a state of emergency, unprecedented quarantine, social distancing, and border closing efforts were underway.

Without a vaccine or available pharmaceutical treatment during 2020, the actions to contain the dissemination of SARS-CoV-2 had initially concentrated on isolation measures and lock-down implementation which were adopted by many countries (WHO, 2020a). Differently from what was observed in 2012 with the Middle East respiratory syndrome (MERS) and in 2002 with the severe acute respiratory syndrome (SARS), isolation and quarantine were not sufficient to contain the dissemination of the new coronavirus. SARS-CoV-2 presents high transmissibility, from the onset of symptoms but also from asymptomatic cases of COVID-19 (KISSLER et al., 2020).

Every country had chosen their own public health instruments to control pandemic, whereas some scenarios where successful, some countries have been declared disastrous consequences of pandemic despite the isolation measures. Mass testing of the population, when possible, has also demonstrated to decrease the propagation of the virus efficiently. The objective of this strategy is to reduce the intensity peak of the epidemic curve, decreasing the risk of health system collapse while simultaneously increasing the opportunity of developing studies focused on effective treatments and vaccines (CDC, 2020b; ANDERSON, HEESTERBEEK, KLINKERBERG, HOLLINGSWORTH, 2020).

What sets the COVID-19 pandemic apart from previous novel coronavirus outbreaks was both the magnitude of event and the scale of the coordinated governmental responses, both locally and around the globe. Diverse supply chains, including those for medical supplies, hospital equipment, and pharmaceuticals, depend on global integration, often with deep links with COVID-19-affected regions. The crisis extends well beyond these considerations and includes the impact of disruptions in the global supply chains that affect basic hospital supplies, medications, and items that everyone depends on for daily routine activities (SEGAL, GERSTEL, 2020).

Even more concerning was the misallocation and maldistribution of healthcare-suitable personal protection equipment (PETERS, PALOMO, NEY et al., 2021; WANG, WU, SONG, 2020). The risk of health care workers exposure was substantial during the COVID-19 response, especially when faced with limited protection supplies and a surging volume of infected patients. Shortages of N95 masks prompted many institutions in different countries to decontaminate and reuse of personal protection equipment. Many different solutions were proposed to address the acute ventilator device shortages.

The global response to the COVID-19 pandemic was widely varied, including complete lockdowns, social distancing measures, and population screening policies—or none of the above. The outbreak continues to exert pressure beyond capacity on countries globally, revealing in some instances a lack of preparation and infrastructure to protect the public and healthcare practitioners, as was seen by the shortage in emergency medical supplies (SWERDLOW, FINELLI, 2020).

COVID-19 has proven to be difficult to control as compared to previous outbreaks due to a large number of cluster transmissions or super spreader events, relatively limited health resources, and the unavailability/shortage of rapid testing kits. Countries that enforced public health measures early on during the progression of their national outbreak, were better able to control the spread of the virus compared to other countries who had not done so.

2.1.3 Brazilian scenario

On February 26, 2020, the first COVID-19 case was reported in Brazil, approximately one month after WHO was declared an international pandemic emergency (VEIGA E SILVA et al., 2020). This was followed by disease detection in individual from São Paulo following his return from Lombardy, Italy, on 21st February 2020. The first death was announced on the 17th of March, while a disease has been already spread across the country with the most devastating scenario possible.

Brazil has 27 states divided territorially into five regions: North, Northeast, Central-West, Southeast, and South, with population more than 211 million of people, and it is the largest country in Latin America and sixth-most populous in the World (IBGE, 2020a). Each region has its own specific geographic, demographic, environmental and socio-economic characteristics. The demographic aspects combined with the urban built environment and socio-economical aspects have influenced the conditions of living and, therefore, of dying (SOUSA, 2000).

Historically, socio-economic differences and uneven mortality patterns have been part of mortality scenario in Brazil with poorer urban areas experience a double burden of diseases (BARRETO, 1993). Although SARS-CoV-2 has a high potential for contamination and reaches all communities, some areas may be more affected than others, as many regions do not have adequate health resources and infrastructure to face the pandemic effectively (SMITH, JUDD, 2020).

Initially, São Paulo was the most severely affected, where confirmed number of cases accounted for almost one-third of the total in Brazil by 16th epidemiological week (BRASIL, 2020a). Local transmission chains were identified between large cities, neighboring towns, and rural areas in almost every region of Brazil at this time. By the end of 21st epidemiological week (May 2020), 3.701 municipalities had at least one confirmed case of the disease, which represented 66.4% of Brazilian municipalities. Deaths due disease were registered in 1,463 municipalities, representing 26.3% of the total number of Brazilian cities. At least one death was confirmed in 682 (46.6%) municipalities, while 53 municipalities (3.6%) had more than 50 confirmed deaths.

The epidemiological dynamics of COVID-19 in Brazil had changed over the course of months. Furthermore, there was observed heterogeneity related to different regions. According to the Epidemiological Bulletin by the Ministry of Health, at the beginning of pandemic most cases were concentrated in the Southeast region, followed by the Northeast, South, Center - West and North regions. Among all Federated Units (FUs), at this time, the highest number of cases and deaths were notified in São Paulo, Rio de Janeiro, Ceará, Amazonas and Pernambuco (BRASIL, 2020a).

The health regions with the highest incidence rates were the 1st Region of Fortaleza in Ceará; São Luís in Maranhão; Manaus, Entorno and Alto Rio Negro in Amazonas; Rio Negro and Solimões in Amazonas; and São Paulo. Regions of São Paulo, Rio de Janeiro, and Amazonas are important ports of entrance to Brazil. Amazonas hosts the Free Economic Zone of Manaus and most of the international flights route through São Paulo and Rio de Janeiro: in 2019, 7.7 million international passengers landed in São Paulo and 2.2 million in Rio de Janeiro (BAQUI et al., 2020). The absolute number of cases alone does not provide a complete picture of the disease severity and transmission rates (ROCHA et al., 2021). Since the end of April, the states of Amapá, Roraima, Amazonas, and Acre have presented high community transmission of the coronavirus, and this has resulted in a new focus on the North region of Brazil

Even though the Federative Units from the Southeast region presented most of the confirmed cases, the highest average daily percentage change (ADPC) values were found in the North and Northeast regions. This was particularly warning because these regions present the lowest human development indices, and the highest proportion of poverty and low education rates in Brazil (NEIVA et al., 2020). According to Baqui et al. (BAQUI et al., 2020), the hospital mortality pattern in North region was attributed to some specific socio-demographic characteristics: higher hospital mortality rate was observed among Pardo and Black ethnicities comparing to White; and lower socio-economic situation correlated with the higher risk of mortality due COVID-19.

According to Rocha et al. (2020), the initial spread of COVID-19 infections and deaths in Brazil was mostly affected by patterns of socioeconomic vulnerability rather than population age structure and prevalence of existing chronic disease morbidity (ROCHA et al., 2020). Although the pandemic started in Southeast region, death rates increased quickly in states with marked socioeconomic vulnerabilities, particularly in the North and Northeast regions. The pandemic has been spread fiercely across the country and within five months, from February to July 2020, were declared more than 1,5 million of cases and 64,265 deaths. By the end of July 2020, Brazil was the second country in the worldwide ranking by number of cases and deaths due COVID-19, considered the one of the most affected countries and the disease epicenter in Latin America (BRASIL, 2020d).

2.1.3.1 COVID-19 pandemic in Northeast region

COVID-19 pandemic in the Northeast region of Brazil represents a serious public health problem and its impact may be greater, considering the interiorization process and its growing expansion to more vulnerable areas. This region, one of the most populated (27% of the Brazilian population) and poorest regions in the country, represented during a pandemic about third of all cases (34%) and deaths (32%) due disease (GOMES et al., 2020).

The first state in Northeast region who reported COVID-19 cases was Ceará, on the 15th of March, followed by the other states for a matter of days (XIMENES et al., 2021). As of June 27, 2020, in region was notified 451,076 total confirmed cases (34.3%) in the country:

with highest number of detected cases in states of Ceará (23.6%), Maranhao (17.3%), Bahia (14.5%) and Pernambuco (12.6%). State of Paraiba took the 5th place in statistics of region with 44,242 confirmed COVID-19 cases (9.8%) (BRASIL, 2020b). Chronologically, following the course of pandemic, by the time of September, the Northeast region reached 1.191.103 of confirmed COVID-19 cases (28.9%), and had the second place in country´s disease statistics. Bahia and Ceará together represented 41,3% of all confirmed cases in region (492,356), while Paraiba reached more than 100,000 of cases (9.2%) at that time (BRASIL, 2020c).

From an early stage of the pandemic, Northeast region quickly became one of the most affected territories with one of the highest rates of mortality in the country. Epidemiological situation in region characterized by progressively growing number of deaths during first months of pandemic. In a period from March to June 2020, the proportion of confirmed deaths in region increased from 5.0% to 32.2% considering the total number of deaths in the country (BRASIL, 2020d; MARINELLI et al., 2020). From nine states of the region, the highest coefficient of mortality was notified in Ceará, followed by states of Pernambuco, Rio Grande do Norte and Paraiba. Although lethality found for cases in region in general was lower than the average estimated by WHO (3.4%), many of the Northeastern states recorded lethality above the Brazilian average (5.4%) (KERR et al., 2021).

Considering the accumulated data on cases and deaths, from February 26, 2020, to March 27, 2021, the Northeast region reached 2.865.482 diseases cases with confirmed more than 67,000 of deaths. State of Paraiba had the second highest cumulative disease incidence (6.295,7 cases per 100.000 population) and the third highest cumulative mortality coefficient in Northeast region (136,4 deaths per 100.000 population) (KERR et al., 2021). During one year of pandemic 2020, the epidemiological situation in Northeast region continued to be unstable, characterized by periods of improvements and downfalls. It is hard to say without certain scientific analysis, what specific groups of determinants or their components played a key role in worsening of disease transmission chains and diversity of pandemic course in different parts of the region.

There are some studies related to epidemiological context (BAQUI et al., 2020; SOUSA, TORRES, MOURA et al., 2020) or individual direct and indirect characteristics (ROCHA et al., 2020; XOMENES et al., 2021; MARINELLI et al., 2020) of pandemic in region. Yet, there are many scientific gaps, including factors related to heterogeneity of the course of pandemic in different municipalities or urban/rural areas: real magnitude of mortality, specific risk factors, demographic, environmental, socio-economic, and other determinants.

2.1.3.2 Paraiba scenario

The first COVID-19 case was confirmed in Paraiba on 18th March 2020, approximately one month after disease was officially announced in the country (PARAIBA, 2020a). The disease was detected in a 60-year-old man, resident of João Pessoa, with a history of traveling to Europe. On the 31st of March 2020 the first death due COVID-19 was announced (PARAIBA, 2020b).

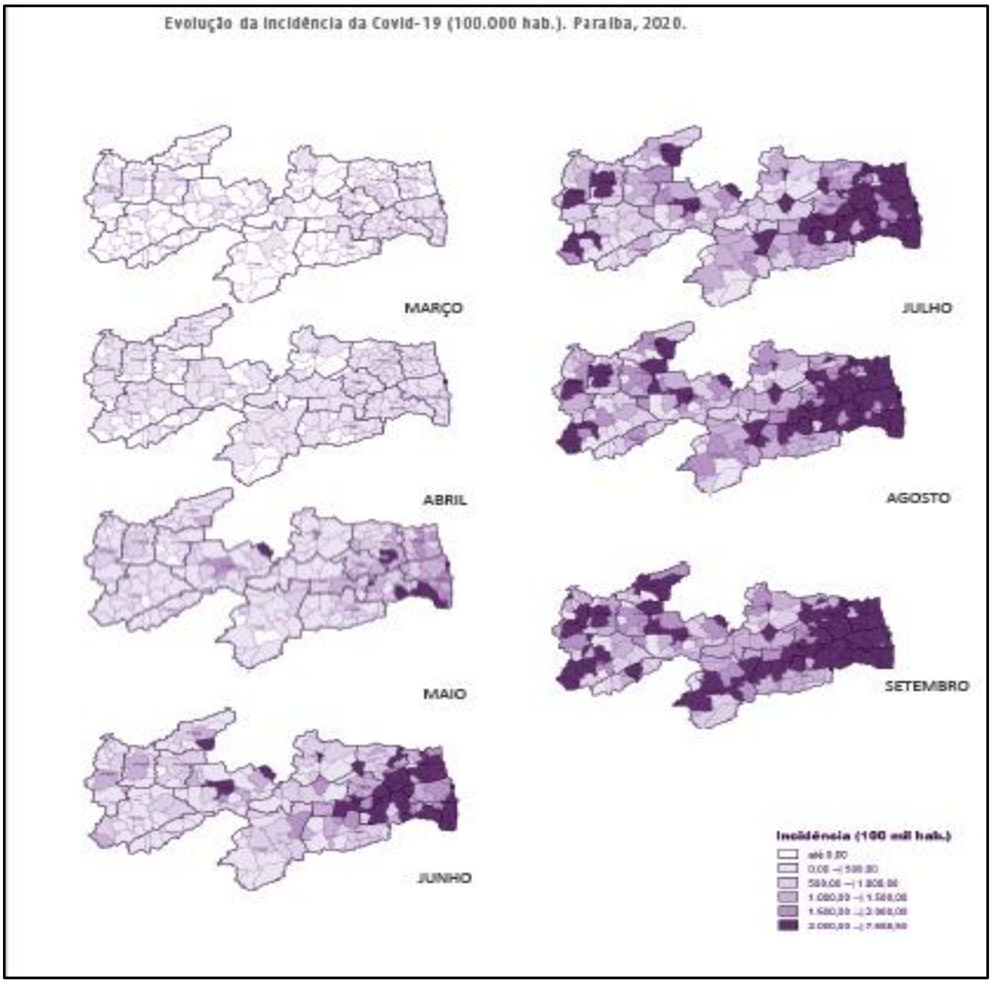
As of April 4th, 2020, the transmission chain was observed predominantly in six municipalities: Joao Pessoa, Campina Grande, Cabedelo, Patos, Sousa e Igaracy (PARAIBA, 2020c). The epidemiological situation was closely monitored by the State Government authorities, and its health department (Secretaria da Saude), with everyday information provided publicly. According to State Government´s press-releases, the initial outbreak was characterized by steadily growing number of cases with disease detected all across Paraiba. By the end of May (20th of May), the clusters of cases were notified in 157 its municipalities, with totally 5838 cases and 230 deaths (PARAIBA, 2020d). The occupancy of adult ICU beds at that time throughout the state was 66%, with 83% in Metropolitan Region of João Pessoa.

The statistics on 30th of July 2020 demonstrated critical worsening of situation in Paraiba: total number of cases during two month of virus active transmission folded approximately in 14 times, while number of deaths in 7,7 times. In the state were confirmed 81.108 disease cases and 1785 deaths, with spread of disease in 221 from 223 its municipalities (PARAIBA, 2020e). Joao Pessoa was represented 26% (21.000 cases) of all cases in Paraiba. During period, Paraiba had the second highest incidence rate (2.077,1 cases per 100 000 population) and fifth highest mortality rate (45,6 deaths per 100 000 population) in region (BRASIL, 2020i). The COVID-19 chain of incidence in Paraiba territories during seven months of pandemic is presented in Figure 2.1 (PARAIBA, 2020f).

Following the course of pandemic, in Paraiba was observed two periods with serious disease outbreaks characterized by progressively increasing of new cases and deaths: May-July 2020 and January-March 2021 (BRASIL, 2020b). Without a vaccine, sufficient testing capacity or available pharmaceutical treatment on March-June 2020, the actions to contain the dissemination of disease have been initially concentrated on isolation measures. However, according to State Secretary of Health, the Social Isolation Index at that period was notified as

39,5%-43,8%, considered low comparing to the target of 70% and the minimum of 50% (PARAIBA, 2021a).

Figure 2.1 - COVID-19 incidence dynamic in Paraiba, March-September 2020.



Source: Government of Paraiba. Secretary of State for Health, 2020.

The period of weakening of lockdown measurements in October 2020 accompanied by Christmas/New Year celebrations was followed by steadily growing number of cases and deaths since the beginning of 2021. For one week (27th of February until 10th of March), the state was registered 690 new cases and 50 new deaths, whereas 34 deaths were registered during 24h. Five municipalities represented more than 50% of all new cases in Paraiba: Joao Pessoa, Campina Grande, Patos, Cabedelo and Cajazeiras (PARAIBA, 2021b).

The average occupation of intensive care units (ICUs) beds was approximately 56% during one year of pandemic in Joao Pessoa, with increasing demands up to 66-98% in a period of outbreaks (May-July2020/January-March 2021). The highest occupation of ICUs beds was observed in a period January-March 2021 in Joao Pessoa (83-98%), Campina Grande (57-68%) and in the backlands (90-98%) (PARAIBA, 2021c).

2.1.4 Response to pandemic in Brazil

2.1.4.1 Brazil´s level

Brazil experienced a sharp decline of mortality due to infectious diseases in XX-XXI centuries, followed by implementation and development of the sanitary reforms, vigilance network and universal health care system. Despite the long history of successful battling with infectious diseases outbreaks, high levels of communicable diseases are still present in the country due to social and regional inequalities among the distribution of wealth resources (COKER, ATUN, MCKEE, 2008).

Since the start of the pandemic, the situation in Brazil faced many barriers to disease confrontment, primarily related to country´s political issues. While most state and municipal governments have imposed social distancing along with other public health measures to control the spread of the virus, federal government had steadfastly opposed such measures (ORTEGA, ORSINI, 2020).

The different states have adopted different distance measures in their territories, in general, Brazilian states have implemented early restriction measures. For instance, the predicting model conducted by Ganem at al. (2020) showed that, without the adoption of social distancing measures, the capacity of the ICUs for COVID-19 could be overwhelmed by 130% in the first month and 14-fold by followed month (GANEM et al., 2020).

The Brazilian Ministry of Health has made efforts to fulfill the WHO recommendations for testing suspected cases, detecting positive cases, and advising isolation of people with the disease and their household contacts to reduce dissemination. However, once COVID-19 began to spread via community transmission, there was not sufficient tests coverage and the Brazilian Health System (SUS) capacity to diagnose everyone suspected of having the disease (OLIVEIRA, DUARTE, FRANCA, GARCIA, 2020).

Since the very beginning of the pandemic, Brazil has adopted a norm of using the SARS-CoV-2 RT-PCR exam in patients showing more severe symptoms only, mainly those in need for the ICUs, which usually result in a higher mortality rate and the increased number of serious cases in follow up (MARSON, 2020). Brazil quite quickly developed laboratory tests for country use, but production of kits was restricted by dependence on external reagents (ANDRUS et al., 2020).

Brazil is known for its public actions when facing vaccine-preventable diseases over time (MATOS, BARBIERI, COUTO, 2020). Created in 1973, the National Immunization Program, strengthened the Brazilian State's regulation and coordination of vaccination actions at national level. Since then, the program has offered free and universal vaccines and established the National Vaccination Calendar, considered one of the most extensive in the world (DOMINGUES, TEIXEIRA, 2013). Despite advances and international recognition, program has faced challenges, such as the recent decline in vaccine uptake rates and their considerable differences between regions (SATO, 2018). Although Brazil is among one of the countries that would be able to vaccinate 10 million people in a single day, due to the high quality and local penetration of its National Immunization Program, it has managed to vaccinate only 8% of the population by April 2021 (INAYAT, 2020; KERR et al., 2021).

2.1.4.2 Regional level

On regional level, all capitals and states in region adopted isolation (lockdown) as a preventive measure in a situation when treatment or vaccines were not available. Lockdown was decreed almost simultaneously in the nine states. The cities of Fortaleza, Recife and Teresina reached the highest isolation index of all capitals—close to 0.60. Yet, the isolation index then started to decrease, with some variations depending on capitals, reaching its minimum (0.35) around October 9, 2020 (XIMENES et al., 2021). It was followed by increasing transmission chains and growing number of cases and deaths, especially in the beginning of 2021, with a wave close to or even higher than the first one.

The opening of the economy in the second half of 2020, without the full range of non-pharmaceutical measures, is most probable explanation of the second wave quickly became dramatic. Yet, in November 2020, the elections occurred in the 5,570 Brazilian municipalities. The pre-election period and the election itself, with mandatory voting, promoted mass meetings, long lines and a greater possibility of spreading the virus. The situation was even more aggravated by a new strain of SARS-Cov-2 (called P1) emerged in region. A study released in early March 2021, conducted in eight Brazilian states, including three in the Northeast, found that 71.1% of the samples from Ceará, 50.8% from Pernambuco and 42.6% from Alagoas were the P1 variant (FIOCRUZ, 2021). Altogether, those events resulted in a following collapse of the health system in several cities and in the Northeast Region.

Five of the 27 capitals in the country have ICU occupancy rates equal to or greater than 80%, 15 of them exceeded 90% and the situation only worsened (FIOCRUZ, 2021). The situation was further aggravated by the low rates of vaccination coverage. As of June 20, 2021, the coverage by first dose of vaccine in region varied from 25.6 to 29.8% (Piaui and Bahia), with the coverage by second dose from 9.6% to 12.1% (Alagoas and Paraiba).

The negative demographic and environment changes, persistent poverty and social inequality, economic instability, political crisis, insufficient administration, and lack of certain programs and provisions in health care systems, perhaps, one of main reasons, among others, of negative aftermaths due current pandemic.

2.2 Mortality information systems in Brazil

Health systems worldwide depend on reliable information about causes of death to be able to respond effectively to changing epidemiological circumstances (SHIBUYA, SCHEELE, BOERMA, 2005). Within a health information system, accurate and timely mortality data is fundamental for decision making and for measuring distribution of ill-health and diseases in populations (WHO, 2008; RUZICKA, LOPEZ, 1990). The poor state of vital statistics and, particularly, mortality statistics in many countries is widely documented in the literature (WHO, 2013). Although most countries with statistical systems for cause of death now use the international frameworks, assessments of vital registration systems in many countries consistently reveal substantial weaknesses in mortality statistics.

Historically, the evolution of vital statistics in Brazil had faced many challenges (PAES, 2005). The different stages of economic and social development, political changes, and regional differences, over a long period of time influenced the coverage and quality of vital events in the country. Since 1970s in Brazil, two main sources of mortality were developed for public policy formulation and monitoring: the Registry Civil data by Brazilian Institute of Geography and Statistics (IBGE) and Mortality Information System (SIM) database by the Ministry of Health.

More than four decades on, the comprehensive registration of deaths and their causes in the country as well as systematic research of the quality of mortality data are yet undertaken and have been passing through various difficulties (PAES, 2005). Additionally, the current COVID-19 pandemic aggravated the problem of mortality statistics in Brazil even further. This segment of review aims to highlight some specific aspects of mortality statistics development in Brazil, its challenges and advances, and impact of COVID-19 pandemic on mortality data.

2.2.1 Registry Civil and Brazilian Institute of Geography and Statistics

Created in 1934, Brazilian Institute of Geography and Statistics (IBGE) in the 70s became responsible for centralized collection of vital statistics in the country, including mortality data, following the legal determination (Law n. 6.015 of 1973) (BRASIL, 1973). In this way, the IBGE started to collect and systematized data on vital events throughout the national territory.

The implementation process of the Civil Registry was slow in Brazil, characterized by historical stages and tumultuous by the large number of government acts that tried to regulate it. The Civil Registry has been existed since the time the country was a colony of Portugal. The emergence of the government law in 1784 provided implementation of several acts, regulating the records that included births, marriages, and deaths (ALTMANN, FERREIRA, 1979). In 1870 Brazil established its first law on the operation of two sources of demographic data: the Demographic Census and the Civil Registry. Until then, Statistics were limited to non-systematized records with purely fiscal purposes.

Historically, the process of collecting information from the Civil Registry has gone through some phases. In a first stage, the Registry Offices (Cartorios) sent directly to the General Directorate of Statistics the information containing the data of registered births, deaths, and marriages. Later, this function was under the responsibility of the statistical departments of the Brazilian states. This intermediation was extinguished in 1973 by low number 6.015 which determined the centralization of vital data collection by Institute of Geography and Statistics (IBGE). The IBGE became responsible for centralizing of forms and, later, for all the systematization and production of Civil Registry Statistics (IBGE, 2018).

Currently, the collection, which takes place quarterly, is almost entirely computerized using the Notary's information systems or a data entry program provided by the IBGE. For death records, the following variables are investigated: Federation Unit of death registration, municipality of registration, registration district, registration office code, day/month of registration, date of death, nature of death (natural or external), place of death (hospital, domicile, etc.), Federation Unit of the deceased's residence, city of residence of the deceased, sex/age of the deceased, marital status, Federation Unit of the deceased's birth, country of residence of the deceased, country of birth of the deceased, and number of Death Declaration (BRASIL, 2001). The systematization of Civil Registry Statistics involves two relevant dimensions: (1) supplying the society with information about the occurrence of births and deaths, to contribute to the monitoring of population evolution in each geographic area; (2) provide society with data of citizenship, either at its beginning, when the live birth is registered, or at its extinction, when the death is registered.

In Brazil, despite the improvement in the effective registration of vital events, unfortunately, in general, underreporting of vital events is not fully eradicated (PAES, 2005). The incompleteness of vital statistics records, on the one hand, limits the production of demographic indicators associated with birth and mortality, especially when disaggregated into subnational areas. On the other hand, it reveals that citizenship is not being exercised as it should, reaching the extreme case of individuals who are born and die without realizing their existence.

2.2.2 The Mortality Information System (SIM)

The Mortality Information System (SIM) is a national epidemiological surveillance system with main objective to collect data on deaths in the country to provide information on mortality for health system policy (BRASIL, 2018). The Information Systems regarding vital events – the Mortality Information System (SIM) and Live Birth Information System (SINASC) - were developed by the Ministry of Health for epidemiological analysis, monitoring, and to guide health management and decision making in public health areas.

The Mortality Information System was created in 1975 (Law n. 6,259; 10.30.1975) (BRASIL, 1975), with establishment of the National System of Epidemiological Surveillance - SNVE, being essential to have a subsystem of mortality information. Previously, in July of that year, a working group was created to guide the development of the subsystem. Thus, the SIM resulted from the unification of 43 different models, which provided data on mortality (JORGE, LAURENTI, GOTLIEB, 2007). Initially, the flow of information was centralized, as well as the processing of mortality data. In this period, the process of collecting the mortality information was struggled by various difficulties, including insufficiency of trained staff and manual workflow which characterized by technical errors.

With the implementation of the Brazilian Unified Health System (SUS) in 1988, was provided the decentralization of health actions to states and municipalities, which became responsible for data collection, including mortality data, through the respective Health Departments. In 1992 was developed and implemented in the state Health Departments by technicians from the National Foundation of Health/Ministry of Health, a system of computers that made the Worksheets for Coding the Death Certificate (DC) obsolete (BRASIL, 2018).

In addition to decentralization of health information to the state's health authorities, the SIM was computerized. From 1994 was developed a new module for the system, which automatized the codification of the basic causes based on the diagnoses entered by the physician in the "Medical Certificate" block of the DC. However, the growing volume of data each year and consequent increasing of technical problems had demanded using more modern technologies for system operation.

The current information flow of SIM was established by the Low n. 116 in November 2009. The process of collection, aggregation, proceeding and analyzing of mortality information is multitasking. According to the low, the Death Certificates should be filled by the Health Units (Unidade da Saúde) in case the death occurs in a health facility; by assistant physician in cases the death occurs at home and has been assisted; by the institute of forensic medicine in cases of unassisted deaths that occurred outside the health units (home, street, etc.) (JORGE, LAURENTI, GOTLIEB, 2007).

The Municipal Health Departments are fully responsible for the collection, analysis and proceeding of the Death Certificates information. Locally consolidated data sent to the database of the State Health Departments, which after aggregation process is passing information to the federal level. The Health Surveillance Department, as an authority of SIM under Ministry of Health regulation, being responsible for the analysis, evaluation and distribution of information related to mortality based on SIM aggregated nationally. They are also responsible for preparing analytical reports, indicator panels and other statistical instruments. Having as objectives of providing epidemiological information, SIM has a larger set of variables than Civil Registry Statistics.

The standard document of SIM is the Death Certificate (DC), used by the Notary Publics to issue the Death Certificate (Annex I) (JORGE, LAURENTI, GOTLIEB, 2007). The Death Certificate represented by nine blocks, with a total of sixty-two variables:

Block I - Notary: with six variables

Block II - Identification: with 14 variables

Block III - Residence: with five variables

Block IV - Occurrence: with seven variables

Block V - Fetal death or less than one year: with 10 variables

Block VI - Conditions and Causes of Death: with seven variables

Block VII - Physician: with six variables

Block VIII – External causes: with five variables

Block IX - Location without a Doctor: with two variables.

The completion of DC is under the Physician's responsibility, according to the Federal and Regional Councils of Medicine. The DC´s block ``Conditions and Causes of death`` are following the international model for recording the causes that contributed to death, approved by the WHO, and contains information on present or pre-existing pathology conditions at the time of death, using the International Statistical Classification of Diseases and Related Health Problems 10th Revision (ICD-10) (ICD, 2020).

2.2.3 Growing Number of Mortality Information Systems during COVID-19 pandemic

With the increasing spread of COVID-19 in Brazil, there has been a considerable growth in the population's interest for information about the disease (VEIGA E SILVA et al., 2020). Following the public increased interest to pandemic, various governmental and non-governmental organizations developed public information platforms related to pandemic statistics on local or national level.

The Civil Registry Transparency Portal. In 2020 with emerge of COVID-19 pandemic, the Civil Registry Transparency Portal developed a new addition "COVID-19 Special", the webpage with permanent updating of the number of death records during pandemic (BRASIL, 2020g).

In 2018, the National Association of Registrars of Natural Persons (ARPEN Brazil) was maintained the Civil Registry Transparency Portal as a free-access website aimed to provide citizens with open information and statistical data on births, marriages, and deaths, among others related content. It was initiative of the Civil Registry Offices of Brazil, which in this way reinforce their commitment to transparency with society, in compliance with Ordinance No. 57/20, of the National Council of Justice.

The updating of the Transparency Portal by the records of deaths drawn up by the Civil Registry Offices follows legal deadlines. The family has up to 24 hours after death of its member to register the death in the Registry Office, which, in turn, has up to five days to register the death, and then up to eight days to send the deed done to the National Civil Registry Information Center, which updates the Portal.

The Transparency Portal profile is represented by a mortality data related to COVID-19 on national level: the data collected from 27 Federative Units of Brazil. The Portal discloses cases of suspected and confirmed deaths due to COVID-19, and its associated respiratory and cardiac conditions. The Portal´s information considers both: date of registration and date of occurrence of deaths.

The data of Portal has its limitations: the number of confirmed or suspected deaths restricted by the cities/municipalities with more than 50 deaths; information about deaths due respiratory and cardiovascular conditions does not contain international coding ICD-10; the Portal does not provide individual information by Death Certificates; the source in general does not permit download electronic version for analysis- all procedures should be done manually.

“Coronavirus Panel” by the Ministry of Health. The “Coronavirus Panel” was developed by the Ministry of Health as a part of official communication with the public on the epidemiological situation of COVID-19 in Brazil (BRASIL, 2020h).

The process of updating data on confirmed cases and deaths due COVID-19 in Brazil is carried out daily through official information provided by the State Health Departments of the 27 Brazilian Federative Units. The data provided by the states is consolidated by the Ministry of Health and made publicly available every day.

Panel´s basic mortality information includes number of new confirmed deaths due COVID-19 that were registered by the Municipal and State Health Departments in relation to the previous day. It reflects the number of deaths reported by the health departments on the date they had laboratory or clinical epidemiological confirmation and does not consider the date of occurrence of the death. The panel provides the number of accumulated deaths in a considered period and mortality coefficient.

The description of Panel includes some limitation, such as: complexity of information collecting, possible errors in number of cases/deaths, the information about mortality is limited by the date of registration; the mortality information requires correction on sub-notification, especially from the North and Northeast regions.

"COVID-19 Microdata". Created by the Paraiba State Department of Health (SES), the "COVID-19 Microdata" is the open internet-platform that aggregates epidemiological data due disease from each municipality of the state (PARAIBA, 2020g). The platform provides daily updated information related to new and cumulated confirmed cases and deaths due COVID-19, as well as the number of recovered cases. The mortality information is presented by the following variables: (i) date of death occurrence, (ii) municipal of residence. (iii) date of symptoms onset, (iv) sex/age, (v) laboratory confirmation, (vi) pre-existed diseases (co-morbidity).

The platform has its limitations: (a)- the variable "pre-existed diseases" does not follow the ICD-10 coding classification (for example, "respiratory disease" without providing additional information about type of respiratory pathology); (b)- the complete data of individuals Death Certificate is not available; (c)- the way of COVID-19 confirmation is not detailed (for example, clinic-epidemiological without further information of specific COVID-19 criteria).

2.3 Quality of Mortality Statistics

Reliable and valid vital statistics are widely acknowledged as essential information for monitoring the impact of health interventions and developing public health policies (WHO, 2008). Developing of comprehensive health information systems, including mortality statistics, is a challenging task. The gold standard is a system that provides a complete record of all deaths with accurately medically certified causes of death.

Whatever the source of a data item, it is essential to pay special attention to the activities and subsystems concerned with data collection, storage, analysis, and dissemination. The aim is to carefully assemble data from a variety of disparate sources – both within the health system and beyond – and to ensure its quality prior to releasing information to a broader public (WHO, 2008).

2.3.1 Principles of the quality of vital statistics

Strong health information systems ensure that data meet high standards of reliability, transparency, and completeness. According to the United Nations Statistics Division recommendations, the quality of data should be measured according to the standards of completeness, correctness, availability and timeliness (UNITED NATIONS, 2014):

- ***Complete*** registration has been achieved when every vital event that has occurred to the members of the population of a particular country (or area), within a specified time period, has been registered in the system, i.e., has a vital event registration record. This means that the system has attained 100 per cent coverage. Any deviation from complete coverage is measured by "coverage error".
- ***Correctness or accuracy of registration*** when data items for each vital event on the vital record have been accurately and completely filled. In register-based vital statistics, accuracy means that data items in the statistical report have been accurately registered in and no errors have been introduced during the transcription of data from the vital records to the statistical report or during the processing stages (coding, editing, imputation and tabulation).
- ***Availability*** means that data that have been collected, filed, processed and stored in each system (civil registration and vital statistics) are accessible to users in a user-friendly format, upon request.
- ***Timeliness*** in registration means that every event that has occurred in the country has been reported for registration within the legally stipulated time allowance. In register-based vital statistics, it means that for every timely registered event, a statistical report form has been forwarded to the agency responsible for vital statistics within the fixed time schedule established by the vital statistics program.

The knowledge of the size and characteristics of a country's population on a timely basis are essential to socioeconomic planning and informed decision-making (UNITED NATIONS, 2014). It is important that different sources of vital statistics employ the same concepts and definitions of vital events so as to ensure national and international comparability (BENNETT, HORIUCHI, 1981).

Total numbers of registered deaths should be based on date of occurrence, which is the recommended basis for the time reference of all vital statistics tabulations. The differences in elapsed time between dates of registration and dates of occurrence should be analyzed in order to provide insight into the lag between the occurrence of events and their registration, giving some indication of the magnitude of delays in registration and of the under-registration problem (SPENCER, AHMAD, 2016).

Cause of Death. Statistical information on deaths by underlying cause is important for monitoring the health of the population, evaluating public-health interventions, recognizing priorities for medical research and health services. Death certificate data are used extensively in research on the health effects of exposure to a wide range of risk factors associated with the environment, the workplace, medical and surgical care, and other areas (UNITED NATIONS, 2014).

Causes of death are "all those diseases, morbid conditions or injuries which either resulted in or contributed to death and the circumstances of the accident or violence which produced any such injuries". From the standpoint of public health and prevention of disease and premature death, it is important to understand the morbid process from onset to conclusion and to break that chain of events. In order to ensure uniform application of the above principle, it is imperative that the medical certification form recommended by the World Health Assembly be used.

It is assumed that the certifying medical practitioner is in a better position than any other individual to decide which of the morbid conditions led directly to death and to state the antecedent conditions, if any, that gave rise to this cause.

Coverage. Vital statistic should be compiled, as far as possible, for the total geographical area of the country, for each major or other minor civil division and for each principal town and city. They should also distinguish between urban and rural for at least the country as a whole and for each major or other civil division.

In countries where the social and economic characteristics of large segments of the population vary greatly, such as among ethnic (or national) group, it is recommended that, as far as possible, the identity of each important population subgroup be maintained in the tabulations (UNITED NATIONS, 1998).

Quality assurance. Quality assurance procedures need to be set up as regular and routine activities in a vital statistics system at all stages—collection, compilation and processing. The errors and omissions that may be introduced in the original statistical reports, as well as during coding, keying, sorting, posting and tabulation, should be detected and corrected before the vital statistics are published (UNITED NATIONS, 1998).

If an automated system is used, it is important that the tables produced be critically inspected for credibility and consistency, since errors might be introduced through programming mistakes. Therefore, it is most vital for all tabulations to be inspected by both statisticians and data-processing personnel in order that as many errors as possible may be detected and corrected.

Quality assessment entails specific studies that aim to answer specific questions of quality as it applies to the civil registration and vital statistics systems. These questions could relate to the coverage of the registration of a vital event at the country level or in a smaller area; the accuracy of one of the variables recorded or published in vital statistics; or the overall status of civil registration and vital statistics systems.

2.3.2 Quality of Brazilian Mortality Information Systems

Studies on mortality in countries, such as Brazil, have been limited by the lack of a better quality in data, problems with completeness of death registration and the quality of population information (PAES, 2005; AGOSTINHO, QUEIROZ, 2008; LIMA, QUEIROZ, 2014). Despite the improvement of country´s vital statistics in past decades, unfortunately, there are still present problems with under-registration of vital events and luck of accuracy on cause of death data. The incompleteness of records in the country limits the production of important demographic indicators associated with mortality, especially when disaggregated into subnational areas.

In general, in Brazil, the Vital Events Information Systems are well structured, yet lacking the coordination, collaboration and integration (IBGE, 2018). The co-existing of two major informational systems related to mortality in Brazil- Registry Civil by IBGE and Mortality Information System (SIM) by the Ministry of Health- demanding collaboration of actions on their production. Yet, they are not achieved expected harmonization/integration.

According to Paes (2005), several decades of vital statistic´s production in Brazil were not enough to remove the scientific delay concerning the knowledge of the behavior of these statistics and their components (PAES, 2005). Several factors can be attributed to this delay, but they are certainly associated with the large differences between regions and states. Moreover, these factors are related to social, economic, and living conditions of populations, which have strongly influenced the quality of vital records. Regional asymmetries in social and economic development, as well as the permanence of excluded population segments are barriers to be overcome in the search for completeness of records/notifications.

There is scarce empirical research as relates to Brazil's mortality estimates. Most studies were based exclusively on data from vital statistics. These studies generally focus on localized regional spaces. In relation to the Brazilian states, some studies, for certain points of time, provided an analysis of the evolution of data quality. However, these studies do not use the same methodology, which makes it difficult to compare the results (FRANCA et al., 2014; LIMA, QUEIROZ, 2014).

There are common studies in Brazil that address mortality through indirect estimates, characterized by severe restrictions on the demographic behavior of populations and on the use of assumptions. Despite the development of procedures that allow the estimation of death coverage, there are few Brazilian studies in this direction (PAES, 2005; PAES, SANTOS, CAUTINHO, 2021; MARINHO, 2019; QUEIROZ et al., 2017).

In recent decades, the quality of mortality information in Brazil has shown significant advances, but with great regional variability (PAES, 2007; TEIXEIRA et al., 2019). The completeness of death counts coverage increases from about 80% in 1980-1991 to over 95% in 2000- 2010, while at the same time the percentage of ill-defined causes of deaths was reduced by about 53% in the country. There are still large regional differences; the South and Southeast have much better data quality than the rest of the country. However, even though the coverage of female deaths reached the minimum level of 90% in 2000, in the South-Southeastern States of the country, there was no great advance for men. In some states in the Northeast and North, the quality of information is lower, but these show recent expressive advances, when compared to the period 1991-2000 (QUEIROZ et al., 2017).

In Brazil, a high proportion of deaths have been attributed to causes that should not be considered as underlying causes of deaths, named Garbage Codes (GCs) (TEIXEIRA et al., 2019). To tackle this issue, in 2005, the Brazilian Ministry of Health implemented the investigation of GCs (codes from chapter 18 "Symptoms, signs and abnormal clinical and laboratory findings, not elsewhere classified, ICD-10") to improve the quality of cause-of-death data. Although with a decreasing trend, GCs still represent an important percentage of total deaths in the country, influencing the quality of mortality information. Despite the improvement in cause of death quality, GCs and other ill-defined causes such as heart failure or septicemia, which contain no information of the underlying cause, remain frequent causes (FRANCA, ISHITANI, TEIXEIRA et al., 2020).

By the time this review was conducted (July of 2021), several studies dedicated to analysis of Garbage Codes in Brazilian mortality data were met considering national level (FRANCA, ISHITANI, TEIXEIRA et al., 2020), regional level of five regions (TEIXEIRA et al., 2019), and regional level considering Northeast region (OLIVEIRA et al., 2019). Analysis of garbage codes among registered deaths in Brazil in 1996–2016 according to levels assembled for the Global Burden of Disease (GBD) study, revealed decreasing trend (40.4%) of GCs in mortality statistics, particularly important for the level 1 codes (58.4% over the period). Teixeira et al. (TEIXEIRA et al., 2019) confirmed substantial progress has been seen in the quality of mortality data, analyzing period 2000-2015, which indicates improvements due to Ministry of Health initiatives.

Specific GCs such as unspecified pneumonia, heart failure or septicemia are still representing an important percentage of total deaths in Brazil, influencing the quality of mortality information. The highest proportion of GCs occurred among elderly people, especially those over 80 years and were due mainly to level 4 GCs (MARTINS, FELZENBURG, DIAS, COSTA, SANTOS, 2016). Higher proportions of ill-defined causes among the elderly are probably due to the higher number of comorbidities, such as neoplasms, hypertension, diabetes, and other cardiovascular diseases, making it difficult to provide information on the underlying cause of death during the completion of the Death Certificate.

On the other hand, children aged 1–14 years also represented a high fraction of major GCs (FRANCA, ISHITANI, TEIXEIRA et al., 2020). High proportions of GCs in this age group, although in accordance with the results of Naghavi et al. (NAGHAVI, 2010) in other settings, are of concern as it is particularly important for prevention to correctly identify the leading causes of premature deaths.

2.3.2.1 Coverage and completeness of mortality data in Northeast region and Paraiba

Available studies related to the quality of vital statistics in Northeast region and Paraiba suggest at least two statements: the improvement in coverage over time and that the underreporting and negligence of information about the underlying causes of deaths regarding death certificates (DC) are still worrisome (BRASIL, 2004; PAES ,2005; PAES, SANTOS, CAUTINHO, 2021).

In a cross-sectional ecological study of deaths due main types of cancer (2010 -2015) adopted to the 188 micro regions of the Northeast verified problems in the quality of information on basic death causes, which demanded correction for underreporting, ill-defined causes and garbage codes (CARVALHO, 2018).

The study of neonatal deaths registry in Paraiba (SANTOS, 2021) verified that as of 2012, the percentage of paired records was above 50%, reaching a maximum value of 58.8% in 2015. The problem with underreported data is the absence of information that will never be captured, leading to errors in the estimation of other indicators. The degree of underreporting in the municipal characterizations ranged from a minimum of 12.6% to a maximum of 24.1%, that is, these estimates refer to neonatal deaths that were not registered.

The percentage of deaths from ill-defined causes (IDC) is an important indicator to evaluate the quality of mortality information systems (MARTINS, COSTA, LORDELO, FELZEMBURG, 2011). Data on causes of death are fundamental to the knowledge of the epidemiological profile of the population and is decisive to guide the activities of planning and evaluation of health actions.

A study comparing the 1980-1991 and 2000-2010 periods showed that there was a 53% reduction in IDCs in the country, and the proportions of ill-defined causes of deaths declined from 72% in 1991 to approximately 25% in 2010 in the North and Northeast regions (MARTINS, COSTA, LORDELO, FELZEMBURG, 2011). Moreover, the study concluded that in areas where mortality was concentrated at older ages, the percentage of deaths registered as ill-defined also was increased. Considering the global process of aging of population, including in Brazil, the problem related to ill-defined causes of deaths in older ages group could be even more profound in terms of quality of mortality data (LIMA, QUEIROZ, 2014). Nevertheless, despite the significant decline of ill-defined causes of deaths (IDCs) in recent years, Northeast state still show a level above the 10% limit recommended by the Ministry of Health, to make possible the use of information on the cause of death to understand changes in mortality patterns and their impact on different population groups.

The studies dedicated to Garbage Codes (GCs) investigation in Northeast region, reflected the cause-of death incompleteness of mortality data, are even less optimistic. In the municipalities studied in the Northeast region of Brazil, about one quarter of the deaths were classified as priority garbage codes (MARTINS, COSTA, LORDELO, FELZEMBURG, 2011). According to study results, the SIM coverage, and the quality of information on causes of death vary widely in region. In the 18 municipalities (state´s capitals) studied in the Northeast region, 70% had the causes reclassified, of which 4,087 were changed to specified causes. Deaths with priority garbage codes corresponded to 24% of the total deaths in the municipalities studied, with 6 municipalities had more than 30% of garbage code deaths, especially Arapiraca-AL and Feira de Santana-BA with 41.3% and 40.2%, respectively.

The results of the study were particularly alarming considering the fact that the capitals presumably have better access to diagnosis and quality of care, in addition to better information on causes of death comparing with rest of municipalities in the region. These findings signalized that the garbage codes marked on the DC could be avoided for many deaths if the physicians sought complementary information in the medical records.

2.4 Excess Mortality

According to the theory of epidemiological transition, despite the inherent difficulties in attempting to structure a matrix that includes all the complex vital factors of population dynamics, the need to do so is urgent (CHECCHI, ROBERTS, 2005). Diseases associated with both the modern pattern of death and the old pattern of death seem to be highly present in all settlements. The attributes "old" and "modem", used to define epidemiological patterns, come from epidemiological transition theory. Conceptually, it focuses on the complex change in patterns of disease and mortality, and on the interactions between these patterns and their demographic, economic and sociologic determinants, and consequences. Whereas theories suggest, the understanding of mortality´s patterns and their components attributed to the natural causes of deaths (infectious/non-communicable diseases) or external causes (e.g. violence, accidence) are fundamental for public health policies.

2.4.1 Excess Mortality concept

Excess mortality is a term used in epidemiology and public health that refers to the number of deaths from all causes during a crisis above and beyond what we would have expected to see under ‘normal’ conditions (ARON, MUELLBAUER, 2020). Mortality rates describe the frequency with which deaths are occurring in a given population over a given time.

If these are higher than the expected (baseline) mortality rate in non-crisis conditions in that population, we can say that the difference between observed crisis and expected non-crisis mortality rates represents excess mortality, i.e. the mortality attributable to the crisis, above and beyond deaths that would have occurred in normal conditions.

A disaster may be defined as a relatively acute situation created that adversely impacts on the health and economic wellbeing of a community to an extent that exceeds the local coping capacity. In terms of patterns of mortality three types of crises can be delineated (CHECCHI, ROBERTS, 2005):

- ***Sudden natural disasters***, in which most mortality occurs as a result of the mechanical force of the elements or resulting injuries and is therefore concentrated in a period of hours or days;
- ***Acute emergencies*** due to large-scale armed conflict and/or rapid displacement; where these result in relocation of the population to camps, crude mortality rate is known to fall progressively as a result of better protection and the arrival of humanitarian aid, although neglect of vaccination and disease control efforts can lead to devastating epidemics of diarrheal diseases or measles;
- ***Slowly evolving, chronic or intermittent emergencies*** in which mortality may increase slowly over the course of months and years from near-normal levels, as a result of the progressive breakdown of health infrastructures, loss of livelihoods, isolation from international aid and nutritional problems, or in which crude mortality rate (CMR) can display regular peaks as a result of poor harvests, displacement waves, low-level conflict or epidemics affecting a chronically vulnerable population.

The excess mortality indicator can draw attention to the magnitude of the crisis by providing a comprehensive comparison of additional deaths amongst the countries and allowing for further analysis of its causes (CDC, 2020a). Mortality studies have occasionally played a prominent role in attracting aid and international political interest to a crisis. They can also serve to document the direct and indirect impact of crisis and population's displacement.

The literature has many examples of exceed mortality related to humanitarian crisis, including severe pandemics. As the COVID-19 pandemic has unfolded, many were drawn to the parallels with the influenza pandemic (BOW, 2014; BEACH, CLAY, SAAVEDRA, HUGO, 2020). Both are respiratory diseases caused by a virus, could spread from casual close contact, reached most parts of the globe within months, and both pandemics were characterized by excess of deaths.

Any evidence of excess mortality should lead to a reaction [35]. The amount of evidence needed in order to act depends on (i) how much can reasonably be collected; and (ii) what the data will be used for. When data are insufficient, the criterion for action should be to minimize the risk of overlooking or under-estimating a crisis.

2.4.2 Global evidence of excess mortality due COVID-19 pandemic

Mortality estimation is a challenging task, especially in the context of the health system' crisis. During current pandemic, many countries have been reported excess mortality on their territories (VEIGA E SILVA et al., 2020; CDC, 2020a; BANERJEE, PASEA, HARRIS, GONZALEZ-IZQUIERDO et al., 2020; GIATTINO, RITCHIE et al., 2020). There were certain concerns about correct diagnosis of disease in a period with limited availability of viral testing and the imperfect sensitivity of the tests; deaths that not caused by the virus could be improperly attributed to COVID-19 (LEON et al., 2020).

The excess death estimation approach can be applied to specific causes of death directly related to the pathogen (eg, pneumonia or other respiratory conditions), or this approach can be applied to other categories of deaths that may be directly or indirectly influenced by viral circulation or pandemic interventions (eg, cardiac conditions, traffic injuries, or all causes) (CDC, 2020a). It is a more comprehensive measure of the total impact of the pandemic on deaths than the confirmed COVID-19 death count alone and captures not only the confirmed deaths, but also COVID-19 deaths that were not correctly diagnosed and reported as well as deaths from other causes that are attributable to the overall crisis conditions.

Estimation of excess mortality better capture the total impact of the pandemic on deaths, for several reasons (CDC, 2020a; GIATTINO, RITCHIE et al., 2020):

- Some countries only report COVID-19 deaths that occur in hospitals — people that die from the disease at home may not be recorded;
- Some countries only report deaths for which a COVID-19 test has confirmed that a patient was infected with the virus — untested individuals may not be included;
- Death reporting systems may be insufficient to accurately measure mortality;

- The pandemic may result in increased deaths from other causes for a number of reasons including weakened healthcare systems; fewer people seeking treatment for other health risks; or less available funding and treatment for other diseases (e.g. HIV, malaria, tuberculosis);
- The pandemic may also result in fewer deaths from other causes. For example, the mobility restrictions during the pandemic might lead to fewer deaths from road accidents. Or there might be fewer deaths from the flu because of interventions to stop the spread of COVID-19, or because COVID-19 now causes deaths that would have otherwise been caused by the flu.

The confirmed deaths often undercount the total impact of the pandemic on deaths, but in contrast to excess mortality they contain information about the cause of death (GIATTINO, RITCHIE et al., 2020). In other hand, the excess mortality includes not only those who have died from COVID-19, but also those from all other causes. This means both metrics are needed to understand the total impact of the pandemic on deaths (BANERJEE, PASEA, HARRIS, GONZALEZ-IZQUIERDO et al., 2020).

Weekly excess deaths could provide the most objective and comparable way of assessing the scale of the pandemic and formulating lessons to be learned (LEON et al., 2020). This measure can be constructed by comparing the observed weekly deaths throughout 2020 to values expected from the experience of previous non-pandemic years.

Excess mortality data is unfortunately not available for many countries, and because the required data from previous years is lacking this will continue to be the case. When the goal is to monitor a global pandemic, this is a major limitation of this metric (ARON, MUELLBAUER, 2020). Excess mortality can only be calculated on the basis of accurate, high-frequency data on mortality from previous years. But few countries have the capacity and infrastructure to report the number of people that died in a given month, week or even day-to-day.

Several regional data and media are publishing public databases with estimated COVID-19 excess mortality:

- Eurostat publishes downloadable data for European countries on its website (EUROSTAT, 2020);

-Centers for Disease Control and Prevention (CDC) publishes US country´s statistics (CDC, 2020a);

-Pan American Health Organization (PAHO) Mortality Surveillance in Latin America and the Caribbean through All-Cause Mortality Surveillance (PAHO, 2020);

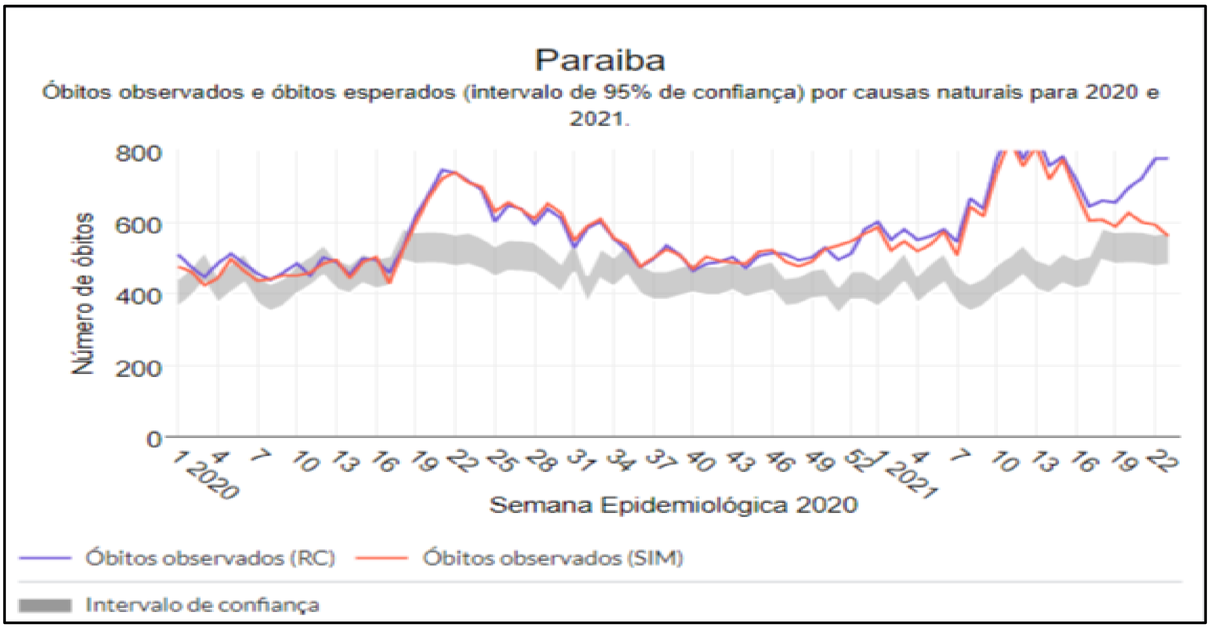
- The Economist, The New York Times, The Washington Post published the first database on excess mortality on GitHub (THE ECONOMIST, 2020; THE NEW YOURK TIMES, 2020; THE WASHINGTON POST, 2020);

-The Brazilian Ministry of Health, Excess Mortality Monitoring Panel (BRASIL, 2021).

The Excess Mortality Monitoring Panel was developed by the Brazilian Ministry of Health in collaboration with Vital Strategies Brazil (BRASIL, 2021). Originated as an epidemiological instrument to estimate exceed deaths due current pandemic in Brazil, the Excess Mortality Monitoring Panel has several limitations:

- The Panel does not remove the limitations of both Mortality Information Systems (Transparency Portal of Civil Registry Offices and Mortality Information System), which were described in a thesis´s chapter 2.2 " Brazilian mortality information systems"; There is no specific description available in Technical Note on the following framework: the way the data was derived from both resources and synthesized into one data; what exact estimation instruments (techniques) were applied (Figure 2.2).

Figure 2.2 - Observed and expected deaths due natural causes, 2020-2021.



Source: The Brazilian Ministry of Health. The Excess Mortality Monitoring Panel. July 2021.

Reporting deaths from COVID-19 is important to monitor impact of the disease and guide response efforts. But confirmed disease deaths alone are unlikely to capture the full extent of the disease's burden on a population. Analysis of excess mortality can help provide a more complete picture needed to support evidence-based policymaking.

By the time this review was written (12^{th} of July 2021), the search of publications through PUBMED/MEDLINE, Web of Science and Scielo public libraries identified a few publications on COVID-19 related excess mortality in Brazil (MARINHO et al., 2022; SILVA, JARDIM, SANTOS, 2020; FERNANDES, JUNIOR, AZEVEDO et al., 2021). However, there were no empirical studies that assessed the impact of COVID-19 epidemic on excess mortality in Paraiba.

3 METHODS

3.1 Study Design and study setting

Study design

This is an exploratory and analytical study performed by using official nationally consolidated death records data by age and sex for Paraiba, its counties João Pessoa, Campina Grande and Other Municipalities. COVID-19 deaths refer to the period from March to December 2020 monthly.

The methodological steps included:

1) Mortality data quality study (section 3.3). This was an assessment of death data quality through application of the following approaches: i) analysis of data quality using coefficient of variation and sex ratio, ii) analysis of the coverage by General Growth Balance method application, iii) analysis of deaths registration completeness by redistribution of ill-defined causes and iv) redistribution of garbage codes. The main output of data quality assessment was estimates of expected deaths due to COVID-19 in 2020 (after corrections based on quality assessment).
2) Calculation of mortality indicators in the study areas (section 3.4), by age and sex, before and after corrections based on data quality study. Two indicators were used – proportion of deaths attributable to COVID-19, and mortality rate per 100 000 population
3) Estimates of excess mortality (section 3.5) in 2020 based on weekly 2015-2019 time-series.

Study setting

Located in the Northeast part, Paraiba is one of 27 federative units (states) of Brazil and the third most densely populated state in its region (IBGE, 2020a). According to the Brazilian Institute of Geography and Statistics (IBGE, 2020b), Paraiba had a population of 4.039.277 inhabitants in an area of over 56.467 square kilometers with 66.70 hab./km² demographical density.

The Paraiba federal unit is represented by 223 counties, with the two most populated among all: Joao Pessoa and Campina Grande. The state had rapidly changed its economic and demographic characteristics in the past 30 years. The main socio-economic characteristics of the region, Joao Pessoa and Campina Grande are represented in Table 3.1.

Table 3.1- Socio-economic characteristics of Paraiba, Joao Pessoa, and Campina Grande.

Characteristics	**Paraiba**	**Joao Pessoa**	**Campina Grande**
Population size, 2020	4 039 277	817 511	411 807
Urban percentage, 2020	75.4%	-	-
Gross National Product (GNP) per capita, 2018	64,374 R$	25,036 R$	22,584 R$
The Gini Index, 2020 for region/2010 for counties	0,559	0,628	0,586
Unemployment rate, 2020	12.5%	-	-
Occupied population, 2020 for region/2018 for counties	42.5%	36.1%	27.0%
Human Development Index (HDI), 2010	0,658	0,763	0,720
Basic Education Development Index, 2010	4,7	4,9	4,6
Schooling rate from 6 to 14 years of age, 2010	-	96.9%	97.6%
Infant Mortality Rate (IMR), 2017	13,29	12,92	13,55
Source: Brazilian Institute of Geography and Statistics (IBGE), 2021			

According to the IBGE census as of 2010, 75.4% inhabitants of Paraiba were concentrated in the urban area whereas 24.6% in the rural area, with the prevalence of females (51.5%). Other numbers included (Table 3.1): Population growth: 0.8% (1991–2000), Gross National Product (GNP) per capita: 64,374 R$ (2018), Basic Education Development Index: 4,7 (2010), Human Development Index (HDI): 0,658 (2010) and Infant Mortality Rate (IMR): 13,29 per thousand live births (2017). According to the statistics (IBGE, 2020b), in 2019 were registered 57 227 newborns and 26. 637 all-cause deaths, whereas the Infant mortality rate as of 2017 was equal to 13,29 [156].

The capital city of Paraiba, João Pessoa, represents 19.2% of the state population and has the highest demographic density in the region (3.421.28 inhab./km²). According to IBGE, estimated population of the capital was 817 511 inhabitants in 2020. Considering occupation and income, the proportion of employed persons in relation to the total population was 36.1% in 2018 and in comparison, with the other municipalities, it took the first place in Paraiba state (Table 3.1).

Campina Grande is the second most populated county in Paraiba state, with population 411 807 inhabitants (2020) and demographical density 648.31 inhab./km² (2010) (IBGE, 2020b). In 2018, the average monthly income was 2.2 minimum salaries with the proportion of employed persons in relation to the total population was 27.0%. Some of socio- economical characteristics (Table 1) include: GNP per capita 22.583,86R$ (2018), Municipal Human Development Index (MHDI) was 0.720 (2010) and Infant Mortality Rate (IMR): 13.55 per 1,000 live births (2017).

3.2 Data Sources

The population estimates for Paraiba federative unit and its counties Joao Pessoa and Campina Grande for 2020 were extracted from IBGE (the Brazilian Institute of Geography and Statistics) (WHO, 2020b). The data of population was used for mortality indicators calculation, particularly for COVID-19 specific mortality rate.

Data related to all-cause deaths, natural deaths and respiratory system diseases deaths of period 2015-2020 for Paraiba was retrieved from official Brazilian governmental source the Mortality Information System (SIM) of DATASUS (Department of Informatics of the Unified Healthcare System). The data related to COVID-19 mortality for Paraiba and its municipalities for 2020 year of pandemic was retrieved from SIM. The data was used for excess mortality projection and analysis of mortality data quality.

The data related to the number of deaths due COVID-19 in Paraiba and its municipalities 2020 was collected from three additional sources: Panel Coronavirus by Ministry of Health, Transparency Portal by Registry Civil and “Coronavirus Microdata” by the Paraiba State Secretariat of Health (SES) and was considered for data quality comparative analysis. Three sources mentioned above were created specifically for COVID-19 monitoring purposes and did not providing information related to all-cause mortality, nor contain any historical data.

3.2.1 Mortality data

Mortality data was analyzed by epidemiological weeks. Weekly (1^{st}-52^{nd} epidemiological weeks) all -causes, natural causes and respiratory system diseases deaths for 2015-2020 in Paraiba, concisely presenting all the information contained in the death certificate, were compiled from the Mortality Information System (SIM). Weekly (12^{th}- 52^{nd} epidemiological weeks) COVID-19 deaths for Paraiba, Joao Pessoa, Campina Grande and rest of municipalities grouped as Other Municipalities were also extracted. The 12^{th} epidemiological week 2020 was considered as a start point for COVID-19 data collection based on data of first death registration in Paraiba (PARAIBA, 2020a).

Data was structured by age groups and sex. For comparative data quality analysis was considered 10-year age groups as follows: 0-9, 10-19, 20-29, 30-39, 40-49, 50-59, 60-69, 70-79 and more than 80 years old. For ill-defined causes (IDC), garbage codes analysis and expected/ projected deaths were considered two age group: < 60-years-old and ≥ 60 years-old.

International (WHO) and nationally adopted by Brazilian Ministry of Health guidelines according to COVID-19 deaths definitions, certifications, and classifications, as well as 10th revision of the International Classification of Diseases (ICD-10) for presentation of all-cause, natural causes, respiratory system diseases deaths, circulatory system diseases, ill-defined codes (IDC) and Garbage Codes were considered (WHO, 2020c; BRASIL, 2020i; ICD, 2020). The circulatory system diseases were collected for ill-defined causes study purposes only.

Deaths due COVID-19 were considered as a death resulting from a clinically compatible illness, in a confirmed COVID-19 (B34.2, U071, B97.21) case, unless there was a clear alternative cause of death that cannot be related to COVID-19 disease (e.g. trauma). Details on the International Statistical Classification of Diseases and Related Health Problems 10th Revision (ICD-10) rubrics/codes used in the datasets are given in Table 3.2.

Table 3.2 - The International Classification of Diseases (ICD) and related health problems codes 10th revision used for data analysis.

ICD-10 Revision/ Rubrics	**Codes**
Diseases of the Respiratory System	J00-J99- Diseases of the Respiratory System, U07.1, B34.2- Confirmed COVID-19, B97.21- SARS-associated coronavirus as the cause of diseases classified elsewhere.
Diseases of the Circulatory System Diseases	I00-I99- Diseases of the Circulatory System
Natural causes of deaths (ICD-10 all rubrics except for external causes of deaths)	Excluded: S00-T98- Injury, poisoning and certain other consequences of external causes, V01-V99- External causes of morbidity and mortality
Ill-defined causes (IDC)	R00-R99- Symptoms, signs and abnormal clinical and laboratory findings, not elsewhere classified

Data source- International Statistical Classification of Diseases and Related Health Problems 10th Revision (ICD-10), 2020

3.3 Quality of mortality data

The specific criteria, organized into a framework of four quality concepts (coverage, completeness, regularity, and reliability), usually are considered for comprehensive assessment of the quality of mortality data (UNITED NATIONS, 2014).

According to Paes (2018), *coverage* means the magnitude or level, usually measured in percentage, with which vital records are effectively listed in the systems; regularity is related to the frequency that a recording system keeps capturing data at a certain level over time; *reliability* represents degree of confidence or correct information in the variables observed in vital records; and *completeness* means the magnitude or level of declaration of a given variable informed when the registration was performed in the systems (PAES, 2018).

Paes (2018) points out that among the four quality concepts, the two most important are coverage and completeness. In this thesis, the quantity of all deaths due COVID-19 (*coverage*) and analysis of garbage codes and ill-defined cases (*completeness*) related to disease were considered as a concept of the quality of mortality data. The study of the quality of individual Death Certificates and the frequency of recording system was not included in a work, since this type of information was not available, furthermore was not the objective of the study.

3.3.1 Quality of deaths data sources

The comparison of mortality data retrieved from Brazilian official public portals related to COVID-19 deaths in a pandemic period 2020 for Paraiba and its municipalities was performed. The quality of sources of deaths were assessed by following the certain characteristics such as completeness, consistency, and timeliness.

The data sources that were considered for the analysis were official governmental platforms that collect vital statistics or mortality, death data related to COVID-19, all-cause mortality, and specific respiratory diseases, and aggregated death data related to Paraiba and its counties.

The following resources with response to these characteristics were chosen to be analyzed: The Mortality Information System (SIM) by Ministry of Health, the Registry Civil Transparency Portal by Brazilian Institute of Geography and Statistics (IBGE), “Portal

Coronavirus" by the Ministry of Health and "Coronavirus Microdata" by the Paraiba State Secretariat of Health (SES).

For each data source, total number of deaths, number, and proportion by sex, and by age groups were summarized by the most affected counties. The geographic areas were João Pessoa, Campina Grande, and the regional category labeled as "Other municipalities" of the state was investigated. The difference in death counts between data sources was calculated as absolute difference and as percentage change.

The calculation of coefficient of variation (CV) and sex ratio (SR) of death data was performed for Paraiba, João Pessoa and Campina Grande, considering the death data recorded by the Paraiba State Secretariat of Health (SES) for three periods (March-May, June-August and September-December 2020).

The following aspects for comparative analysis were considered: time-lag, considered as a time elapse between date of death occurrence and date of death registration; occurrence of the peak of the pandemic treated by different portals in Paraiba and its counties.

The Coefficient of Variation (CV) was calculated as follows:

$CV = \frac{\sigma}{\mu}$, where σ- standard deviation (SD) and μ- mean.

The -sex ratio (SR) was calculated related to COVID-19 death data for all Brazil using the Mortality Information System (SIM) data, and for Paraiba using data from SIM and SES, for different age groups. The 10-year age groups were divided as follows: 0-9, 10-19, 20-29, 30-39, 40-49, 50-59, 60-69, 70-79 and more than 80 years old.

The Sex Ratio (SR) was calculated as follows:

$SR = \frac{m}{f}$, where m-number of males and f-number of females.

For each source of information, the data were imported from the websites in the format provided (comma delimited csv file) and were organized by using the Microsoft Excel Office 2016. Map was constricted using program QGis version 3.4.

3.3.2 Coverage of deaths

The death distribution methods have been widely used to evaluate the coverage of registered deaths in developing countries (HILL, YOU, CHOI, 2009). Where the necessary data exist, death distribution methods are the method of choice because they provide age-period specific estimates of mortality rates. The study of adult mortality in less developed countries is problematic due to data quality issues, and it could be more compromising in a period such as pandemics.

The estimates of the coverage of total deaths of individuals for each sex above 5-years old age in Paraiba in 2020 was considered by using the General Growth Balance (GGB) method proposed by Brass (1975) (BRASS, 1975).

The method makes use of the observation that in a stable population (i.e. a population with an unchanging age structure over time – at least for the adult ages – growing at a constant rate, r, each year) that is closed to migration and has accurately reported data, the growth rate, r, is equal to the birth rate, b, less the death rate, d. In a stable population, the growth rate is constant for all segments, so the entry rates and the death rates must be linearly related.

The method was calculated as follows:

$$\frac{N(a)}{N(a+)} = r + k.\frac{D\prime(a+)}{N(a+)}, \text{ where}$$

N(a) and *N(a+)* -the number of entries (that is, birthdays at age a), and the population of, the age group a and over respectively;

r -the stable population growth rate;

k -correction factor;

D(a+)- the deaths at ages a and over.

The following assumptions were considered to attain reliable results (Brass, 1975): i) relative stability of the population; ii) age distribution of deaths must show a constant degree of coverage; iii) age distribution of the population must not present problems of enumeration or declaration of age.

Therefore, the following criteria were established to estimate the coverage of deaths to overcome these difficulties (PAES, 2018), that is, to select the most stable age groups to be used in regression model:

1. Consider a variation limit for age groups between 20 and 65 years old;
2. Not considered any coverage above 100%;
3. Not considered coverage below of what was verified for 2011 by RIPSA (RIPSA 2012);
4. Coverage of male deaths greater than coverage of female deaths.

In this sense, the classification of adult death coverage proposed by Chackiel (1987) in adaptation of Paes (PAES, 2018) for both sexes were used to provide verification of the “maximum” coverage estimated in this study (Table 3.3).

Table 3.3 - Classification of adult death coverage by sex.

Coverage (%)	Classification
>90	Very good
81-90	Good
71-80	Regular
≤70	Deficient

Source: Adaptation by Paes (2018) of the method proposed by Chackiel (1987)

3.3.3 Redistribution of ill-defined causes (IDC)

Timely and reliable data on causes of death (COD) are fundamental for monitoring health situation of populations in order to better inform health policy decisions. The completeness of death registration statistics in Brazil during the last decade remained a problem, as the country presented relatively high levels of ill-defined causes with wide variability between cities and regions (FRANCA, ISHITANI, TEIXEIRA, DUNCAN, MARINHO, NAGHAVI, 2020).

In this study, the ill-defined causes of deaths were defined according to classification R00-R99 (symptoms, signs and abnormal clinical findings, not elsewhere classified) in the Chapter XVIII of International Statistical Classification of Diseases and Related Health Problems 10th Revision (ICD, 2020) .

Ill-defined causes of deaths (IDC), deaths due COVID-19, respiratory system conditions, circulatory system conditions and deaths due other causes registered for Paraiba, Joao Pessoa, Campina Grande and Other Municipalities by Mortality Information System (SIM) in a period 12^{th}-52^{nd} epidemiological weeks 2020 were collected to perform method of redistribution of ill-defined causes (Table 3.4). The Mortality Information System (SIM) was considered as a data source for this analysis, because it collects and processes the cause of death data across the country, including Paraiba.

Table 3.4 - Specific causes of deaths codes according to International Statistical Classification of Diseases and Related Health Problems 10th Revision (ICD-10) considered for redistribution of ill-defined causes

ICD-10 Chapter	Description	Codes
Chapter XVIII	Symptoms, signs and abnormal clinical and laboratory findings, not elsewhere classified	R00-R99
Chapter X	Diseases of the respiratory system	J00-J99
Chapter IX	Diseases of the circulatory system	I00-I99
Chapter I, II, III, VI, V, VI, VII, VIII, XI, XII, XIII, XIV, XV, XVI, XVII, XIX, XX, XXI, XXII	**Other causes of deaths**[a] (Certain infectious and parasitic diseases; Neoplasms; Diseases of the blood and blood-forming organs and certain disorders involving the immune mechanism; Endocrine, nutritional and metabolic diseases; Mental and behavioral disorders; Diseases of the nervous system; Diseases of the eye and adnexa; Diseases of the ear and mastoid process; Diseases of the digestive system; Diseases of the skin and subcutaneous tissue; Diseases of the musculoskeletal system and connective tissue; Diseases of the genitourinary system; Pregnancy, childbirth and the puerperium; Certain conditions originating in the perinatal period; Congenital malformations, deformations and chromosomal abnormalities; Injury, poisoning and certain other consequences of external causes; External causes of morbidity and mortality; Factors influencing health status and contact with health services; Codes for special purposes).	A00-B99; C00-D48; D50-D89; E00-E90; F00-F99; G00-G99; H00-H59; H60-H95; K00-K93; L00-L99; M00-M99; N00-N99, O00-O99; P00-P96; Q00-Q99; S00-T98; V01-Y98; Z00-Z99; U00-U85

[a] description of other causes of death listed according to numerical appearance of ICD-10 Chapters

Total number and proportions of IDC, COVID-19, respiratory/circulatory systems conditions and other causes of deaths notified in 2020 were structured by sex for each analyzed territory. Sex-adjusted data (absolute number/proportions) for 2020 was compared with previous year 2019 (without pandemic).

The Ledermann´s method (LEDERMANN, 1955) was applied to perform the procedure of redistribution of ill- defined causes into defined causes. A procedure to redistribute ill-defined causes into defined causes was proposed by Ledermann and applied by Vallin. The method proposes a simple linear regression between the proportion of a specific cause of death (defined as dependent variable) and the proportion of ill-defined causes of death (defined as independent or explanatory variable).

The angular coefficient of the regression, which can be estimated by the Least Square Method (LSM), provides an estimation of the proportion of ill-defined causes of death that shall be attributed to the specific cause of death or group of causes.

The sum of the proportions derived by the angular coefficients generated to each cause of death shall be equal to -1. In turn, the sum of the linear coefficients shall be equal to zero. In this way, the angular coefficient provides a factor of redistribution of the ill-defined causes for each involved defined cause.

The method was calculated as follows:

$$\hat{Y}_{ij} = a_j + b_j X_i, \text{ where}$$

a_j and b_j represent angular and linear coefficients;

$\hat{Y}_{ij}$ -the variable that represents the proportion of deaths in specified territory (i) attributed to a specific cause of death (j);

X_i represents the proportion of ill-defined deaths in a corresponding territory.

The proportion of deaths in all age-groups by the main groups of causes was considered as a dependent variable (COVID-19, circulatory diseases, respiratory diseases, etc.) and the proportion of deaths from ill-defined causes in Paraiba, disaggregated by sex, was considered as an independent variable.

The equation for the redistribution of ill-defined deaths has the following expression:

$$O_{ij} = -b_j W_i + Z_{ij}, \text{ where}$$

O_{ij} : deaths attributed to the j-th group of causes for the i-th territory, after the redistribution of ill-defined causes;

b_j : angular coefficient of the Ledermann regression line, expressed in proportion;

W_i : deaths from ill-defined causes referring to the i-th territory;

Z_{ij} : observed deaths from the i-th territory assigned to the j-th group of causes.

3.3.4 Redistribution of Garbage Codes (GCs)

Besides ill-defined codes, there are several other causes of deaths called Garbage Codes (GCs) that do not represent useful information from a policy perspective and whose inappropriate overuse compromises vital statistics (MURRAY, LOPEZ, 1996). In Brazil, despite observed decreasing trend in major GCs, they are still representing an important percentage of total deaths in the country, influencing the quality of mortality information (FRANCA, ISHITANI, TEIXEIRA, DUNCAN, MARINHO, NAGHAVI, 2020).

Frequent use of GCs across countries statistics and over time profoundly limits meaningful comparisons of causes of death, for this reason, WHO and other analysts have sought to reassign deaths coded to GCs to other causes following various methods (NAGHAVI, 2010; FRANCA et al., 2014).

The Mortality Information System (SIM) data, the national consolidated mortality information source which contain cause of death (COD), was used to extract the underlying cause of deaths attributed to Garbage Codes for Paraiba and its municipalities. The study was followed the same pattern for analysis considering for territories (Paraiba, Joao Pessoa, Campina Grande and Other Municipalities), disaggregated by sex and two group of age (under 60-years-old and ≥ 60-years-old).

For redistribution of Garbage Codes to COVID-19 cases, the study followed conceptual approach outlined in detail by Naghavi et al. (NAGHAVI, 2010), which has been widely used, and not changed since Global Burden of Diseases 2013 study (GBD, 2017). The algorithm was followed three main steps (Figure 3.1): identification of GCs; identification of target causes where the deaths assigned to a GCs should in principle be reassigned (based on pathophysiology); and calculation of the fraction of deaths assigned to a GCs that should be reallocated to target cause.

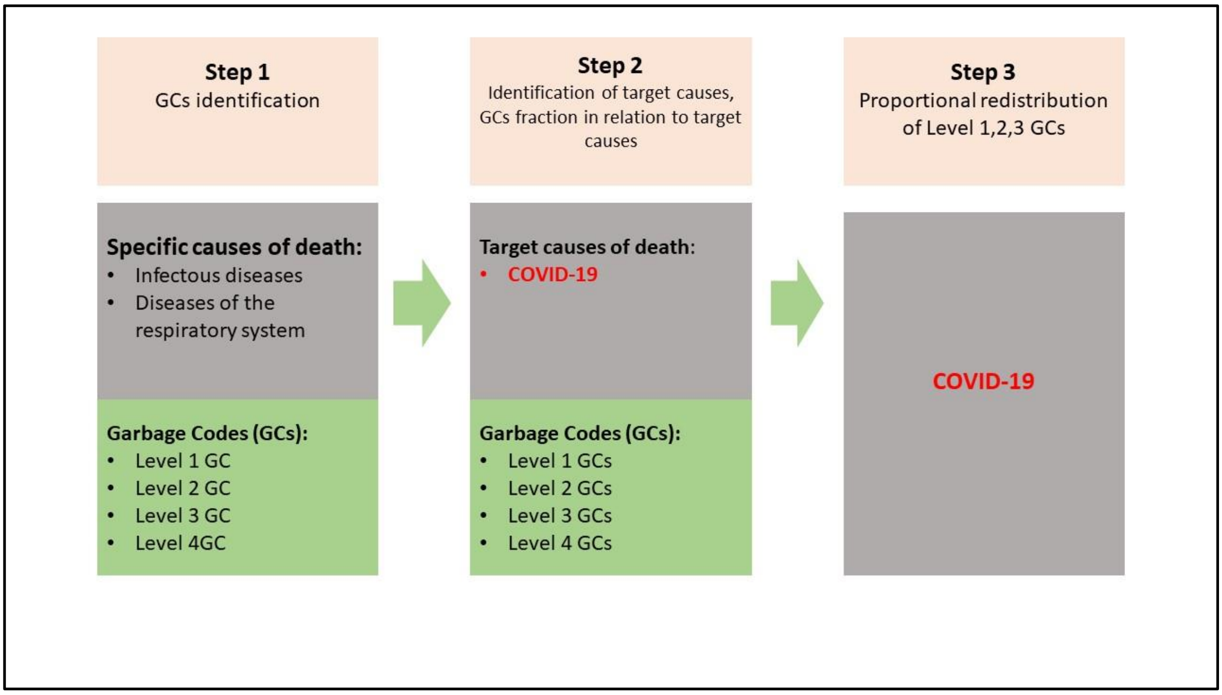
Step 1. Definition of causes of deaths groups and GCs identification.

Following the steps of algorithm, GCs was established two major group of causes considering International Statistical Classification of Diseases and Related Health Problems 10th Revision: ICD-10 Chapter I "Certain Infectious Diseases" (A00-B99) and ICD-10 Chapter X "Diseases of the Respiratory System" (J00-J99). In addition to identify specific Garbage Codes (GCs) list and mapping it across specific causes of deaths based on ICD-10, the typology of GCs was used (GBD, 2017).

The full list of Garbage Codes considering their typology established by GBD study is presented in Appendix II.

It is important to highlight, that there is no specified GCs for COVID-19 since this disease is relatively new, with newly opened ICD-10 rubrics, and yet under observation/investigations in terms of pathogenesis, systems involved to pathology and specific reasons of deaths. The CGs for investigation were chosen according to scientific knowledge about primarily respiratory system damages due COVID-19 and its generalized sepsis complications (ZHOU, FEI et al., 2020; GUAN et al., 2020).

Figure 3.1 - Algorithm of Garbage Codes (GCs) redistribution



LEGEND: COVID-19-Coronavirus disease 2019; GC -Garbage Codes, ICD-10- International Statistical Classification of Diseases and Related Health Problems 10th Revision;
Source: Modification of algorithm for GCs redistribution, proposed by Naghavi et al 2010

Table 3.5 shows specific Garbage Codes that were chosen to redistribution following the algorithm of the study and target causes of deaths.

Table 3.5 - List of Garbage Codes chosen for redistribution according to their typology and target cause of deaths

Typology of GCs	Specific Garbage Codes (GCs)[a]
Level 1 (very high)- codes with serious policy implications	A41.9- Sepsis, unspecified; (J80- J80.9)- Adult respiratory distress syndrome; (J85-J85.3)- Abscess of lung and mediastinum, Abscess of mediastinum; (J86-J86.9)- Pyothorax; Pyothorax without fistula; (J96-J96.9)- Respiratory failure, not elsewhere classified, Respiratory failure, unspecified; (J98.1-J98.3)- Pulmonary collapse, Compensatory emphysema
Level 2 (high)- codes with substantial policy implications	J81-Pulmonary oedema; J90- Pleural effusion, not elsewhere classified; J94.1- Fibrothorax; (J94.8-J94.9)- Pleural condition, unspecified
Level 3 (medium) – codes with important policy implications	(J71-J79, J83, J85.9, J87-89, J90.9, J93.6, J97-J98.0, J98.4-J99.8)- Other disorders of lung, Respiratory disorders in other diseases classified elsewhere
Level 4 (low)- codes with limited implication for policy	(J17-J17.1)- Pneumonia in diseases classified elsewhere, Pneumonia in viral diseases classified elsewhere; J18- Pneumonia, organism unspecified; J18.8 -Other pneumonia, organism unspecified; J18.9- Pneumonia, unspecified; J22- Unspecified acute lower respiratory infection;

Source: International Statistical Classification of Diseases and Related Health Problems 10th Revision (ICD-10)

Step 2. Identification of target causes and calculation of GCs fractions

Each GC was revised in terms of pathophysiology connection to COVID-19, and those that are likely belong to another ICD chapter or rubrics were excluded (for example, J69.8- Pneumonitis due to other solids and liquids or J93-J93.1- Pneumothorax unspecified; Other Pneumothorax).

Firstly, the number of GCs were extracted from two major group of death causes established previously. This number was distributed by sex and age groups (under 60-years-old and equal or above 60-years old) and estimated their proportions. The proportion of GCs related to target causes of deaths were calculated as follows:

$$GCs^{j'} = \frac{GCs^{j}}{Total\ number\ of\ deaths^{j}} \times 100, \text{ where}$$

GCs^{j} - Garbage Codes related to target group(s) of causes,

$Total\ number\ of\ deaths^{j}$ - total number of deaths in target group(s) of causes

To assess changes over time, the absolute number and proportion of specific GCs (Table 3.5) calculated for 2020 were compared with previous 2019 year

Step 3. Proportional redistribution of Garbage Codes (GCs)

On this stage of the study, the number of GCs according to their typology and two major group of causes (Table 3.5) were extracted from Line A (diseases or condition directly leading to death) for all COVID-19 deaths registered in Paraiba and its municipalities.

Total, age-group and sex adjusted proportions of GCs for each level were estimated considering target disease. All GCs previously extracted from major groups were redistributed accordingly to calculated fraction for COVID-19 considering their typology and sex-adjusted distribution. Re-distribution of GCs were proceeded as follows:

$$GCs_{redistr.}^{Covid'(Level1,2,3,4)} = \frac{GCs_{prop.}^{Covid,line\ A\ (level\ 1,2,3,4)} \times GCs_{total\ number}^{j\ (Level\ 1,2,3,4)}}{100}, \text{ where}$$

$GCs_{prop.}^{Covid,line\ A\ (level\ 1,2,3,4)}$- Garbage Codes proportions for each level considering COVID-19,

$GCs_{total\ number}^{j\ (Level\ 1,2,3,4)}$- total number of Garbage Codes related to target group(s) of causes

3.2.1 Calculation of expected deaths due COVID-19 in Paraiba

In this thesis the term expected deaths is used for 2020 estimates corrected based on the results of the mortality data quality study. To summarize two principal concept of the mortality quality study- coverage and completeness- in Paraiba during COVID-19 pandemic 2020, were established following steps for expected deaths calculation:

1) The generic equation proposed by Paes 2021 was applied to calculate expected deaths considering estimated coverage of deaths by application of the General Growth Balance method (Session 3.3.2) and completeness by redistribution of ill-defined causes and Garbage Codes (Sessions 3.3.3 and 3.3.4).

The general equation was formulated as follows:

$$D_{exp} = f * D_{obs}^{s}, \text{ where}$$

f- correction factor of under registration deaths based on "golden standard" source of data,

D_{obs}^{s}- observed deaths considering “golden standard” data source.

The ” golden standard ” data source was considered those which performed better in terms of volume of deaths registration or completeness of information related to death certificate (DC).

The equation was adapted to COVID-19 study for Paraiba as follows:

$$D_{Covid\ exp}^{SIM\prime} = D_{Covid\ exp}^{SIM} + IDC_{Covid}^{SIM} + GC_{Covid}^{SIM}$$, where

$D_{Covid\ exp}^{SIM\prime}$- COVID-19 expected deaths considering estimated coverage and completeness,

$D_{Covid\ exp}^{SIM}$- COVID-19 expected deaths considering under-registration based on the Mortality Information System (SIM) as a ” golden standard ” source of data,

IDC_{Covid}^{SIM}- Ill-defined causes (IDC) related to COVID-19 considering the Mortality Information System (SIM) as a ” golden standard ” source of data,

GC_{Covid}^{SIM}- Garbage Codes (GC) related to COVID-19 deaths considering the Mortality Information System (SIM) as a ” golden standard ” source of data.

2) Application of sex-adjusted proportion of expected deaths to all deaths distributed by 12^{th}-52^{nd} epidemiological weeks.

The Mortality Information System (SIM) data was considered at all stages of the mortality quality study since it represents nationally consolidated deaths registration source based on death certificate (DC) and includes ICD-10 coding of causes.

3.4 Mortality Indicators

COVID-19 age-proportionate deaths ratio and COVID-specific mortality rate per 100 000 population were estimated for Paraiba, Joao Pessoa, Campina Grande and Other Municipalities period 2020, based on the Mortality Information System (SIM) data were calculated for this study.

Age-proportionate mortality ratio represents percentage distribution of deaths by specific age or age-group in the population residing in a given geographic space, in the considered period (RIPSA, 2012). The indicator provides estimate of a relative importance of a specific cause of death in relation to all deaths (RIPSA, 2012). The indicator permits analyze geographic and temporal variations in mortality by age and contributes to the assessment of the population's health levels.

Age-proportionate mortality ratio was adopted for COVID-19 and calculated as follows:

$$\frac{Number\ of\ deaths\ due\ COVID{-}19\ ,by\ age\ group}{Total\ number\ of\ deaths,\ \ excluding\ ignored\ age\ cases} \times 100$$

The following age-groups were considered in age-proportionate mortality ratio calculation: < 60-years-old and ≤ 60-years old.

The cause-specific mortality rate is the mortality rate due a specified cause for a population. The numerator is the number of deaths attributed to a specific cause and denominator remains the size of the population in a determined geographical space at the midpoint of the time period.

The fraction is usually expressed per 100,000 population. The cause (COVID-19) specific mortality rate permits estimate the risk of death from communicable disease considered its magnitude as a public health problem. The indicator was estimated as follows:

$$\frac{Number\ of\ deaths\ assigned\ to\ Covid{-}19\ during\ a\ given\ enterval\ of\ time}{Mid{-}interval\ population} \times 10^{n}$$

For COVID-specific mortality rate was considered sex-adjusted distribution. Both indicators (COVID-19 age-proportionate deaths and COVID-specific death rate) calculations were estimated before and after expected deaths correction (session 3.3.5).

3.5 Excess mortality

In this study, the excess mortality is defined as the number of deaths during a pandemic above and beyond what we would have expected to see under “normal” conditions (CDC, 2020a). The main principal behind the excess mortality is how the number of deaths during crisis compares to the deaths we would have expected if the pandemic not occurred — a crucial quantity that cannot be known but can be estimated.

The traditional actuarial approach to the measurement of mortality is based on the comparison of actual and expected deaths, which also has been applied to the measurement of excess mortality associated with an extra risk in the comparison of actual and expected deaths for a group of policyholders exhibiting the particular risk under consideration (ENGLAND, HABERMAN, 1993).

In the literature related to excess mortality, “expected deaths” is the term used to define deaths that are expected under normal conditions. In this thesis, the term “expected death” is used for estimates after correction in the death quality study (section 3.3.5). In the thesis, baseline 2015-2019, or projected deaths, is used to describe mortality expected under normal conditions

3.5.1 Excess deaths calculation using historical data by epidemiological weeks

The *baseline* deaths for Paraiba were estimated based on weekly historical data for the last five years 2015-2019 obtained from the Mortality Information System (SIM) data source. The *observed* deaths in 2020 are referred to the deaths as registered in SIM database. *Expected* deaths in 2020 are the number of deaths after corrections based on the mortality quality study (Section 3.3.5)

The all-causes, natural causes and respiratory system diseases deaths data was structured by epidemiological weeks (1^{st} -52^{nd} epidemiological weeks) and adjusted by sex and age groups. An age breakdown of 0-59 years and 60+ years were applied.

The following steps were considered:

1 Step- Before estimation of expected deaths, each year of data for any mortality “shocks”, such as other epidemics or natural disasters, which might not represent long-term mortality trends was observed and removed from the data.

2 Step- The trend line of the deaths (historical data 2015-2019) to calculate excess deaths in the period of interest was constructed. The average of historical data using standard error for the confidence intervals and the forecasting exponential smoothing function in Excel using the square root of deaths for the confidence interval were applied.

3 Step- two sets of data were used to excess deaths calculation and comparison: registered data and expected deaths data as a result of quality data correction (session 3.3).

3.5.1.1 Average of historical data

A study followed recommendations by Centers for Diseases Control and Prevention (CDC) for excess deaths associated with COVID calculations (CDC, 2020b). A range of estimates of excess deaths was estimated by comparing the observed and expected in 2020 death numbers of deaths to baseline: the upper bound of the 95% prediction interval of the projected number of deaths.

By calculating standard error (SE) and confidence interval (CI) according to the values of each week in five years (2015-2019), was obtained baseline value, which was the weekly upper limit for expected deaths under normal conditions. Next, was obtained the number of excess deaths for each week by separately subtracting weekly baseline from observed/ expected number of deaths corresponding to the same week of 2020.

As a result of these subtractions, values in which the weekly excess deaths were negative or incorrect were corrected as 0. The lower end of the excess death range was generated by comparing the observed counts to the upper bound baseline, and a higher end of the excess death range was generated by comparing the observed count to the average of projected number of deaths.

Negative values, where the observed count fell below baseline, were set to zero. The total number of excess deaths for Paraiba was calculated by summing the excess deaths in each epidemiological week, from January 1, 2020, to December 31, 2020.

The average is defined as the mean value which is equal to the ratio of the sum of the number of a given set of values to the total number of values present in the set. The average of 2015-2015 weekly historical series was calculated as follows:

$\mu = \frac{\sum x}{N}$, where N-data values in the population.

3.5.1.2 Exponential smoothing for time-series forecasting

The exponential distribution is a continuous distribution that used to model the time that elapses before an event occurs (HYNDMAN, ATHANASOPOLOUS, 2021). The Excel

FORECAST.ETS (exponential triple smoothing) function was used to project deaths in 2020 based on historical time series 2015-2019.

Triple Exponential Smoothing (Holt-Winter Method) can model seasonality, trend, and level components for univariate time series data. Seasonal cycles are patterns in the data that occur over a standard number of observations.

The basic equations for the method are given as follows:

$S_t = \alpha \frac{y_t}{I_{t-L}} + (1-\alpha)*(S_{t-1}+b_{t-1})$, Overall smoothing;

$b_t = \gamma(S_t - S_{t-1}) + (1-\gamma)b_{t-1}$, Trend smoothing;

$I_t = \beta \frac{y_t}{S_t} + (1-\beta)*I_{t-L}$, Seasonal smoothing;

$F_{t+m} = (S_t + mb_t)*I_{t-L+m}$, Forecast, where

F- forecast at m period ahead,

S- smoothed observation,

I- the seasonal index,

L- periods in a season,

t- index denoting a time period,

b- trend factor,

y- observation,

α, β and γ- constants.

Similarly, to the average of historical data, two thresholds were considered in excess deaths calculation: 1) forecast projected deaths and 2) the upper bound of the 95% prediction interval of the projected number of deaths (session 3.5.1.1).

3.5.1.3 Error Measures

The residual analysis was performed in order to choose the most adequate model for the calculation of excess deaths due to COVID-19.

Residual analysis. In a non-linear regression, the residual analysis of a model is done to verify the plausibility of the assumptions involved. The diagnostics of the models by residuals measurements was performed.

The difference between the observed value of the dependent variable (y) and the predicted value (ŷ) is called the residual (e). Each data point has one residual. Residual = Observed value - Predicted value (e = y – ŷ), where both the sum and the mean of the residuals are equal to zero (SILVA, 2015).

In order to verify the assumption of normality, the Shapiro-Wilk statistical test was performed, which is one of the most used to verify the assumption in which it rejects the null hypothesis when the p-value is ≤ 0,05, the hypotheses are:

H_0 = has normality

H_1= does not have normality.

The statistical test frequently used for heteroscedasticity is called Breusch-Pagan, in which the null hypothesis is rejected when p-value is ≤ 0,05, the hypotheses are:

H_0 = has homoscedasticity

H_1= does not have homoscedasticity.

Time-related residuals are called auto-correlated and to check for the existence of a correlation between the residuals, should plot them against time or any variable of interest. The Durbin-Watson test was used to verify the existence of first-order autocorrelation, and its hypotheses are:

H_0 = there is no correlation between the residues

H_1= there is no correlation between the residues.

Mean absolute error (MAE) is a measure of errors between paired observations expressing the same phenomenon.

$$MAE = \frac{\sum_{i=1}^{N}(V_{oi} - V_{ei})}{N}$$

V_{oi}= the value of observed variable

V_{ei}= the value of estimated variable

N = period

The V can have any real value, where values closer to zero, by definition, represent less error. It is measured with the same unit used in the series.

Mean absolute percentage error (MAPE) is calculated by dividing the Percent Error (EP) by the number of periods N. The EP measures the percentage of the error in relation to the real value.

$$MAPE = \frac{\sum_{i=1}^{N}(\frac{V_{oi}-V_{si})}{V_{oi}}}{N} \times 100$$

V_{oi}= the value of observed variable

V_{ei}= the value of estimated variable

N = period

Mean square error (MSE) is defined by the sum of the squares of the differences between estimated / predicted results and observations.

$$MSE = \frac{\sum_{i=1}^{N}(V_{oi} - V_{si})^2}{N}$$

V_{oi}= the value of observed variable

V_{ei}= the value of estimated/expected variable

N = period

It is the most used error measure which highly sensitive to a large deviation between the values of the compared series, which becomes more relevant when it comes to evaluating large errors.

Root mean square error (RMSE) is the standard deviation of residuals. This parameter is commonly used in climatology, forecasting, and regression analysis to verify experimental results.

$$RMSE=\sqrt{\frac{\sum_{i=1}^{N}(V_{oi}-V_{ei})^2}{N}}$$

3.5.2 Excess Deaths Measures

The calculation of excess deaths was based on recent historical data for the last five years, 2015-2019 according to the "best" performed model between the average of historical data and exponential smoothing function.

Two measures were used in this thesis – absolute number of excess deaths, and relative measure, P-score. The absolute number of excess deaths is the difference between number of observed and number of projected deaths (baseline):

$$Excess\ deaths_{\ week\ (x)2020} = Observed\ Deaths_{\ week\ (x)2020} - Projected\ Deaths_{week(x)2020}$$

The absolute number of excess of deaths provides the measure of scale, however this measure has its limitations, including being less comparable across the territories due to large differences in populations (CDC, 2020a). If the result was a positive number, the week was marked as having experienced excess mortality.

A measure that is more comparable across countries is the P-score, which calculates excess mortality as the percentage difference between the number of deaths in 2020 and the average number of deaths in the same period — week or month — over the years 2015–2019.

- P-score, the percentage difference between the number of deaths in 2020 and the average number of deaths in the same period — week or month — over the years 2015–2019. The P-score is a measure that permits compare across the territories/regions.

$$P - score = \frac{Deaths_{Period\ \#2020} - Average\ Deaths_{Period\ \#2015-2019}}{Average\ Deaths_{Period\#2015-2019}} *100$$

While the P-score is a useful measure, it too has limitations. For example, the five-year average death count might be a relatively crude measure of expected deaths because it does not account for trends in population size or mortality (CDC, 2020b).

4 RESULTS AND DISCUSSION

This chapter presents the results and discussion of the study according to formulated objectives. The chapter is organized in sections related to the respective study objectives (section 1.3, page 1) as follow:

1) Section 4.1 shows the results of the quality of mortality data study and includes comparative analysis of five Brazilian COVID-19 official data sources (the Mortality Information System, State Secretariat of Health, Coronavirus Panel and Registry Civil by date of occurrence and date of registry) based on total amount and proportion of deaths in Paraiba and its municipalities in 2020 adjusted by age and sex, considering epidemiological weeks, pandemic peaks, time lag and spatial distribution of deaths; estimates of the coverage of total deaths of individuals above 4 years in Paraiba in 2020 by application of the General Growth Balance method modified by Brass; and analysis of garbage codes and ill-defined causes of death related to COVID-19.
2) Section 4.2 represents by weekly all -cause and respiratory diseases deaths for 2015-2019 and weekly COVID-19, all-cause and respiratory diseases deaths in a period of March 1st-December 30th, 2020, desegregated by sex and age-specific groups for Paraiba, Joao Pessoa and Campina Grande, both compiled from the Mortality Information System (SIM).
3) Section 4.3 describes results of COVID-19 excess mortality estimates in Paraiba and its municipalities based on the average of five-year time series construction and exponential forecasting method applications.

4.1 Quality of COVID-19 mortality data

4.1.1 Comparative analysis of Brazilian COVID-19 data sources

The comparative analysis of deaths due COVID-19 in Paraiba and its municipalities, considering period 12th-52nd epidemiological weeks of 2020, revealed differences in total number of deaths among five official Brazilian data sources (Table 4.1).

According to results, regardless of date of death reference, the highest number of deaths in Paraiba was reported by State Secretariat of Health (SES), represented overall 3659 of deaths. The difference between data released by SES comparing with other sources varied from 1.3%

(Coronavirus Panel by date of death registry) to 20% (Transparency Portal by date of death registry).

Table 4.1 - Total number and difference of deaths due COVID-19 based on five different data sources, 12th-52nd epidemiological weeks, Paraiba 2020

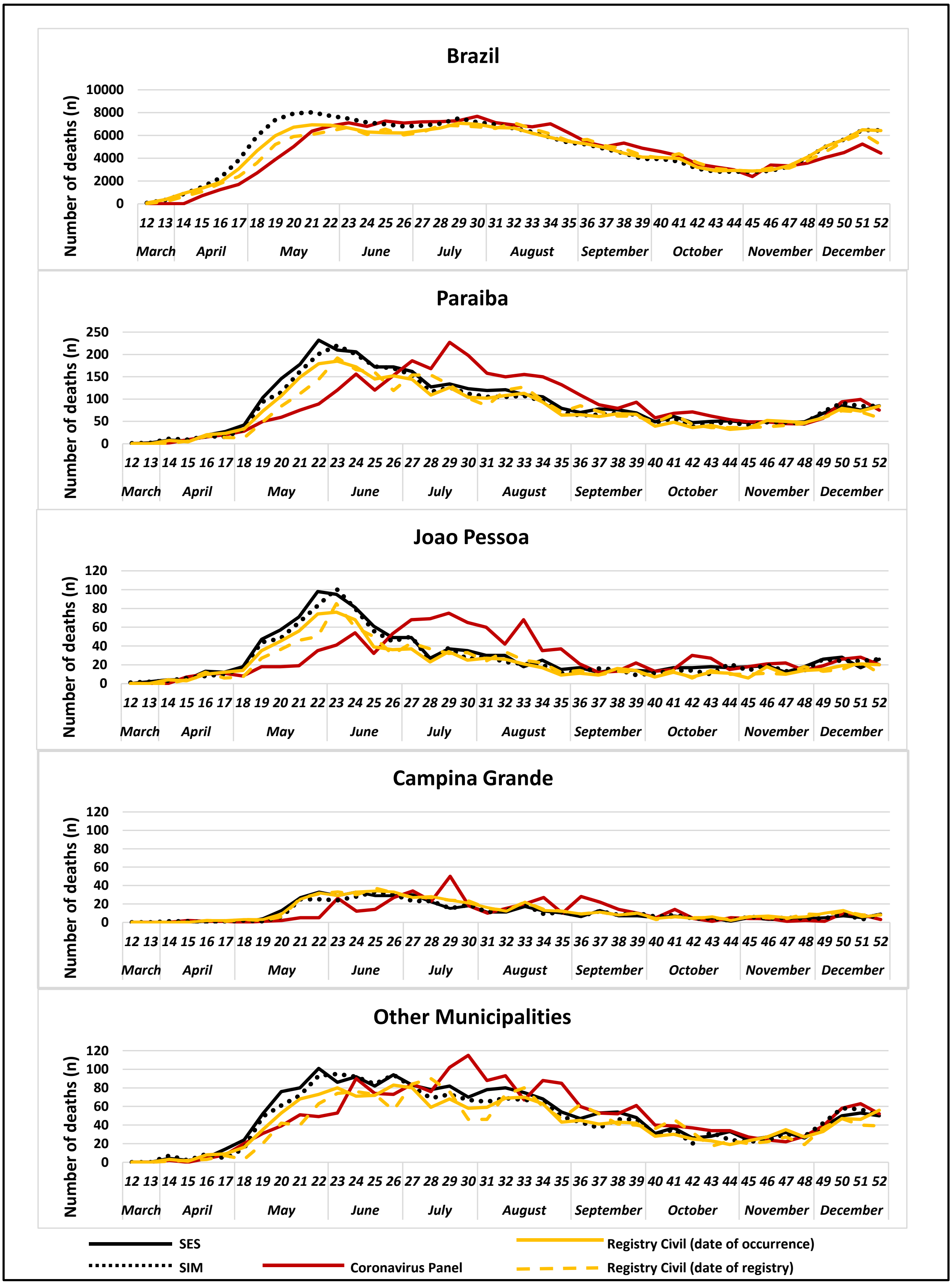
Data sources	Paraiba	Joao Pessoa	Campina Grande	Other municipalities	Brazil
	N (total number of deaths)				
SES-State Secretariat of Health (occurrence)	3659	1182	440	2037	-
Coronavirus Panel by Ministry of Health (registry)	3613	1161	437	2015	189997
SIM-Mortality Information System (occurrence)	3426	1094	425	1907	205062
Transparency Portal by Registry Civil (occurrence)	3145	913	501	1731	194697
Transparency Portal by Registry Civil (registry)	3049	887	500	1662	189396
	Difference				
	n (%)	**n (%)**	**n (%)**	**n (%)**	**n (%)**
SES (occurrence) vs Coronavirus Panel (registry)	46 (+1.3)	21 (+1.8)	3 (+0.7)	22 (+0.9)	-
SES (occurrence) vs SIM (occurrence)	233 (+6.8)	88 (+8.0)	15 (+3.5)	130 (+6.8)	-
SES (occurrence) vs Transparency Portal (occurrence)	514 (+16.3)	269 (+29.5)	-61 (-12.1)	306 (+17.7)	-
SES (occurrence) vs Transparency Portal (registry)	610 (+20.0)	295 (+33.5)	-60 (-12.0)	375 (+22.6)	-

Sources: Paraiba State Secretariat of Health-SES; Transparency Portal by Registry Civil; Coronavirus Panel by the Ministry of Health; Mortality Information System-SIM, 2020

The comparative analysis by date of death occurrence in Paraiba revealed the difference by 233 deaths (11.8%) and 514 deaths (16.3%), considering data from Mortality Information System (SIM) and Transparency Portal respectively (Table 4.1). Furthermore, the comparison among sources by date of death registry shown the maximum difference by 564 deaths between Coronavirus Panel and Transparency Portal data.

In the contrary to the state, data for Brazil, which was considered as a reference, shown the different trajectory in terms of released numbers by different portals: the source that captured the highest number (205062 deaths) was the Mortality Information System (SIM) followed by the Transparency Portal (occurrence), Coronavirus Panel and Transparency Portal (registry), (Figure 4.1). State Secretariat of Health data was not considered in this stage of comparison since it does not contain information related to country level.

Figure 4.1 - Deaths due COVID-19 in Brazil, Paraiba, Joao Pessoa, Campina Grande and Other Municipalities released by five data sources, 12th-52nd epidemiological weeks 2020



Sources: Paraiba State Secretariat of Health-SES; Transparency Portal by Registry Civil; Coronavirus Panel by the Ministry of Health; Mortality Information System-SIM, 2020

The difference between number of deaths registered by SIM and the rest of observed sources on country level varied from 5.3 % compared with Transparency Portal (occurrence) to 8.3% compared with Transparency Portal (registry), 10365 to 15666 deaths respectively.

The tendency of deaths volume disclosed by five different data sources in Joao Pessoa and Other Municipalities was matching to previously observed in Paraiba state: in decreasing order- State Secretariat of Health (SES), Coronavirus Panel, Mortality Information System (SIM), Transparency Portal by date of death occurrence and date of death registry. In Joao Pessoa, the difference varied from 21 deaths (1.8%) to 295 deaths (33.5%), while for Other Municipalities the maximum percentage was presented by 22.6%.

In Campina Grande, in the contrary with Paraiba and Joao Pessoa, was noticed predominant number of deaths due COVID-19 captured by Transparency Portal among all five data sources, considering both date of death occurrence and date of death registry. In terms of difference, the highest percentage 12% (61 deaths) was noted between data of Transparency Portal and the State Secretariat of Health.

The discrepancy between the number of deaths due COVID-19 in Brazil, Paraiba state and its municipalities disclosed by different data sources was more evident while comparing the "behavior" of curves during epidemiological weeks of pandemic (Figure 4.1).

As comparative analysis showed, the number of deaths released by five different official Brazilian sources related to COVID-19 mortality in 2020 had disagreement between all databases both in the context of the country and on regional level. In addition, the highest values of sub-registration of deaths were 8.3% for Brazil (considering SIM), while 20% for Paraiba, 33.5% for Joao Pessoa and 22,6% for Other Municipalities (considering Transparency Portal by date of registry). Campina Grande had the lowest number with approximately 4% of sub-registration considering data of SIM.

The reporting bias for COVID-19 may have occurred in any stage of deaths cause identification: due to delays in releasing the results, lack of tests, or even errors in diagnosis of the disease. Therefore, the inconsistency doubled by discordant of data released by five official data sources for 2020 pandemic in Brazil and state of Paraiba could be a serious barrier to public health policy making and scientific conclusions related to COVID-19 mortality in Brazil, and it is a subject to be further investigated.

Time lag

"Time lag" event, which represents a lag between when a death occurs (date-of-death) and when it was registered (date-of-report), was examined in present study for better understanding of delay in deaths counts during pandemic 2020 in Paraiba. Without a possibility to track an individual Death Certificates, the study was focused on general observation of data released by different sources based on date of death occurrence and date of death registry to have "brief" idea about magnitude of deaths counts delays in Paraiba.

Taking into account the Registry Civil which released COVID-19 deaths -related data both by date-of-death and date-of-report, a comparison was made for all studied territories. In a state level, was observed "loss" of 96 (3.0%) deaths registration comparing with those that were notified by date-of-death (3145 and 3049, respectively). For Joao Pessoa, from all deaths notified by date of occurrence (913 deaths), 26 deaths (8%) weren't registered. Approximately 4% (69 death cases) of deaths wasn't notified for Other Municipalities. In the contrary, in Campina Grande were registered approximately all occurred deaths in an observed period (501 and 500 deaths, respectively).

The comparison between State Secretary of Health, which released the highest number of deaths for Paraiba by date of death occurrence, revealed the difference by 233 death cases (6.8%) comparing with SIM, and by 514 deaths (16.3%) comparing with data of Registry Civil (Table 4.1).

For Brazil, the difference between date-of-death and date-of-registration was approximately 5300 deaths, considering Registry Civil data. The most significant difference in deaths counts was observed between Registry Civil data by date of registry and SIM by date of occurrence (15 666 deaths, 8.3% respectively).

The lag time between when a death occurs and when information from the certificate is available for analysis should be considered when conducting mortality surveillance [170]. The pandemic situation brought "expansion" of informational systems in Brazil, which produced near real-time mortality data (Coronavirus Panel, SES, Transparency Portal). However, daily totals of COVID-19 deaths released by different sources could underestimate numbers of deaths because of incomplete or delayed reporting.

The comparative analysis of "loss" between sources that notified deaths by date-of death and date-of-register shown certain delay in terms of registered number of deaths for Brazil, which was much more prominent in case of Paraiba and its municipalities. The delay in information tracking, especially related to unprecedent circumstances such as pandemic, could have resulted in delays with data management, and affected the real time data issued to the public.

Pandemic peaks

Changes in the magnitude of COVID-19 mortality curves in Paraiba not only revealed differences in the number of deaths between weeks, but also a disagreement in the time of the "peak" appearance according to data provided by the five data sources.

According to State Secretariat of Health, the peak of COVID-19 mortality was observed on 22nd epidemiological week 2020 in all regions of state Paraiba (Table 4.2). Meanwhile, relying on data released by SIM and Registry Civil (date of occurrence and date of registry), the pandemic peak in Paraiba and Joao Pessoa was marked on 23d epidemiological week, while by data of Coronavirus Panel the peak was fallen on 29^{th} epidemiological week for Paraiba and even more distanced in case of Joao Pessoa (29^{th} -33d epidemiological weeks). Considering the fact, that Coronavirus Panel has been released data by date of their registry, was observed a delay of information in Paraiba at least for 4-5 weeks (considering 2 weeks according to protocol). If the Panel's source was disregarded, it can be said that the "peak" for Paraiba and João Pessoa occurred between the 22nd and 23rd epidemiological week of considered period.

More divergencies occurred while interpreting peaks occurring for pandemic curves in Campina Grande and Other Municipalities, where in first case three different weeks were marked as peaks distancing from 22d to 29th, whereas for Other Municipalities each from five sources of data released period of peaks differently with a distance in 8 weeks.

For Brazil, the observation of curves changes throughout epidemiological weeks in 2020 captured by different sources shown divergence in peaks appearance, especially at the first month of pandemic. The difference in peaks interpretation considering date of occurrence defers in 8 weeks comparing with Registry Civil. This gap became even more wider when compared SIM with Registry Civil by date of registry (11 weeks).

The comparative analysis of pandemic peaks together with time lag allowed better understand the gaps in terms of information repassing and delay in COVID-19 deaths registration. Information related to peaks of disease outbreak in 2020 released by five data sources had its discrepancies for all observed territories: from country level to state and its municipalities.

Table 4.2 - Epidemiological weeks with COVID-19 pandemic peaks in Brazil and Paraiba, 2020

Data sources	Epidemiological weeks of pandemic peaks				
	Paraiba	Joao Pessoa	Campina Grande	Other Municipalities	Brazil
SES	22	22	22	22	-
Coronavirus Panel	29	29	29	30	30
Registry Civil (occurrence)	23	23	25	26	29
Registry Civil (registry)	23	23	25	28	32
SIM	23	23	25	23	21

Sources: Paraiba State Secretariat of Health-SES; Transparency Portal by Registry Civil; Coronavirus Panel by the Ministry of Health; Mortality Information System-SIM, 2020

For Paraiba and its municipalities notable difference was observed between Coronavirus Panel with the rest of data sources: the widest gap was 7 weeks comparing with SES for Paraiba, Joao Pessoa, Campina Grande and Other Municipalities. On country level, the controversy was even more evident when difference between highest number of deaths during pandemic 2020 was 8 weeks between SIM and Registry Civil (both by date of occurrence), and 11 weeks comparing with Registry Civil by date of registry.

The discordancy between COVID-19 related deaths released by Brazilian official sources was marked not only by difference in number of deaths, but also by dissonance in terms of interpretation of pandemic peaks in 2020. Once again, such kind of controversies could possibly affect the understanding of real magnitude of mortality in Paraiba during pandemic, its consequences for population and public health in general.

Distribution of deaths by age groups and sex

This part of analysis involved age and sex adjusted distribution analysis in Paraiba according to four data sources, and disregarded Coronavirus Panel since it doesn't provide information related to sex and age.

Age groups (<60 and ≥ 60 years old) distribution in total number of deaths in Paraiba.

In terms of age-distribution of total numbers and percentage of deaths due COVID-19 in a state of Paraiba, independently of data sources, was observed significant prevalence of deaths of individuals in age 60-year- old and higher (Table 4.3). The prevalence of deaths in these age-groups was notified by all data sources and varied from 70.2% (SES) to 76.1% according to data of Transparency Portal by date of occurrence.

The analysis of deaths in Paraiba shown significant predominance of deaths of individuals 60-year-old and above among both sexes. For males, the percentage varied from 70.7% (SES) to 73% (Transparency Portal/occurrence), while for females the variation was between 78.5% (SES) and 80.3% (SIM) (Table 4.3). Referring to all data sources, if male sex has dominated among deaths in age groups from <10-year-old to 70-year-old, the prevalence changed towards females starting from age-group 80-year-old and higher. According to SES, the number of female deaths in these age groups represented approximately 16% of all deaths in Paraiba.

Table 4.3 - Absolute number, percentage, and difference of deaths of individuals 60-year-old and higher due COVID-19 divided by sex, based on four different data sources, 12th -52nd epidemiological weeks, Paraiba 2020

Data Sources	Paraíba		Joao Pessoa		Campina Grande		Other Municipalities		Brazil	
	≥60-year-old (n, %)									
	M	F	M	F	M	F	M	F	M	F
State Secretariat of Health (SES)	1436 **70.7**	1279 **78.5**	457 **68.4**	402 **78.2**	171 **70.6**	162 **81.8**	808 **72.1**	715 **78.1**	-	-
Mortality Information System (SIM)	1387 **71.9**	1202 **80.3**	429 **69.6**	385 **80.5**	162 **69.8**	163 **84.5**	796 **73.6**	654 **79.2**	88088 **75.1**	69518 **79.2**
Registry Civil (occurrence)	1309 **73.3**	1085 **79.8**	372 **70.4**	303 **78.7**	210 **74.7**	183 **83.2**	727 **74.5**	599 **79.3**	85140 **76.4**	66824 **80.2**
Registry Civil (registry)	1263 **72.8**	1048 **79.7**	372 **70.4**	303 **78.7**	210 **74.7**	183 **83.2**	681 **73.6**	562 **79.5**	83031 **76.5**	64793 **80.2**
	Difference (n, %)									
SES vs SIM	49 **+3.5**	77 **+6.0**	28 **+6.5**	17 **+4.2**	9 **+5.5**	-1 **-0.6**	12 **+1.5**	61 **+8.5**	-	-
SES vs Registry Civil (occurrence)	127 **+9.7**	194 **+17.8**	85 **+22.8**	99 **+32.7**	-39 **-18.6**	-21 **-11.5**	81 **+11.1**	116 **+19.4**	-	-
SES vs Registry Civil (registry)	173 **+13.7**	231 **+22.0**	85 **+22.8**	99 **+32.6**	-39 **-18.6**	-21 **-11.5**	127 **+18.6**	153 **+27.2**	-	-

Sources: Paraiba State Secretariat of Health -SES; Transparency Portal by Registry Civil; Mortality Information System-SIM, 2020

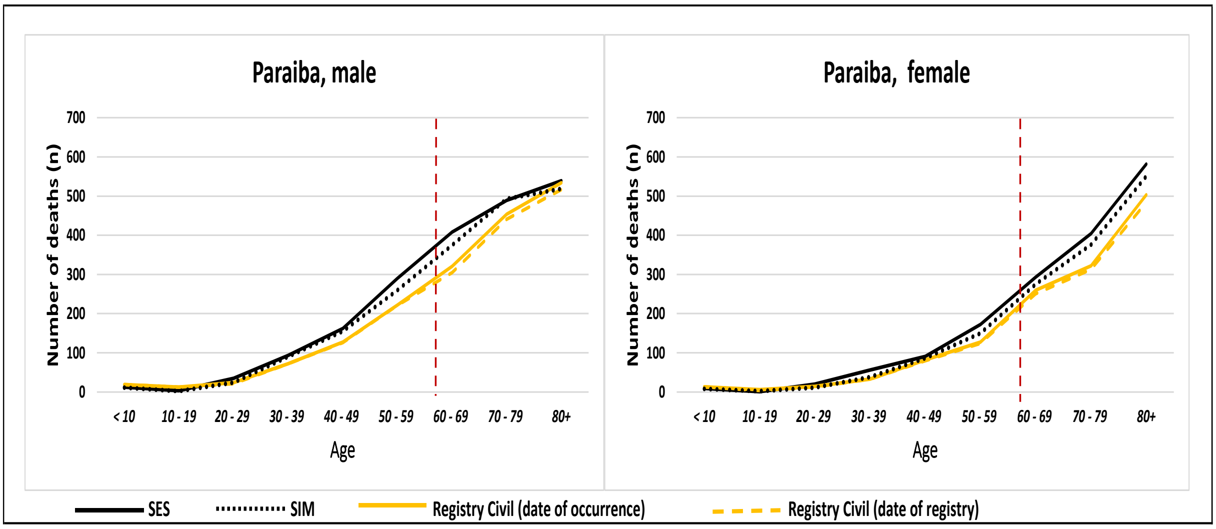
Distribution of deaths by sex in Paraiba

Referring to four observed data sources, the male sex was responsible for the majority of deaths in Paraiba. Looking to data provided by SES as a source that captured the highest volume of deaths, the total number of deaths was 2031 (55.5%) among males and 1628 (44.5%)

among females. Moreover, the variation in percentage of deaths by sex for Paraiba did not reveal important discrepancies between sources. For males, variation of extreme values ranged from 55.5% (SES) to 56,2% (SIM). While for females, the variation was between 44.5% (SES) and 43,1% (Transparency Portal based on date of registration).

Interestingly, an increasing evolution of deaths due COVID-19 in Paraiba as the ages increase, configuring the death curves with a logistic behavior for male and semi-concave for female (Figure 4.2). As figure shown, until age group of 30-39 years old, the numbers of deaths were very close among all four data sources, diverging after with predominant level of data by State Secretary of Health (SES). In general, there was noted 10 years interval of deaths magnitude between both sex, and, for example: when the amount of 100 deaths was reached by men in the range of 30 to 39 years, women reached the same magnitude in the range of 40 to 49 years.

Figure 4.2 - Distribution of deaths due COVID-19 by age and sex presented by four different data sources, 12th-52nd epidemiological weeks, Paraiba 2020



Sources: Paraiba State Secretariat of Health-SES; Transparency Portal by Registry Civil; Mortality Information System-SIM, 2020

In Joao Pessoa, was observed prevalence of deaths due COVID-19 among individuals 60-year-old and above, similar to what was noticed for Paraiba. The percentage for males among individuals in these groups varied from 68.4% (SES) to 70.4% (Transparency Portal), while for females was noted between 78.2% (SES) and 80.5% (SIM) (Table 4.3).

The distribution by sex for Joao Pessoa as well showed the prevalence of deaths among male comparing with female in total. The percentage not varied significantly among all data sources and was from 56.3% to 57.8% for males, and from 42.2% to 43.7% for females (SES and Transparency Portal, respectively).

Similar to what was noticed on state level, in Joao Pessoa was observed changing of prevalence towards female sex in age groups 80 years old and above, where females represented approximately 17% of all deaths. For males, according to SES and SIM data, the highest number of deaths in Joao Pessoa was registered in age group 70-79 years old (157 and 158 deaths, respectively), represented approximately 14% of all deaths. This 10-years “transition” in magnitude of deaths among male and female was also previously seen for Paraiba.

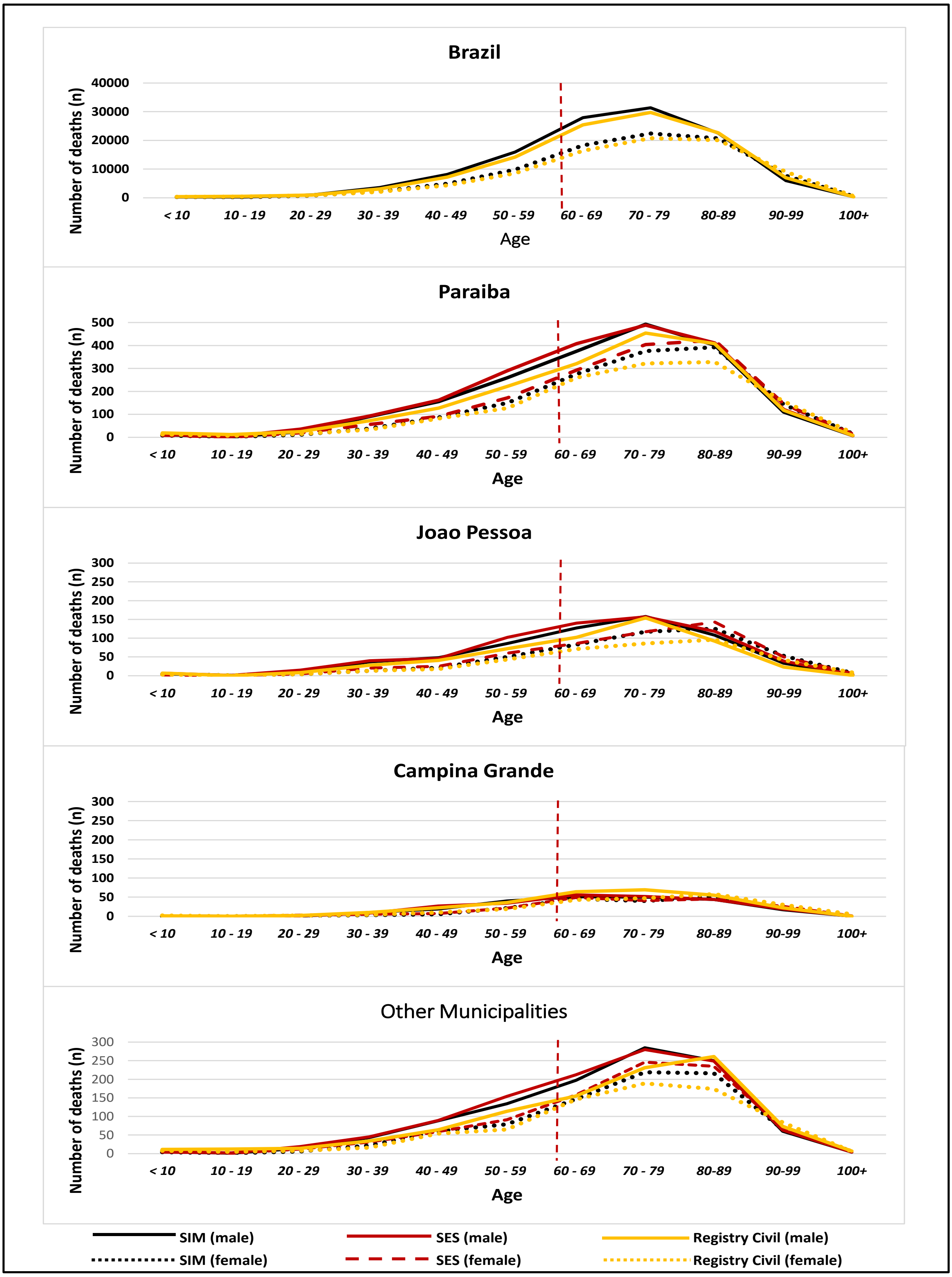
Analysis related to Campina Grande shown the prevalence of deaths among individuals 60 years and higher referring to all data sources, represented approximately 71% among males and 82% among females according to data of SES (Table 4.3). Similar to Joao Pessoa and Paraiba, was observed predominance of male deaths registered by all data sources, which varied from 54.6% (SIM) to 56.1% (Transparency portal), 232 and 281 deaths respectively.

In this municipality was observed divergence of age distribution among female and male between data sources. According to data of SIM and Registry Civil (both by occurrence and registry), the highest number of deaths for females was found in the age group of 80-89 years (51, 58 and 58 deaths, respectively), while based on SES the greater number of female deaths was found in the age group of 60- 69 years (total 49 deaths).

The highest number of males deaths in Campina Grande was registered in the age group of 60-69 years rereferring to SES and SIM (56 and 51, respectively), while according to data of Registry Civil the higher number of male deaths was verified in the age group 70-79 years (total 69 deaths, both by occurrence and registry).

For Other Municipalities, according to all sources, a greater number of deaths was also observed in older age groups with prevalence of male sex. The volume of deaths in age 60-year-old and above was 1523 (74.7%) referring to SES. In terms of sex, for these particular age-groups, was noticed predominance of deaths both males and females comparing with other ages. The percentage of male deaths in total for Other Municipalities varied from 55% (SES) to 56.7% (SIM). The highest number of deaths for both sexes, male and female, was registered in 70-79 years age group considering SES and SIM data. As for data of Registry Civil by date of registry and occurrence, the highest number of male deaths was observed in age group 80-89 years old (161 and 250, respectively), which defers from what was noticed for Paraiba and Joao Pessoa. Referring to analysis in Brazil related to age and sex distribution of COVID-19 deaths, was observed the same pattern of significant deaths prevalence in older age groups (60-year-old and above) and male sex (Figure 4.3).

Figure 4.3 - Distribution of deaths by sex and age due COVID-19 in Brazil, Paraiba, João Pessoa, Campina Grande and Other Municipalities, 12th -52nd epidemiological weeks, 2020



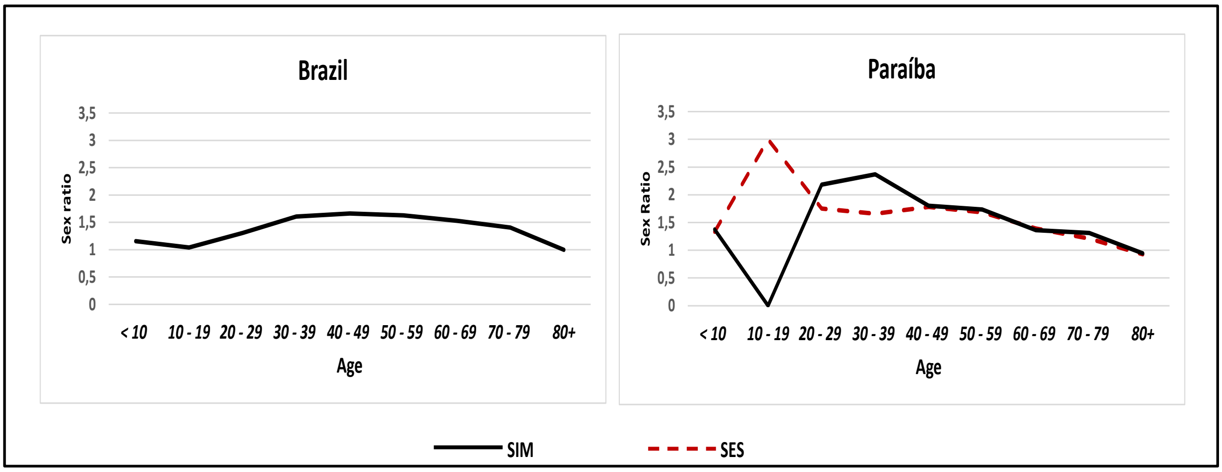
Sources: Paraiba State Secretariat of Health-SES; Transparency Portal by Registry Civil; Mortality Information System-SIM, 2020

According to data of both SIM and Transparency Portal, the prevalence of deaths of individuals 60-year-old and above varied from 76.8% to 78%, respectively. It is not deferred from what was observed in Paraiba and its municipalities. For both sexes, the percentage was approximately equal referring to both data sources and represented in average 57% of males and 43% of females. On country level, the highest volume of deaths for both sexes were registered at age group 70–79-year-old, representing 15% of males and approximately 11% of females from all registered deaths according to data of SIM.

Figure 4.4 represents the sex ratio curves by age group for Brazil and Paraiba according data sources SIM and SES. A ratio above 1 revealed for Brazil higher mortality among men up to 80 years of age. The highest ratios were for the age groups between 30 and 70 years old, above 1.5, reaching 1.66 in the peak age group of 40 to 49 years old. In other words, at this point, for every 100 female deaths in Brazil, 166 were male.

For Paraiba, the general scenario of the behavior of the sex ratio curve by age groups was similar to those for Brazil in terms of deaths magnitude in ages from 40 to 90 years, considering both data by SES and SIM. The different pattern was notified for age group 10-19 years by SIM due to the luck of registration in this particular age group.

Figure 4.4 - Sex ratio of deaths due COVID-19 by age group for Brazil and Paraiba, 2020



Sources: Paraiba State Secretariat of Health-SES; Mortality Information System-SIM, 2020

Disregarding the divergences between the sources up to the age of 39 years, it can be said that the peak of the sex ratio, regardless of the source, occurred between 40 and 49 years, similarly to Brazil and Paraiba, although with a higher level 1.8. In other words, in this age group for Paraiba, for every 100 female deaths, there was approximately twice as much male deaths.

The comparative analysis of age and sex adjusted distribution in Paraiba and its municipalities with the reference to country level, shown the same pattern in terms of significant prevalence of deaths in older ages, particularly 60-year-old and above, with predominance of males according to all data sources. The results of analysis are comparable with other studies conducted in Brazil and globally, which highlighted the higher risk of death due COVID-19 among individuals of older age groups and male sex [6,11, 14, 15]. Considering generally aging Brazilian population, the results of the study are particularly important for better understanding of certain demographic risk factors to magnitude of mortality in Paraiba and its territories due pandemic, to provide effective public health interventions and planning toward protective measures, prevention, and diagnosis of disease.

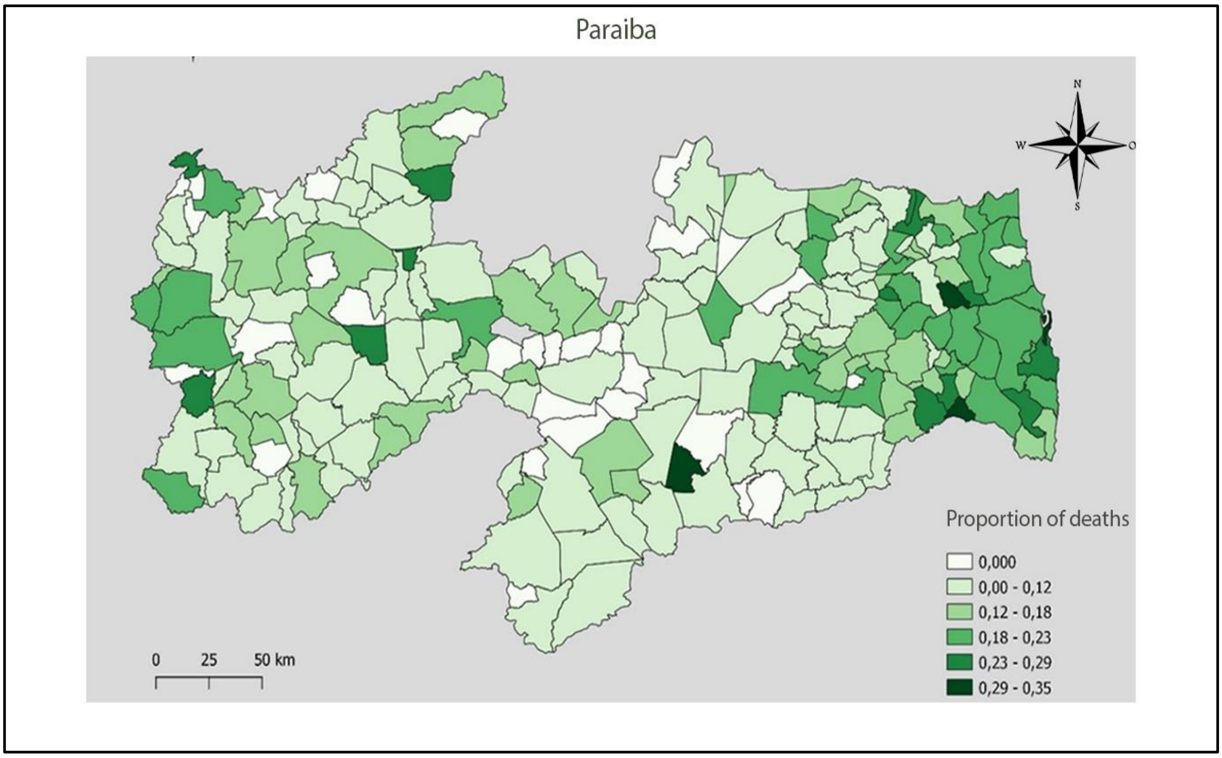
Spatial distribution of deaths

The visualization of COVID-19 deaths proportions distribution through mapping allowed to observe disease spreading across Paraiba and the most impacted territories during pandemic in 2020. The spatial distribution of deaths proportion among all municipalities of Paraiba in a period from 12^{th} to 52^{nd} epidemiological weeks according to data of State Secretariat of Health is shown on the Map 4.1 For the municipalities where the proportion of deaths ranged between 0 and 0.01-0.12, it was denoted with a legend in white to lighter green color, while range with highest proportions (over 0.12) were represented by variation of the caption in dark green color, respectively.

The spatial distribution of deaths proportions due COVID-19 in Paraiba was not uniform. Among the 223 municipalities of the state, 30 municipalities did not had record of deaths due disease in observed period. The metropolitan region concentrated most of deaths during pandemic outbreak 2020, especially those represented from the third to the sixth categories (0.18 to 0.23; 0.23 to 0.29; 0.29 to 0.35, respectively).

Observing the map, it was possible to notify the highest concentration of densely proportioned deaths due disease in Northeast and opposite West part of Paraiba. The large cities located in Northeast part, especially Joao Pessoa, had probably contributed as a source of pandemic propagation and internalization. As a state´s capital, Joao Pessoa has concentration of main transportation network (airport, railroad, transportation roads), connecting territories inside and outside of the state. As, for example, one of the largest road BR-230, which extends throughout the state from the capital to backwoods territories (sertão), could possibly contribute to disease dissemination from Northeast to interior and West parts of the state.

Map 4.1 Spatial distribution of COVID-19 deaths proportion across Paraiba territories, 12th-52nd epidemiological weeks 2020



Source: Paraiba State Secretariat of Health-SES, 2020

4.1.2 Coverage of deaths

The study of adult mortality in many countries is problematic due to data quality issues (HILL, YOU, CHOI, 2009. In Brazil, despite recent advances in a quality of vital events registration, still has large regional differences, which in a time as pandemics could be even more prominent.

According to results, the coverage of deaths was greater for males comparing with females. In case of males, the coverage of deaths was higher than 90% for all observed territories and classified as ”very good” (Table 3.3). In this case, the percentage of coverage varied from 90.7% to 98.6% (Other Municipalities and Campina Grande, respectively).

Table 4.4 shows the coverage of deaths in Paraiba and its territories adjusted by sex after application of the General Growth Balance method proposed by Brass (1975).

Table 4.4 - Coverage of total deaths by sex in Paraiba, Joao Pessoa, Campina Grande and Other Municipalities, 2020

Territory	**Males (%)**	**Females (%)**
Paraíba	95.5	91.1
Joao Pessoa	96.3	93.8
Campina Grande	98.6	94.1
Other Municipalities	90.7	86.5

Source: Mortality Information System -SIM, 2020

For females, the variation of coverage was from 86,5% (Other Municipalities) to 94.1% (Campina Grande). Application of Brass´s method didn't work adequately (didn't fit formulated in methodology assumptions) for Other Municipalities. In this case was adapted adjustment through applying proportion of deaths between men and women for the entire state: calculated proportion equal 0,96 was applied to males' coverage (90.7%) resulting in 86,5% for females.

For decades the mortality pattern in Brazil has been highlighted by sex differential in terms of prevalence in completeness of male's deaths registration, and one of the main reasons for such tendency have been deaths caused by violence and traffic accidents (PAES, 2008).

Table 4.5 shows historical trends (2000-2011) in total deaths coverage in Paraiba according to Brazilian Interagency Health Information Network data (Rede Interagencial de Informações para a Saúde-RIPSA).

Table 4.5 - Total deaths coverage (%) time series, Paraiba, 2000-2011

FU	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
Paraíba	82.1	83.9	85.8	87.3	88.2	88.2	88.4	89.4	89.8	90.7	91.1	91.2

LEGEND: FU- Federative Unit
Source: Rede Interagencial de Informações para a Saúde-RIPSA, 2012

According to data (Table 4.5), Paraiba had steady improvements in deaths coverage over time from 82.1% in 2000 to 91.2% in 2011. Furthermore, the coverage of deaths for 2011 was used as a baseline in configuration of assumption applied to 2020 coverage in Paraiba, considering both sex and age-groups. As was shown on Table 4.4, the application of Brass´s method resulted in higher coverage for Paraiba and its territories in 2020 comparing with 2011, except for Other Municipalities.

Table 4.6 shows the results of GGB method (Brass, 1975) application to total number of registered deaths for Paraiba and its territories in 2020.

The percentage of calculated sub-registered deaths was higher for females then for males in all observed territories of Paraiba.

For Paraiba, the number of under-registered deaths was calculated as 4.8% for males and 9.8% in case of females (823 and 1392 deaths, respectively). For Joao Pessoa and Campina Grande were estimated 3.8% and 1.3% males' deaths, while for males 6.7% and 6.3%, respectively. The highest fraction of under-registered deaths was calculated for Other Municiaplities: 10.2% for males and 15.5% for females (1243 and 1473 deaths, respectively).

Table 4.6 – Under registration of total deaths for both sex in Paraiba and its municipalities considering application of General Growth Balance method proposed by Brass, 2020

Territory	MALES				FEMALES			
	Registered deaths (n)	Correction factor, k	Under-register (%)	Corrected deaths (n)	Registered deaths (n)	Correction factor, k	Under-register (%)	Corrected deaths (n)
Paraiba	17332	1,0475	4.8	18155	14185	1,0981	9.8	15577
JP	3422	1,0383	3.8	3553	3128	1,0665	6.7	3336
CG	1762	1,0133	1.3	1785	1582	1,0626	6.3	1681
OM	12148	1,1023	10.2	13391	9475	1,1555	15.5	10948

LEGEND: JP-Joao Pessoa; CG- Campina Grande; OM- Other Municipalities
Source: Mortality Information System -SIM, 2020

The quality of mortality data in Brazil has improved steadily overtime but has been characterized by large regional variations [Paes 1999; Paes 2005; Queiroz 2017]. The results of the coverage of deaths study by application of General Growth Balance method (GGB) for Paraiba, 2020, showed strengthened statistic classified as "very good " for a state, Joao Pessoa and Campina Grande, and classified as "good " for Other Municipalities.

4.1.3 Redistributions of ill-defined causes of death

High quality cause of death (COD) data is a key source of evidence for implementing certain decision-making policies towards improving population health (WHO, 2013). A major problem with COD data is poor cause of death certification practices that result in codes that provide little or no information about the true underlying cause of death.

Among all analyzed 223 municipalities of Paraiba, 199 (89.2%) presented ill-defined causes of deaths. The proportion of ill-defined causes (IDC) in Paraiba dataset varied substantially by municipalities, ranging from 0.68% to 36% (Guarabira and Matinhas, respectively). Importantly, the higher fraction of ill-defined causes was found in 59 less populated municipalities (less than 10,000 habitants) comparing with more populated and developed cities. The percentage of IDC among all causes of death in these areas varied from 8.1% to 36%, with an average approximately 16%. For example, in municipality Matinhas (4.496 inhabitants, 2020) was found 36% (9 cases) of IDC among 25 total of deaths. If these counties were omitted, the strength of inverse relationship was much less apparent.

Table 4.7 shows total number and proportion of ill-defined causes by sex in comparison with selected specific causes of deaths (COVID-19, diseases of the respiratory system, diseases of the circulatory system and other causes of deaths).

Table 4.7 - Total number and proportion of specific causes of deaths (COVID-19, ill-defined causes, diseases of the respiratory system, diseases of the circulatory system, other causes of deaths) by sex, 12^{th} -52^{nd} epidemiological weeks, in Paraiba and its counties, 2020

Territory	COVID-19	RESP	CIRC	Ill-defined causes	Other causes
			MALES (n/%)		
Paraiba	1929	1156	3051	895	7006
	56.3	**50.9**	**51.8**	**55.8**	**56.9**
Joao Pessoa	616	216	523	78	1372
	56.3	**46.2**	**49.0**	**57.8**	**52.9**
Campina Grande	232	99	316	54	732
	54.6	**50.3**	**49.3**	**59.3**	**54.1**
Other	1081	841	2208	763	4902
Municipalities	**56.7**	**52.4**	**52.9**	**55.4**	**58.6**
			FEMALES (n/%)		
Paraiba	1497	1114	2843	709	5305
	43.7	**49.1**	**48.2**	**44.2**	**43.1**
Joao Pessoa	478	252	545	57	1220
	43.7	**53.8**	**51.0**	**42.2**	**47.1**
Campina Grande	193	98	325	37	622
	45.4	**49.7**	**50.7**	**40.7**	**45.9**
Other	826	764	1969	615	3463
Municipalities	**43.3**	**47.6**	**47.1**	**44.6**	**41.4**
			TOTAL (n/% from all causes)		
Paraiba	3426	2270	5894	1604	12311
	13.4	**8.9**	**23.1**	**6.3**	**48.3**
Joao Pessoa	1094	468	1068	135	2592
	20.4	**8.7**	**20.0**	**2.5**	**48.4**
Campina Grande	425	197	641	91	1354
	15.7	**7.3**	**23.6**	**3.4**	**50.0**
Other	1907	1605	4177	1378	8365
Municipalities	**11.0**	**9.2**	**23.9**	**7.9**	**48.0**

LEGEND: COVID-19 (coronavirus diseases 2019); RESP: diseases of the respiratory system; CIRC: diseases of the circulatory system.
Source: Mortality Information System -SIM, 2020

Paraiba had in total 6.3% of IDC codes among all causes of deaths (6.4% males and 6.2% females, respectively). Joao Pessoa and Campina Grande represented in total 2.5% and 3.4% of ill-defined codes, respectively. The highest total proportion (7.9%) of IDC was observed in Other Municipalities.

The proportion of IDC was higher for males comparing with females for all analyzed territories. For males, the total proportion of IDC varied from 55.4% (Other Municipalities) to 59.3% (Campina Grande). In case of females, the variation was from approximately 41% to 45%, respectively.

To better understand dynamic of changes in number of ill-defined causes (IDC) and its proportions by sex among all deaths throughout pandemic period 2020, was conducted the comparison with previous year 2019 (without pandemic) (Table 4.8).

Table 4.8 - Comparison of total number and proportion distribution by sex of ill-defined causes (IDC) among all deaths between 2019 and 2020 in Paraiba and its municipalities

Territory	**Ill-defined causes (IDC)**				**All-causes**			
	2019		**2020**		**2019**		**2020**	
	n	**%**	**n**	**%**	**n**	**%**	**n**	**%**
MALES								
Paraiba	863	**54.5**	1090	**55.5**	14779	**54.0**	17332	**55,0**
Joao Pessoa	73	**67.0**	96	**60.4**	2680	**51.4**	4322	**58,0**
Campina Grande	64	**51.6**	67	**59.8**	1534	**52.0**	1762	**52,7**
Other Municipalities	724	**53.6**	927	**54.7**	10555	**55.0**	12148	**56,2**
FEMALES								
Paraiba	722	**45.5**	875	**44.5**	12599	**46.0**	14185	**45.0**
Joao Pessoa	36	**33.0**	63	**39.6**	2538	**48.6**	3128	**42.0**
Campina Grande	60	**48.4**	45	**40.2**	1416	**48.0**	1582	**47.3**
Other Municipalities	626	**46.4**	767	**45.3**	8645	**45.0**	9475	**43.8**
TOTAL[a]								
Paraiba	1585	**5.8**	1965	**6.2**	27378	**100**	31517	**100**
Joao Pessoa	109	**2.1**	159	**2.1**	5218	**100**	7450	**100**
Campina Grande	124	**4.2**	112	**3.4**	2950	**100**	3344	**100**
Other Municipalities	1350	**7.0**	1694	**7.8**	19210	**100**	21623	**100**

[a] -the proportion of ill-defined causes (IDC) in relation to total number of deaths in each territory

Source: Mortality Information System, 2020

For ill-defined causes (IDC) in Paraiba, the comparison shown increasing of ill-defined causes (IDC) proportions from 5.8% in 2019 to 6.2% in 2020, respectively.

More significant increasing of IDC was notified in Other Municipalities (from 7% to 7.8%, respectively). In Joao Pessoa, the difference was 50 IDC more (45.8%), considering the absolute numbers, but proportions weren't changed between observed years (2% for both years). In a contrary, for Campina Grande was notified decreasing of ill-defined causes of deaths proportion: from 4.2% to 3.4%, respectively.

Sex-specific distribution analysis between 2019 and 2020 shown different "pattern" of changes for males and females. In case of males, increasing of IDC proportions were observed in Paraiba and Other Municipalities with more significant elevation for Campina Grande (in approximately 8%).

For females, increasing of IDC was notified only in Joao Pessoa from 33% in 2019 to 40% in 2020. As for other territories, was observed decreasing of IDC fractions, more prominent in Campina Grande. Notably, the decreasing of ill-defined causes for Campina Grande was observed only for females (25% less IDC in 2020 comparing with 2019).

The results of sex-specific distribution of IDC in Paraiba during 2020, highlighted by prevalent proportions of "poor" deaths registration for males, were far from what could be expected. For decades, the mortality pattern in Brazil, including Northeast region, had specific sex differential in terms of prevalence in completeness of male's deaths registration, and the main reason for such tendency have been deaths caused by violence and traffic accidents (Paes 2000; Queiroz 2017). Moreover, comparison with previous year 2019 in a state (without pandemic) shown the same predisposition: prevalence of males among all ill-defined causes of deaths.

The proportion of sex-specific deaths before and after redistribution of ill-defined causes is shown on Table 4.9.

After application of Ledermann´s method for redistribution of deaths, total number and proportion of deaths had elevated substantially in all groups of causes, for both sexes in Paraiba and Other Municipalities. The level of increasing was highly dependent on causes of deaths: less for respiratory diseases and higher for diseases of the circulatory system and group of causes denominated as Other Causes.

Table 4.9 - Sex-adjusted total numbers and proportions of specific causes of deaths (COVID-19, ill-defined causes, diseases of the respiratory system, diseases of the circulatory system, other causes of deaths) before and after redistribution, Paraiba and Other Municipalities, 2020

Territory	**Males**				**Females**			
	COVID	RESP	CIRC	OC	COVID	RESP	CIRC	OC
	BEFORE REDISTRIBUTION (n, %)							
Paraiba	1929	1156	3051	7006	1497	1114	2843	5305
	56.3	**50.9**	**51.7**	**56.9**	**43.7**	**49.1**	**48.2**	**43.1**
Other Municipalities	1081	841	2208	4902	826	764	1969	3463
	56.7	**52.4**	**52.8**	**58.6**	**43.3**	**47.6**	**47.1**	**41.4**
	REDISTRIBUTED NUMBER (n, %)							
Paraiba	228	89	1028	3507	228	99	1055	2346
	6.6	**3.9**	**17.4**	**28.5**	**6.6**	**4.4**	**17.9**	**19.0**
Other Municipalities	125	71	760	2481	126	76	752	1548
	6.5	**4.4**	**18.2**	**29.6**	**6.6**	**4.7**	**18.0**	**18.5**
	AFTER REDISTRIBUTION (n, %)							
Paraiba	2157	1245	4079	10513	1725	1213	3898	7651
	55.6	**50.6**	**51.1**	**57.9**	**44.4**	**49.4**	**48.9**	**42.1**
Other Municipalities	1206	912	2968	7383	952	840	2721	5011
	55.9	**52.1**	**52.2**	**59.6**	**44.1**	**47.9**	**47.8**	**40.4**

LEGEND: COVID-19 (coronavirus disease 2019); RESP: diseases of the respiratory system; CIRC: diseases of the circulatory system; OC- other causes of deaths
Source: Mortality Information System, 2020

In Paraiba, among males increasing proportions of deaths after redistribution were in approximately 4% for respiratory diseases, in 6.6% for COVID-19 and in 17% for diseases of the circulatory system. The highest elevation of deaths after redistribution was observed for Other Causes (approximately 29%, respectively).

Among females, for COVID-19 the proportion of redistributed deaths did not differ from what was notified for males (6.6%). For this group, was observed slightly higher fraction of respiratory diseases and diseases of the circulatory system (in 0.5% for both) and in 9.5% lower proportion of Other Causes then for males.

As for Other Municipalities, also increasing proportion of deaths was observed after redistribution: higher proportions of deaths for males and less prominent for females comparing to Paraiba. Among males, after redistribution, the fractions of deaths were elevated in 6.5% for COVID-19, in 4.4% for respiratory diseases, in 18.2% for diseases of circulatory system and in 29.6% for Other Causes of deaths. The same tendency was observed among females, except for Other Causes were increasing of proportion was approximately 11% less than was observed for males.

On this stage of analysis, estimation of redistributed number for municipalities Joao Pessoa and Campina Grande was not implemented, since the percentages of ill-defined causes in these municipalities were below of 5% (2.5% for João Pessoa and 3.4% for Campina Grande) (Table 4.8). According to Paes (2018), when this percentage is under 5%, there is no need to redistribute the ill-defined causes through Ledermann´s procedure. The pro-rata redistribution of ill-defined causes can be easily applied without any important consequence in the age pattern of defined causes of deaths.

The analysis of deaths in Paraiba and its municipalities based on proportion of ill-defined causes (IDC) among total and specific causes of deaths are particularly alarming. The IDC were common in approximately 90% of municipalities of Paraiba and impacted practically all specific causes of deaths. The volume of IDC varied substantially across territories of the state in a period of pandemic 2020, with significant contribution to poor deaths certification by less populated municipalities (pequenas areas). As was evidenced by Global Burden of Diseases 2016 study (GBD, 2017), territories (countries) with lower level of Socio Demographic Index (SDI) generally showed higher level of ill-defined causes and garbage codes comparing to countries with higher SDI.

The analysis shown increased fraction of ill-defined causes in 2020 comparing to 2019 for Paraiba and Other Municipalities (approximately 6% and 8%, respectively). In a contrary, the results notified a stable relatively low number of IDC in Joao Pessoa and decreasing proportion for Campina Grande.

Analysis of IDC distribution by sex shown prevalence of males among all observed territories of Paraiba for both years: 2019 and 2020. In 2020, the prevalence of males varied substantially in Paraiba: from 9.4% for Other Municipalities to 21% for Joao Pessoa. The practice of poor males’ deaths registration was alarming, and it could potentially affect the quality of vital statistics in general in Paraiba.

According to results of redistribution of ill-defined causes (IDC), at least 450 deaths considering both sex should be added on top of mortality due COVID-19 in Paraiba resulting in 3882 deaths. Moreover, considering the evidence that redistribution of IDC leaded to substantial elevation of deaths volume in Paraiba and the fact that Mortality Information System data wasn’t prevalent in terms of volume of captured deaths among all data sources for Paraiba, the real magnitude of deaths could be still significantly higher than was originally registered.

4.1.4 Redistribution of Garbage Codes (GCs)

The analysis of levels and trends in causes of death, even in countries with well-functioning cause-of-death registration systems, remains challenging for several reasons related to the process of completing and coding each death certificate following standardized international rules (NAGHAVI et al., 2010).

Investigation of cause-of-death data is closely linked to the evolution of the International Statistical Classification of Diseases and Related Health Problems (ICD). The ICD has been used not only to code deaths by underlying cause of death but also to code other types of medical information, such as reasons for admission to or discharge from a hospital. The introduction of multiple purposes for the ICD has led to the addition of many codes (Garbage Codes) for causes that should not be considered underlying causes of death (TEIXEIRA et al., 2019).

From 223 municipalities of Paraiba, 83% had registered causes of deaths classified as Garbage Codes. The proportion of GCs in Paraiba datasets varied substantially by municipalities, ranging from approximately 2% to 29% (Barra de São Miguel and Caaporã, respectively).

Table 4.10 shows age-group and sex specific distribution of Garbage Codes (GCs) in Paraiba and its municipalities, considering four levels of GCs.

In Paraiba was registered total 5.2% of GCs, in Joao Pessoa 6,2%, in Campina Grande 2.8% and in Other Municipalities was notified 5.3% (Table 4.10). Importantly, as was mentioned in methodology part, for the purpose of the study was proceeded registration of GCs that only connected to infectious diseases and diseases of the respiratory system. Considering this fact, the proportion of GCs related to all ICD-10 rubrics could be substantially higher.

Analysis of GCs distribution among males and females, showed higher prevalence of females in total for Paraiba, Joao Pessoa, Campina Grande, except for Other Municipalities. The proportion of females varied from 52.1% (Paraiba) to 57.3% (Campina Grande). The higher prevalence of males was noted for Level 3 GCs in Paraiba and Joao Pessoa, and for Level 2 and Level4 GCs in Other Municipalities. In a contrary with what was observed for ill-defined causes, the prevalence of GCs for female sex is expected, since completeness of male deaths registration in Brazil had time tendency to be higher.

Age-group distribution showed significant prevalence of GCs in group of older individuals (60-years -old and higher) in all territories of Paraiba considering all Levels of GCs. Exception was for Level 3 in Campina Grande were predominance of individuals less than 60-years-old was approximately 66%. The fraction of 60-years-old and higher age individuals among all GCs varied from 77% to 82% (Campina Grande and Other Municipalities, respectively).

Table 4.10 - Deaths classified as Garbage Codes (GCs) considering sex and age group, 12th-52nd epidemiological weeks, Paraiba 2020

Variable	Garbage Codes (GCs)				Total GCs[a]	Total deaths
	Level 1	**Level 2**	**Level 3**	**Level 4**		
				PARAIBA (n/%)		
Sex						
Males	241 **(44.9)**	24 **(48.0)**	11 **(52.4)**	362 **(49.9)**	638 **(47.9)**	14072
Females	296 **(55.1)**	26 **(52.0)**	10 **(47.6)**	363 **(50.1)**	695 **(52,1)**	11442
Age group						
<60 y.o	99 **(18.4)**	14 **(28.0)**	8 **(38.1)**	127 **(17.5)**	248 **(18.6)**	8059
≥60 y.o	438 **(81.6)**	36 **(72.0)**	13 **(61,9)**	598 **(82.5)**	1085 **(81.4)**	17455
Total	537 **(40.3)**	50 **(3.8)**	21 **(1.6)**	725 **(54.4)**	1333 **(5.2)**	25514
				JOAO PESSOA (n/%)		
Sex						
Males	31 **(33.3)**	3 **(30.0)**	4 **(57.1)**	104 **(47.1)**	143 **(42.8)**	2810
Females	59 **(66.7)**	7 **(70.0)**	3 **(42.9)**	117 **(52.9)**	191 **(57.2)**	2552
Age group						
<60 y.o	16 **(16.7)**	4 **(40.0)**	2 **(28.6)**	39 **(17,6)**	61 **(18.3)**	1675
≥60 y.o	80 **(83.3)**	6 **(60.0)**	5 **(71.4)**	182 **(82.4)**	173 **(81.7)**	3687
Total	96 **(28.7)**	10 **(3.0)**	7 **(2.1)**	221 **(66.2)**	334 **(6.2)**	5362
				CAMPINA GRANDE (n/%)		
Sex						
Males	16 **(57,1)**	-	3 **(50.0)**	13 **(34.2)**	32 **(42.7)**	1439
Females	12 **(42,9)**	3 **(100)**	3 **(50.0)**	25 **(65.8)**	43 **(57.3)**	1279
Age group						
<60 y.o	6 **(21.4)**	-	4 **(66.7)**	7 **(18.4)**	17 **(22.7)**	791
≥60 y.o	22 **(78.6)**	3 **(100)**	2 **(33.3)**	31 **(81.6)**	58 **(77.3)**	1927
Total	28 **(37.3)**	3 **(4.0)**	6 **(8.0)**	38 **(50.7)**	75 **(2.8)**	2718
				OTHER MUNICIPALITIES (n/%)		
Sex						
Males	193 **(46.7)**	21 **(56.8)**	4 **(50.0)**	245 **(52.6)**	463 **(50.1)**	9823
Females	220 **(53.3)**	16 **(43.2)**	4 **(50.0)**	221 **(47.4)**	461 **(49.9)**	7611
Age group						
<60 y.o	70 **(16.9)**	10 **(27.0)**	2 **(25,0)**	81 **(17.4)**	163 **(17.6)**	5593
≥60 y.o	343 **(83.1)**	27 **(73.0)**	6 **(75,0)**	385 **(82.6)**	761 **(82.4)**	11841
Total	413 **(44.7)**	37 **(4.0)**	8 **(0,9)**	466 **(50.4)**	924 **(5.3)**	17434

[a]- proportion of total GCs was calculated in relation to total number of deaths

Source: Mortality Information System, 2020

Among all GCs Levels there was a higher prevalence of Level 4, followed by Level 1, Level 2 and Level 3 for all observed territories. The prevalence of Level 4 varied from 50%

(Other Municipalities) to 66% (Joao Pessoa). The higher fraction of low policy implication GCs (Level 4) is not surprising, according to reports it's the most widely use type of GCs across the countries [201]. Importantly, the fraction of high impact Garbage Codes was also relatively high and ranged from 29% (Joao Pessoa) to 45% (Other Municipalities).

Table 4.11 shows the comparison of GCs proportions considering sex between years 2019 and 2020 to observe dynamic of time changes as was previously proceeded for ill-defined causes (IDC).

Table 4.11 - Comparative analysis of GCs proportions distribution by sex, Paraiba 2019 and 2020

Variable	**2019** Garbage Codes (GCs)					**2020** Garbage Codes (GCs)				
	Level 1	Level 2	Level 3	Level 4	All causes	Level 1	Level 2	Level 3	Level 4	All causes
					PARAIBA					
Males	310	43	26	544	14768	298	37	109	487	17309
	46.8	**53.1**	**38.8**	**46.7**		**45.4**	**48.7**	**59.9**	**50.0**	
Females	353	38	41	622	12599	358	39	73	487	14185
	53.2	**46.9**	**61.2**	**53.3**		**54.6**	**51.3**	**40.1**	**50.0**	
total	663	81	67	1166	27378	656	76	182	974	31517
GCs[a]		1977					1888			
		7.2					**6.0**			
					JOAO PESSOA					
Males	30	14	8	125	2679	37	4	31	139	4317
	34.5	**73,7**	**34.8**	**40.9**		**33.9**	**30.8**	**49.2**	**46.6**	
Females	57	5	15	181	2538	72	9	32	159	3128
	65.5	**26.3**	**65.2**	**59.1**		**66.1**	**69.2**	**50.8**	**53.4**	
total	87	19	23	306	5218	109	13	63	298	6550
GCs[a]		435					483			
		8.3					**7.4**			
					CAMPINA GRANDE					
Males	12	3	5	38	1534	18	2	16	19	1760
	42.9	**60.0**	**50.0**	**47.5**		**56.3**	**40.0**	**72.7**	**36,5**	
Females	16	2	5	42	1416	14	3	6	33	1582
	57.1	**40.0**	**50.0**	**52.5**		**43.7**	**60.0**	**27.3**	**63,5**	
total	28	5	10	80	2950	32	5	22	52	3344
GCs[a]		123					111			
		4,2					**3.3**			
					OTHER MUNICIPALITIES					
Males	268	26	13	381	10555	243	31	62	329	12132
	48.9	**45.6**	**38.2**	**48.8**		**47.2**	**53.5**	**63.9**	**52.7**	
Females	280	31	21	399	8645	272	27	35	295	9475
	51.1	**54.4**	**61.8**	**51.2**		**52.8**	**46.5**	**27.3**	**47.3**	
total	548	57	34	780	19210	515	58	97	624	21623
GCs[a]		1419					1294			
		7.4					**6.0**			

[a]- GCs from all causes (n/%)
Source: Mortality Information System, 2020

In a contrary to what was observed for ill-defined causes, the comparison between period of pandemic with previous year 2019 showed decreasing of GCs fractions in 2020 in all observed territories.

In Paraiba the decrease of GCs fraction was by 1.2%, for Joao Pessoa by 0.9%, for Campina Grande by 0.9% and for Other Municipalities was by 1.4%. This finding was particularly surprising since ill-defined causes (IDC) are representing part of Garbage Codes, and in a present study already was identified increasing of these causes of deaths for Paraiba.

Distribution of GCs by sex showed the higher prevalence of female sex in 2019, the same tendency already was observed for 2020. In 2020, only for Other Municipalities was observed prevalence of males 51%, respectively. For Level 2 in terms of sex distribution was observed significant difference between years: in 2019 was notified steady prevalence of GCs in males for Paraiba, Joao Pessoa and Campina Grande and females for Other Municipalities, while in 2020 was observed contrary situation.

The proportion of sex and age-group specific deaths considering GCs is shown on Table 4.12. After application of algorithm for redistribution of GCs to defined deaths due COVID-19, the proportion of last one increased substantially for both sex and age-groups in Paraiba, Joao Pessoa and Other Municipalities. The algorithm was not applied to Campina Grande since it showed relatively low fraction of total GCs.

The increasing of GCs fractions was highly dependent from proportions of Garbage Codes Levels that were calculated in relation to target group of causes for each territory and from prevalence among sex and age-groups.

For males, an increase of proportion of deaths varied from 3.2% to 10.8% (Joao Pessoa and Paraiba/Other Municipalities, respectively). In case of females the highest increasing was in Joao Pessoa (21%, respectively).

For group of individuals less than 60-years-old increasing of deaths proportions varied from 3.8% (Other Municipalities) to 4.4% (Joao Pessoa). Considerable increase of deaths was estimated for group 60-years-old and higher and ranged from 17,8% to 20,2% (Other Municipalities and Joao Pessoa, respectively).

As analysis showed the recording of GCs among all causes of deaths was notified for more than 80% of Paraiba municipalities, while its fractions varied substantially across territories.

Table 4.12 - Total numbers and proportions of COVID-19 by sex and age groups before and after redistribution, Paraiba Joao Pessoa and Other Municipalities, 2020

Territory	COVID-19				
	Males	Females	<60-years-old	≥ 60-years-old	Total
			Before Redistribution (n, %)		
Paraiba	1929	1497	837	2589	3426
	56.3	**43.7**	**24.4**	**75.6**	
Joao Pessoa	616	478	280	814	1094
	56.3	**43.7**	**25.6**	**74.4**	
Other Municipalities	1081	826	457	1450	1907
	56.7	**43.3**	**24.0**	**76.0**	
			Redistributed number (n, %)		
Paraiba	281	305	111	475	586
	10.8	**11.7**	**4.3**	**18.3**	
Joao Pessoa	26	174	36	164	200
	3.2	**21.4**	**4.4**	**20.2**	
Other Municipalities	157	157	55	259	314
	10.8	**10.8**	**3.8**	**17.8**	
			After redistribution (n, %)		
Paraiba	2210	1802	948	3064	4012
	55.1	**44.9**	**23.6**	**76.4**	
Joao Pessoa	642	652	316	978	1294
	49.6	**50.4**	**24.4**	**75.6**	
Other Municipalities	1238	983	512	1709	2221
	55.7	**44.3**	**23.1**	**76.9**	

Source: Mortality Information System, 2020

In terms of volume of Garbage Codes, Paraiba was characterized by relatively low proportions of GCs in total considering target group of diseases: communicable (infectious) diseases and the respiratory system diseases. The highest GCs proportion was observed in Joao Pessoa (7.4%), followed by Paraiba (6%), Other Municiaplities (6%) and Campina Grande (3,3%).

The amount and fraction of GCs variation was highly dependent on its typology. As was previously mentioned, the low impact GCs (Level 4) was highly prevalent among all levels, probably because the coding of such causes has definition of certain disease/condition and make it easier to apply for health policy. What was alarming is high level of high impacted GCs (Level 1), which are seriously compromising mortality statistic in terms of its pattern.

Importantly, the comparison of number and proportion of GCs between years 2019 and 2020 shown contrary results with what was observed for ill-defined causes (IDC). Decreasing of GCs fractions in all observed territories of Paraiba was surprising, considering pandemic period. Looking to balance between IDC and GCs, the decrease in GCs does not necessarily suggests an improvement in the quality (accuracy) of death statistics, since ill-defined causes make a part of GCs. Moreover, this study was focused on particular two target group of causes, which can give idea of GCs distribution in Paraiba, but can't tell exact panorama in relation to all major groups of death causes in 2020.

The redistribution of GCs leads to elevation of deaths due COVID-19 in Paraiba and its municipalities. After application of redistribution method, in total 586 deaths were added for Paraiba, 200 deaths for Joao Pessoa and 314 deaths for Other Municipalities.

4.1.5 Expected deaths due COVID-19

Table 4.13 summarizes the results of COVID-19 expected deaths estimation for Paraiba after investigation of mortality sources data quality (coverage by application of the General Growth Balance method and completeness by redistribution of ill-defined causes and Garbage Codes).

Table 4.13 - Total and sex-specific COVID-19 expected deaths considering the Mortality Information System (SIM) in comparison with registered baseline, Paraiba and its municipalities, 2020

Sources	MALES				FEMALES				TOTAL			
	PB	JP	CG	OM	PB	JP	CG	OM	PB	JP	CG	OM
SIM												
Registered	1929	616	232	1081	1497	478	193	826	3426	1094	425	1907
Expected	2530	666	236	1474	2177	684	206	1237	4707	1350	442	2711
Difference	601	50	4	393	680	206	13	411	1281	256	17	804
(%)	**31.1**	**8.1**	**1.3**	**36.3**	**45.4**	**43.1**	**6.3**	**50.0**	**37.4**	**23.4**	**4.0**	**42.2**

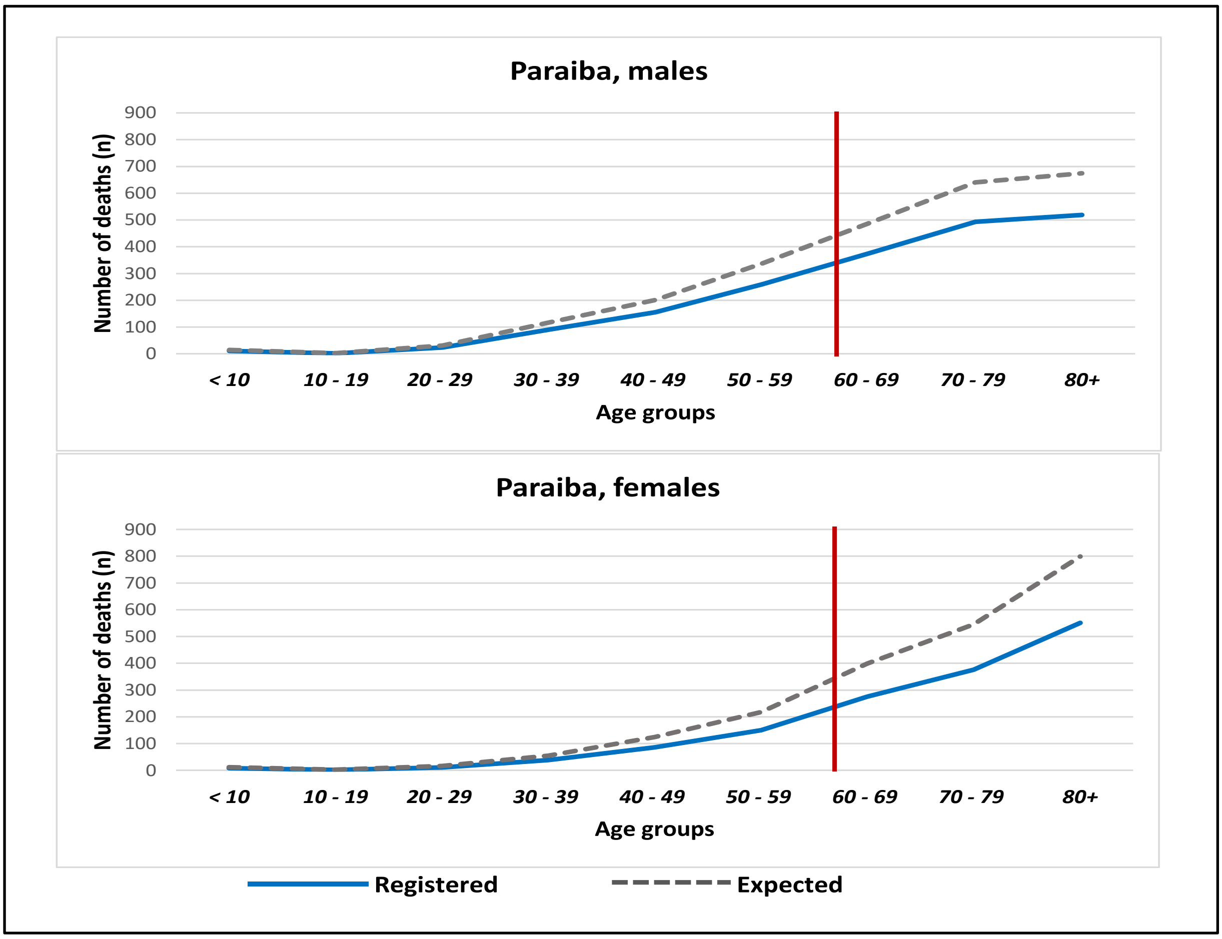
LEGEND: PB-Paraiba; JP-Joao Pessoa; CG-Campina Grande; OM-Other Municipalities
Sources: SIM-Mortality Information System; SES-State Secretariat of Health; RC-Registry Civil, 2020

After investigation of mortality data sources quality related to COVID-19 and expected deaths estimation, was notified an increase of percentage of deaths in all territories of Paraiba. Considering the "gold standard" data source SIM (the Mortality Information System), the highest percentage increasing of expected deaths was notified for other Municipalities (42.2%), followed by Paraiba, Joao Pessoa and Campina Grande (37.4%, 23.4% and 4%, respectively). The same tendency was observed for other data sources with little variation in percentage.

After analysis of data source quality (SIM), an estimated increase in total number of deaths in Paraiba was from 3426 to 4707 (registered and expected, respectively). In Other Municipalities an increase was an estimated of 804 deaths more than was initially registered. Less elevated number of expected deaths for Joao Pessoa and Campina Grande (256 and 17 deaths, respectively) was associated with observed relatively low proportions of ill-defined causes (IDC) and Garbage Codes for these municipalities.

Figure 4.5 shown distribution of deaths by age in Paraiba before and after calculation of expected deaths.

Figure 4.5-Age-specific difference between registered and expected deaths due COVID-19 by sex, Paraiba, 2020



Source: SIM-Mortality Information System, 2020

As was described in session 4.1.1, the number of deaths due to COVID-19 in Paraiba increases with age. Earlier observed significant predominance of deaths in older age groups (60-years-odl and higher) was increased after investigation of sub-register by approximately 50% for females and by 30% in case of male sex.

Investigation of mortality data sources quality with analysis of deaths sub-register due COVID-19 in Paraiba shown important results. Age and sex group analysis of two main characteristics of data quality (coverage and completeness) resulted in higher number of deaths during pandemic period in a state irrespective of data sources. In total, the observed increase of deaths was for approximately 37% (in 31% for males and 45% for females).

The results of the study indicate likely considerable underreporting of deaths due COVID-19 in Paraiba, where the counts of reported deaths released by official Brazilian data sources were lower than the actual number. Moreover, the conclusions about underreported deaths were also notified by several authors in relation to pandemic situation in Brazil, which after all made it difficult to inform health policy (VEIGA E SILVA et al., 2020; ROCHA et al, 2020; SOUSA, TORRES, MOURA et al, 2020).

Furthermore, the results demonstrated crucial importance of investigations related to mortality data quality, including state and municipal levels. Although the quality of mortality data has been improved in the country, the present study showed significant difference of death rates before and after data correction. Improving the mortality data is essential, in this sense the study contributes to better understanding of real magnitude of mortality due COVID-19 pandemic 2020 in Paraiba and could be useful source for health policy planning and decision making.

4.2 COVID-19 mortality indicators

Table 4.14 shows total and age-proportionate ratio of deaths due COVID-19 in Paraiba, Joao Pessoa, Campina Grande and Other Municipalities in relation to total volume of deaths during pandemic 2020. The proportions were calculated to observe weight of specific age-group in a mortality structure and to its changes after quality data corrections.

The total fractions of deaths calculated from registered deaths in Paraiba varied from 8.8% to 16.7% (Other Municipalities and Joao Pessoa, respectively).

The fractions of deaths before correction were higher in group 60-year-old and above in all observed territories. The highest difference between age-groups was observed for Joao Pessoa (4,6%), followed by Campina Grande (3.8%), Paraiba (3.6%) and Other Municipalities (3.3%).

Table 4.14 - COVID-19 deaths, as proportion form total, by age groups before and after data quality correction, Paraiba 2020

Territory	BEFORE			AFTER		
	< 60 y.o.	≥ 60 y.o.	total	< 60 y.o.	≥ 60 y.o.	total
Paraiba	8.4	12.0	10.8	11.4	16.6	14.9
Joao Pessoa	13.6	18.2	16.7	16.2	22.6	20.6
Campina Grande	10.0	13.8	12.7	10.3	14.4	13.2
Other Municipalities	6.6	9.9	8.8	9.3	14.1	12.5

Source: SIM-Mortality Information System, 2020

After quality data correction an increase in COVID-19 proportionate deaths was observed in Paraiba and its municipalities. Considering total fractions, the highest increasing was notified in Paraiba (4.1%). Increasing of deaths in group 60-years old and higher varied from 0.6% (Campina Grande) to 4.6% (Paraiba), respectively.

Table 4.15 shows total and sex-specific COVID-19 mortality rate in Paraiba and its municipalities for 2020.

Table 4.15 - COVID-19- mortality rate per 100 000 population, total and by sex before and after data quality correction, Paraiba 2020

Territory	BEFORE			AFTER		
	M	F	total	M	F	total
Paraiba	99.0	71.6	84.8	129.8	104.2	116.5
Joao Pessoa	161.3	109.7	133.8	174.4	157.0	165.1
Campina Grande	119.1	88.9	103.2	121.1	95.0	107.3
Other Municipalities	78.7	57.4	67.8	107.4	86.1	96.5

LEGEND: M-males, F-females
Source: SIM-Mortality Information System, 2020

According to results, the highest COVID-19 mortality rate was observed in Joao Pessoa, followed by Campina Grande, Paraiba and Other Municipalities. Specific mortality rate was higher for males comparing with females for all territories of Paraiba. For males, was observed variation from 78.7 to 161.3 per 100000 population, while among females from 57.4 to 109.7 per 100000 population (Other Municipalities and Joao Pessoa, respectively).

After quality data correction was notified increasing of COVID-19 mortality rate for all territories. In total, the highest increasing of mortality rate was notified in Joao Pessoa (from 133.8 to 165.1 per 100000 population). In Paraiba an increase was in 31.7 per 100000 population, respectively.

It is necessary to take into account that the expected values are estimates based on data which are subject to multiple errors, such as counting deaths and population by age group and sex, violation of assumptions in the application of the death correction technique proposed by Brass, and the errors that are inherent in any estimate.

The results of COVID-19 proportionate deaths and diseases-specific mortality rate calculations shown influence of data quality corrections not only to absolute number of deaths, but, therefore, to mortality indicators as well. Since mortality measures reflect a wide variety of factors (population´s state of health, access to health care, infection control, sanitation etc.), correct estimation and interpretation of mortality indicators based on trustworthy mortality data are fundamental for health policy.

4.3 Excess mortality in Paraiba during pandemic 2020

The differences and incompleteness of COVID-19 deaths reporting, untested cases and time lags, overwhelmed health care capacities, among other issues, may create variations in death counts, so they do not represent the full mortality picture. In this situation, the excess mortality is a useful non-specific measure of pandemics' severity which can provide more accurate estimate of mortality considering direct and indirect deaths due diseases (CDC, 2020a).

As was described in Session 3.5 of Methodology, the excess mortality estimation for Paraiba 2020 was based on weekly deaths historical time series 2015-2019 as a baseline. The current study represents analysis of all-causes mortality, deaths due natural causes and respiratory system diseases considering the Brazilian Mortality Information System (SIM) data source. Previously calculated expected deaths (Session 4.1) as a result of the quality data correction were used to compare magnitude of COVID-19 pandemic excess mortality in Paraiba 2020.

Table 4.16 shows the results of excess observed and expected deaths numbers in Paraiba 2020 with statistical outcomes based on application of historical series average and forecasting (exponential smoothing function) methods for all-cause deaths, natural causes and deaths due respiratory system diseases.

All-cause mortality.

For all-cause observed deaths there were 4532 (95% CI, 3946 – 5129) excess death in Paraiba in 2020 (p score 16.8%, $p<.0001$), after using historical average approach. Forecasting analysis showed approximately the same result in 16.5% of excess deaths ($p<0.0001$). For all-cause expected deaths (after corrections in quality study), an estimated number of excess deaths was 6773 (95% CI, 5939 – 7022), p-score 25%, when using historical average, estimates obtained using forecast were not different (p-score 24.7%).

The difference in excess deaths, observed vs expected (after correction) in 2020, demonstrated higher estimates after corrections. For example, the forecasting showed the difference in approximately 8.0% (16.5% and 24.7%, respectively).

Table 4.16 –Total excess mortality in 2020 based on historical 2015-2019 average and forecasting methods, all-cause mortality and deaths due to natural causes, and respiratory diseases, Paraiba 2020

	Baseline 2015-2019	**Number of deaths 2020**	**Excess of deaths**		
	N (95% CI)	N	N (95% CI)	P-score (%)	p-value [b]
			Observed deaths		
All-causes					
Historical Average	26984 [25482, 28486]	31517	4532 [3946, 5129]	16.8	0.0001
Forecast	27055 [24732, 29378]	31517	4461 [4174, 4816]	16.5	<.0001
Natural-causes					
Historical Average	24052 [23414, 24691]	28576	4524 [3885, 5162]	18.7	0.0001
Forecast	24177 [23872, 24482]	28576	4399 [4094, 4704]	18.2	<.0001
RESP					
Historical Average	3111 [2972, 3249]	6236	3125 [2987,3264]	100.5	<.0001
Forecast	3221 [3110, 3332]	6236	3015 [2904, 3126]	93.6	<.0001
			Expected deaths[a]		
All-causes					
Historical Average	26984 [25482, 28486]	33757	6773 [5939,7022]	25.0	<.0001
Forecast	27055 [24732, 29378]	33757	6702 [6467,7009]	24.7	<.0001
Natural-causes					
Historical Average	24052 [23414, 24691]	30626	6574 [5935-7212]	27.2	<.0001
Forecast	24177 [23872, 24482]	30626	6449 [6144, 6754]	26.7	<.0001
RESP					
Historical Average	3111 [2972-3249]	6678	3567 [3429-3706]	110.7	<.0001
Forecast	3221 [3110, 3332]	6678	3457 [3346, 3568]	107.3	<.0001

[a]- deaths after quality data correction by application of General Growth Balance (GGB) method
[b] – p-value, student t test to compare observed/expected deaths in 2020 with mean at baseline 2015-2020
LEGEND: RESP- respiratory system diseases,

Source: SIM-Mortality Information System, 2020

Considering number of registered deaths due COVID-19 in Paraiba based on the Mortality Information System data for 2020, the excess deaths were in 75.6% directly impacted by pandemic (3426 COVID-19 deaths vs 4532 excess deaths due all-causes). About one-fourth deaths during 2020 pandemic were attributed to indirect impact of COVID-19.

Natural causes mortality.

Analysis of observed deaths due natural causes showed excess deaths during 2020 pandemic in approximately 19% based on both projection methods: 4524 (95% CI, 3885-5162) and 4399 (95% CI, 4094 -4704) deaths, respectively). Estimation based on expected counts were higher (p-score 27.2%), in historical average approach) than estimates based on observed (reported) counts, and increased excess deaths in approximately 8.5%, considering both average and forecasting projections.

Mortality due to respiratory illness.

The exploratory analysis of excess deaths due respiratory diseases in Paraiba during pandemic 2020 identified values that were two-fold higher than baseline for both observed and expected deaths. The 5-year weekly average baseline showed excess deaths in 100.5% and 110.7% (observed and expected deaths, respectively).

After application of exponential smoothing analysis were observed 3015 excess deaths based on observed deaths and 3457 excess deaths based on expected deaths (93.6% and 107.3%, respectively). The statistically significant excess deaths in Paraiba due respiratory diseases ($p<0.0001$) proved direct influence of COVID-19 on exceed mortality in 2020.

Excess mortality over time by epidemiological weeks.

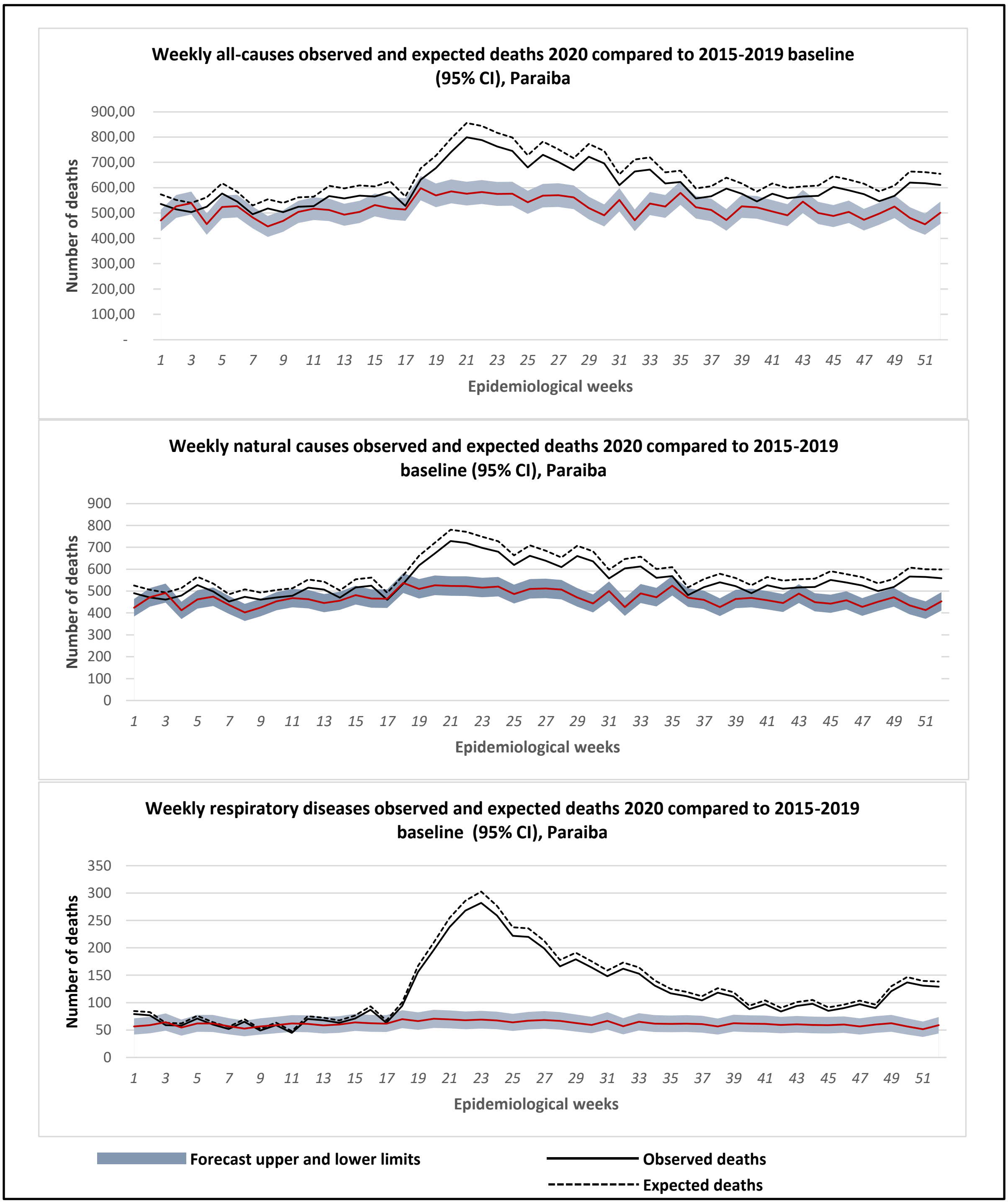
Figure 4.6 shows weekly distribution of exceed deaths due all-causes, natural causes and respiratory diseases deaths in Paraiba during 2020 pandemic based on forecasting baseline with respect to the peak periods for disease activity within the considered timeframe.

For all-cause mortality in 2020, the number of observed and expected deaths showed an increasing trend from 19th to 35th epidemiological weeks compared to 2015-2019 baseline. The projected values are smaller than the actual numbers considering epidemiological weeks distribution with excess deaths notified in 48 from all 52 epidemiological weeks of 2020 (92% of all observed period).

Based on 5-year weekly forecasting results, the proportions of all-causes excess deaths varied from 1.3% to 41.8% (11th and 21st epidemiological weeks, respectively). Expected excess deaths varied from 8.4% to 49.8%, respectively. Taking into account the peak period of

COVID-19 outbreaks in 2020 (Table 4.2), the peak of all-cause excess deaths was notified in same time frame as actual COVID-19 peak in Paraiba.

Figure 4.6 - Observed and expected excess deaths due all-causes, natural causes and respiratory system diseases deaths compared to forecast baseline, Paraiba, 2020



Source: SIM-Mortality Information System, 2020

In terms of natural causes excess deaths was notified the same tendency as was observed for all-causes deaths. Considering forecasting baseline, the fractions of exceed for observed deaths varied from 2.4% to 43% and from 9.6% to 53.6% for expected deaths (11th and 21st epidemiological weeks, respectively).

Respiratory system diseases deaths analysis showed more prominent magnitude of excess deaths during observed period not only in terms of total values but by epidemiological weeks distribution. In a contrary with what was observed for all-causes and natural causes deaths weekly distribution, in case of respiratory diseases statistically significant ($p<0.0001$) excess was notified during all period starting from 18th epidemiological week (102% in 35th week, 71% in 47th week and 122% in 52nd epidemiological week).

In a period from 18th to 52nd epidemiological weeks was notified variation of respiratory diseases excess of observed deaths from 47.3% to 348% based on 5-year weekly baseline. The difference between observed and expected excess deaths considering peaks of pandemic was 33% (348% and 381%, respectively).

Excess deaths study in Paraiba during 2020 pandemic showed statistically significant higher values compared with 5-year baselines for all causes, natural causes and respiratory diseases considering both observed and expected deaths. Weekly distribution of deaths showed the same tendency in terms of periods of increasing, decreasing and peaks that were seen for COVID-19 separately, which proved direct impact of pandemic to overall excess mortality in Paraiba.

Scientific literature scares with examples of exceeded deaths due COVID-19 from different countries including Brazil (VEIGA E SILVA et al., 2020; PAHO, 2020). Reported excess mortality varies highly across territories and countries. Current study proved excess mortality in Paraiba state during 2020 pandemic and measured its magnitude.

Even though COVID-19 deaths made up a large majority of the excess deaths (approximately 76%) during the COVID-19 pandemic in Paraiba, about one-fourth of the excess deaths have been attributed to indirect impact. It is likely that some of these deaths were COVID-19 deaths that were miscoded or misdiagnosed. Many studies ultimately show that around one-third of the excess deaths that occurred at different times throughout the COVID-19 pandemic are not assigned to virus (WOOLF, CHAPMAN, SABO et al., 2021; BILINSKI, EMANUEL, 2020). In particular, COVID-19 cases in rural counties had a higher number of excess deaths not assigned to COVID-19, suggesting COVID-19 mortality in these areas may be undercounted.

The quality data corrected numbers (expected deaths) added significant fractions on top of initially observed deaths which makes magnitude of COVID-19 mortality in Paraiba in 2020 higher than was reported. Both studies, analysis of data quality and excess deaths, are complementing and taking into account important factors such as differences in death reporting and registration process, historical mortality trends, direct and indirect impact of COVID-19 on population mortality.

4.3.1 Error measures analysis

In purpose to better understand which projection model better performed for excess mortality estimation, the analysis of errors was provided.

The Table 4.17 shows the results of statistical outcomes of residuals analysis considering parameters of errors measures, normality of data distribution, homoscedasticity, and residuals autocorrelation.

Table 4.17 - Residuals statistical outcomes for average and exponential triple smoothing (ETS) models

Parameters	**Average model**	**Exponential smoothing model (ETS)**
MAE	24.0	19.3
MSE	916.9	688.5
RMSE	30.2	26.2
MAPE	0.02	0.018
Shapiro-Wilk (p-value)	0.111	0.260
Breaush-Pagan (p-value)	0.004	0.252
Durbin-Watson (p-value)	0.000	0.000

*- MAE- mean absolute error, MSE- mean square error, RMSE-root mean square error, MAPE- mean absolute percentage error

Analysis of mean absolute error (MAE) measures showed smaller deviations after applying exponential triple smoothing (ETS) model comparing with average model.

Another measure used was mean absolute percentage error (MAPE), which provides an indication of the average size of the error, expressed as a percentage of the observed value, regardless of whether the error is positive or negative. According to results MAPE was practically equal for both models (0.02 for average and ETS, respectively).

The mean square error (MSE) was largely distinct between two models. The results showed MSE=916.9 for average model and MSE=688.5 for ETS model, which makes the second one better performed model.

Root mean square error (RMSE) is a metric that represents the average distance between the predicted values from the model and the actual values in the dataset. The concept of this measure is that the lower RMSE, the better a given model can “fit” a dataset. Comparing two models for excess mortality projection, the exponential smoothing method had better outcomes (26.2).

Three diagnostics statistical measures (Shapiro-Wilk, Breaush-Pagan and Durbin-Watson) were applied tests based on statistical assumptions, to verify the adequacy of the models reflecting three main characteristics: normality, homoscedasticity, and residuals autocorrelation.

The Shapiro-Wilk test which measure the normality of distribution of observed vs predicted samples, showed p-values higher than 0.05 for average and ETS models (0.111 and 0.260). In both cases was accepted the null hypotheses (H_0), indicating that two models represented normal distribution.

Exponential triple smoothing model (ETS) showed better results (0.252) comparing with average model (0.004) after the Breusch-Pagan test application. In case of average model p-value was less than 0.05, which support the conclusion that it has problem with homoscedasticity, a situation in which the variance of dependent variable is not the same for all data.

Autocorrelation, also known as serial correlation, can be a significant problem in analyzing historical data. The results of the Durbin-Watson test, which is designed specifically to autocorrelation detection, showed p-values <0.05 for both models, indicating that residuals were independent. The error measures analysis confirmed the better performance of exponential smoothing model compared with average method for excess mortality estimation. The further analysis of sex and age-adjusted distribution of excess deaths were proceeded with application of exponential triple smoothing (ETS) model.

4.3.2 Sex and age-group distribution of excess deaths

Excess mortality by sex.

Table 4.18 shows sex-specific excess mortality in Paraiba considering both observed and expected deaths due all-causes, natural causes and respiratory system diseases deaths during pandemic 2020.

According to results, excess deaths was significantly higher among males compared to females for all-causes, natural causes and respiratory system diseases for Paraiba in 2020.

Table 4.18 - Sex-adjusted excess of observed and expected deaths due all-causes, natural causes and respiratory diseases, Paraiba, 2020

	Baseline 2015-2019	Number of deaths 2020	Excess of deaths		
	N (95% CI)	N	N	P-score (%)	p-value
			Observed deaths		
All-causes					
Males	14711 [12998, 16423]	17434	2723	18.5	<.0001
Females	12395 [10823, 13966]	14083	1688	13.6	<.0001
Natural causes					
Males	12503 [10924, 14081]	14880	2377	19.0	<.0001
Females	11943 [10401, 13486]	13696	1753	15.4	<.0001
RESP					
Males	1512 [963, 2061]	3360	1848	122.2	<.0001
Females	1691 [1110, 2271]	2876	1185	70.1	<.0001
			Expected deaths[a]		
All-causes					
Males	14711 [12998, 16423]	18262	3551	24.1	<.0001
Females	12395 [10823, 13966]	15454	3059	24.7	<.0001
Natural causes					
Males	12503 [10924, 14081]	15587	3084	24.6	<.0001
Females	11943 [10401, 13486]	15024	3081	25.7	<.0001
RESP					
Males	1512 [963, 2061]	3519	2007	132.7	<.0001
Females	1691 [1110, 2271]	3158	1467	86.7	<.0001

[a]- deaths after quality data correction by application of General Growth Balance (GGB) method
LEGEND: RESP- respiratory system diseases,
Source: SIM-Mortality Information System, 2020

For all-causes, P score of excess deaths among males was 18.5% considering registered deaths and 24.1% based expected after correction estimates (2723 and 3551 deaths, respectively), statistically significant ($p<0.001$). Likewise, for females, excess of deaths (P-score) compared with baseline was 13.6% for observed deaths and 24.7% for expected deaths.

Analysis of excess mortality for natural causes in terms of magnitude showed the same tendency as for all-causes. The gap of male's prevalence compared with females was less prominent comparing with all-causes, because of external causes subtracting.

Observed excess of deaths among males was 19% and 24.6% considering observed and expected deaths, respectively. The difference between both number of deaths (observed and expected) was 1174 deaths.

In case of females, for natural causes was notified excess of deaths in 15.4% considering registered deaths and 25.7% for expected deaths (1753 and 3081, respectively).

The highest proportion of exceed deaths was observed for respiratory diseases considering both males and females. For males was notified statistically significant (<0.0001) P-score 122.2% based on observed deaths and in approximately 10% higher considering expected number of deaths. Analysis of sex adjusted all-causes, natural causes and respiratory causes distribution showed the same mortality pattern for Paraiba in 2020 as was seen in previous 5 years (2015-2019): prevalence of males compared with females. In terms of excess deaths fraction for all determined causes was observed statistically significant (<0.0001) deaths exceed both for males and females, more prominent for respiratory diseases.

Excess mortality by age groups.

Table 4.19 shows age-adjusted excess of deaths due all-causes, natural causes and respiratory diseases deaths for Paraiba in 2020 based on historical series (2015-2019) baseline.

Analysis of total number of deaths in 2020 as well as weekly historical baselines showed significant prevalence in mortality pattern deaths in group 60-years-old and higher for all-causes, natural causes and respiratory diseases. However, the excess deaths count, which was used as a tool for better understating of severity, scope, and impact of pandemic, demonstrated interesting outcomes in relation to age-groups distribution. Interestingly, that despite prevalence of older age group (≥ 60-years-old) in total mortality, according to results, the higher excess deaths proportions comparing with historical baseline was notified for group under 60-years-old.

For instance, was observed in approximately 3% higher scope of exceed deaths in group under 60-years-old for all causes, in 12.4% for natural causes and 112.8% for respiratory diseases. Looking to historical baseline for respiratory diseases (483 average deaths), the magnitude of excess for this particular group of diseases was 3 times higher than was seen in previous 5 years. The calculation of excess deaths based on expected number showed increasing of deaths for group under 60-years-old in 27.3%, 35.7% and approximately 212% (all-causes, natural causes and respiratory diseases deaths, respectively).

In group 60-years-old and higher was detected excess of deaths in 16% for all-causes, in 14% for natural causes and approximately in 78% for respiratory diseases. Considering expected deaths, excess deaths was increased in 8.6%, 9.2% and 12.9% (all-causes, natural causes and respiratory diseases, respectively).

Table 4.19 Age-adjusted excess of observed and expected deaths due all-causes, natural causes and respiratory diseases, Paraiba 2020

	Baseline 2015-2019	**Number of deaths 2020**	**Excess deaths**		
	N (95% CI)	N	N	P-score (%)	p-value
	Observed deaths				
All-causes					
<60-years-old	8226 [6946, 9506]	9768	1545	18.7	<.0001
≥60-years-old	18827 [16890, 20764]	21749	2992	15.9	<.0001
Natural causes					
<60-years-old	6069 [4970, 7168]	7678	1609	26.5	<.0001
≥60-years-old	18311 [16401, 20221]	20898	2587	14.1	<.0001
RESP					
<60-years-old	483 [175, 790]	1404	921	190.6	<.0001
≥60-years-old	2717 [1982, 3454]	4832	2115	77.8	<.0001
	Expected deaths[a]				
All-causes					
<60-years-old	8226 [6946, 9506]	10479	2253	27.3	<.0001
≥60-years-old	18827 [16890, 20764]	23332	4505	23.9	<.0001
Natural causes					
<60-years-old	6069 [4970, 7168]	8240	2171	35.7	<.0001
≥60-years-old	18311 [16401, 20221]	22419	4108	22.4	<.0001
RESP					
<60-years-old	483 [175, 790]	1506	1023	211.8	<.0001
≥60-years-old	2717 [1982, 3454]	5184	2467	90.7	<.0001

[a]- deaths after quality data correction by application of General Growth Balance (GGB) method
LEGEND: RESP- respiratory system diseases,

Source: SIM-Mortality Information System, 2020

Analysis of age and sex-adjusted deaths in Paraiba during 2020 pandemic, proved statistically significant excess of deaths in all observed demographic characteristics: males and females, group under 60-years-old and 60-years-old and higher for all observed causes of deaths. The prevalence of deaths among males was followed by the prevalence of excess deaths scope in 2020.

Despite the significant prevalence of total number of deaths in group of 60-years-old and higher, in a contrary, the scope of excess deaths comparing with previous 5-years was also high for group under 60-years-old. It proves that not only elderly people were impacted by COVID-19 pandemic, but younger people also died and probably were underreported or misdiagnosed.

5 FINAL CONSIDERATIONS

Mortality data and their subsequent analysis are essentials for setting targets and evaluating health and population intervention plans. Recognition of vital statistics information systems being capable generating reliable data has been growing during COVID-19 pandemic. There are various sources of vital statistics in Brazil, and it is important that different sources employ same concepts and definitions of vital events to ensure national and international comparability.

Following the first research question and objective, the study evidenced discordant mortality data released by five different official Brazilian national and regional sources related to COVID-19 deaths in Paraiba and its municipalities in 2020. The differences of registered deaths in the state were notified not only in interpretation of total and cumulative number of deaths, but also in appearance of certain characteristics, such as time lag, picks of pandemic and weekly distribution of deaths. The important differences among the numbers of deaths counted by official data sources reflect lack of a national coordination primarily related to country´s political issues.

Even though the State Health Secretariat (SES) was considered as “better” source in terms of captured number of deaths among five data sources (the Brazilian Mortality Information System (SIM), Transparency Portal by the Registry Civil and Coronavirus Panel by the Ministry of Health), all data sources had presented limitations. Such limitations could negatively impact COVID-19 mortality analyses and its indicators measurements and should be considered in studies planning and health policy decision-making.

The spatial distribution of deaths during 2020 pandemic allowed to observe disease´s spreading and evidenced its heterogenicity across the territories of Paraiba. Urban areas with large and most populated cities of the state, especially capital city Joao Pessoa, had probably contributed as a source of pandemic 2020 propagation and internalization. However, the true mortality rate due COVID-19 in rural areas, especially in backwoods territories (sertão) is a question for further investigations.

Mortality is a multi-faceted event and demanding subsequent analysis including entailing of principal characteristics such as coverage, completeness, and accuracy, which was part of first objective of the study. Northeast region, including Paraiba, had shown recent improvements in a quality of vital events registration. However, the studies of the mortality information quality in region and Paraiba are still severely limited.

The main focus of this thesis was on mortality data quality issues, considering unprecedented overburden of health systems during pandemic 2020. The thesis has demonstrated that any analysis of mortality and the excess mortality requires understanding of data quality issues. Being classified as a "very good" coverage for Paraiba, Joao Pessoa, Campina Grande and as "good" coverage for Other Municipalities in 2020 based on Mortality Information System data source, yet it shown significant number of underreported deaths due COVID-19 after the General Growth Balance method application.

The number underreported deaths related to COVID-19 became even more evident after investigation of ill-defined causes (IDC) and Garbage Codes (GCs). One of the main contributions of this study is that it's a first study conducted in Brazil, which was focused on IDC and GCs study related to COVID-19, and precedents was not found in available scientific publications.

The poor death certification was highly common among municipalities of Paraiba in 2020 and impacted practically all specific causes of deaths. The proportions of IDC distribution varied substantially across territories of Paraiba with significant contribution of less populated areas (áreas pequenas). During pandemic 2020 was notified increased number of ill-defined causes in Paraiba comparing with 2019, especially among males, and it is alarming signal, which could negatively affect the quality of mortality statistics and demands a certain policy towards improving of deaths certificates accuracy in the state.

The analyses of underlying causes which triggering the chain of event that led to death are fundamental for public health. While deaths coverage in Brazil showed steady improvements in recent years, the accuracy of deaths registration remains a problem. In present study was proceeded identification of Garbage Codes typology possibly related to COVID-19 and identified specific target causes where the deaths assigned to a GCs should be reassigned.

The study identified the presence of GCs in deaths registration in most municipals of Paraiba in 2020. The highest proportion of GCs occurred among elderly people and were due mainly Level 1 and Level 4 GCs. This tendency is of concern since COVID-19 also impacted prevalent number of elderly individuals, which could "masking" the real mortality among this group of population.

The present study showed clear evidence of excess mortality in Paraiba during COVID-19 pandemic. The magnitude of mortality in 2020 was significantly higher than in previous years. The study proved direct and indirect impact of COVID-19 on overall mortality as well as for natural causes and respiratory system diseases considering time mortality trends and weekly distribution of deaths during pandemic.

While most deaths were directly attributed to COVID-19, about one-fourth of all deaths in 2020 were due indirect impact of pandemic. The insufficiency of testing capacities in 2020, problems with deaths registration, and overburden health systems, one of some possible answers to indirect excess mortality in Paraiba.

Focusing on mortality pattern formulated in second objective, the study proved that age and sex had the considerable impact on excess mortality during 2020 pandemic in Paraiba. Older people died in higher rates, as they are more susceptible to the virus than younger age groups. While COVID-19 undoubtedly impacted mortality in elder population, people younger than 60-years-old also died and probably were underreported in COVID-19 statistics or misdiagnosed. With population generally aging, the significant prevalence of deaths among older groups of individuals is evidence that should be considered for policy making. The study confirmed elder people and males as a group at higher risk of mortality due COVID-19 in Paraiba, and results are comparable with many studies conducted in Brazil and internationally.

The study has several limitations. The data sources considered for the study had presented certain limitations in 2020, such as: preliminary mortality data, registration of suspected cases along with confirmed, limited variables for analysis and disagreements in deaths counts. The proportions of ill-defined causes and Garbage Codes were limited by target causes that possibly could be attributed to COVID-19, and not included all ICD and GCs. In this case, the number of misclassified deaths could be even higher. The statistical models for registered deaths correction and calculation of excess mortality could present some acceptable errors.

Investigation of excess mortality in Paraiba 2020, which reflects aim of the study, provided several important conclusions. Under registration, disagreements, delays of information, poor death certification and other issues with the quality of deaths counts released by Brazilian official mortality systems impacted mortality values, health indicators and do not fully represent the burden of pandemic. Investigation of the coverage, completeness and accuracy should be considered as an important part when conducting studies related to mortality.

Excess mortality analysis proved to be useful tool for understanding direct and indirect impact of COVID-19 pandemic and its magnitude. In addition to being an alternative to death counts, excess mortality estimates provide new perspectives: better understand the relative severity, scope, and impact of an event compared to normal conditions.

Distinguished results have direct relevance to public health planning, and decision making in public health. The study contributes towards improvements of vital statistics and mortality information in Paraiba state, highlighting important demographic characteristics in terms of target population groups for health planning and interventions. Moreover, the current study has potential for further investigations since COVID-19 pandemic is continuing in 2022. Particularly, the proposed methods for mortality data quality investigation could be applied for studies related not only to continuing COVID-19 pandemic, but for any other groups of diseases. Excess mortality estimated for 2020 pandemic in Paraiba is useful tool for comparative analysis of mortality changes in time, or between different territories/regions of Brazil.

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Annex 1 Death Certificate

República Federativa do Brasil
Ministério da Saúde
1ª VIA - SECRETARIA DE SAÚDE

Declaração de Óbito

I Identificação

1 Tipo de óbito: 1 Fetal; 2 Não Fetal
2 Data do óbito — Hora
3 Cartão SUS
4 Naturalidade — Município / UF (se estrangeiro informar País)
5 Nome do Falecido
6 Nome do Pai
7 Nome da Mãe
8 Data de nascimento
9 Idade — Anos completos; Menores de 1 ano: Meses, Dias, Horas, Minutos; Ignorado 9
10 Sexo: M - Masc.; F - Fem.; I - Ignorado
11 Raça/Cor: 1 Branca; 2 Preta; 3 Amarela; 4 Parda; 5 Indígena
12 Situação conjugal: 1 Solteiro; 2 Casado; 3 Viúvo; 4 Separado judicialmente/divorciado; 5 União estável; 9 Ignorada
13 Escolaridade (última série concluída) — Nível: 0 Sem escolaridade; 1 Fundamental I (1ª a 4ª Série); 2 Fundamental II (5ª a 8ª Série); 3 Médio (antigo 2º grau); 4 Superior incompleto; 5 Superior completo; Ignorado 9 — Série
14 Ocupação habitual (informar anterior, se aposentado / desempregado) — Código CBO 2002

II Residência

15 Logradouro (rua, praça, avenida, etc.) — Número — Complemento
16 CEP
17 Bairro/Distrito — Código
18 Município de residência — Código
19 UF

III Ocorrência

20 Local de ocorrência do óbito: 1 Hospital; 2 Outros estab. saúde; 3 Domicílio; 4 Via pública; 5 Outros; Ignorado 9
21 Estabelecimento — Código CNES
22 Endereço da ocorrência, se fora do estabelecimento ou da residência (rua, praça, avenida, etc) — Número — Complemento
23 CEP
24 Bairro/Distrito — Código
25 Município de ocorrência — Código
26 UF

IV Fetal ou menor que 1 ano

PREENCHIMENTO EXCLUSIVO PARA ÓBITOS FETAIS E DE MENORES DE 1 ANO - INFORMAÇÕES SOBRE A MÃE
27 Idade (anos)
28 Escolaridade (última série concluída) — Nível: 0 Sem escolaridade; 1 Fundamental I (1ª a 4ª Série); 2 Fundamental II (5ª a 8ª Série); 3 Médio (antigo 2º grau); 4 Superior incompleto; 5 Superior completo; Ignorado 9 — Série
29 Ocupação habitual (informar anterior, se aposentada / desempregada) — Código CBO 2002
30 Número de filhos tidos — Nascidos vivos; Perdas fetais/abortos — 99 Ignorado; 99 Ignorado
31 Nº de semanas de gestação — 99 Ignorado
32 Tipo de gravidez: 1 Única; 2 Dupla; 3 Tripla e mais; 9 Ignorada
33 Tipo de parto: 1 Vaginal; 2 Cesáreo; 9 Ignorado
34 Morte em relação ao parto: 1 Antes; 2 Durante; 3 Depois; 9 Ignorado
35 Peso ao nascer — Gramas
36 Número da Declaração de Nascido Vivo

V Condições e causas do óbito

ÓBITO DE MULHER EM IDADE FÉRTIL
37 A morte ocorreu: 1 Na gravidez; 2 No parto; 3 No aborto; 4 Até 42 dias após o parto; 5 De 43 dias a 1 ano após o parto; 8 Não ocorreu nestes períodos; Ignorado 9

ASSISTÊNCIA MÉDICA
38 Recebeu assist. médica durante a doença que ocasionou a morte? 1 Sim; 2 Não; 9 Ignorado

DIAGNÓSTICO CONFIRMADO POR:
39 Necrópsia? 1 Sim; 2 Não; 9 Ignorado

40 CAUSAS DA MORTE — ANOTE SOMENTE UM DIAGNÓSTICO POR LINHA — Tempo aproximado entre o início da doença e a morte — CID

PARTE I
Doença ou estado mórbido que causou diretamente a morte. — a

CAUSAS ANTECEDENTES
Estados mórbidos, se existirem, que produziram a causa acima registrada, mencionando-se em último lugar a causa básica.
b — Devido ou como consequência de:
c — Devido ou como consequência de:
d — Devido ou como consequência de:

PARTE II
Outras condições significativas que contribuíram para a morte, e que não entraram, porém, na cadeia acima.

VI Médico

41 Nome do Médico
42 CRM
43 Óbito atestado por Médico: 1 Assistente; 2 Substituto; 3 IML; 4 SVO; 5 Outro
44 Município e UF do SVO ou IML — UF
45 Meio de contato (telefone, fax, e-mail, etc.)
46 Data do atestado
47 Assinatura

VII Causas externas

PROVÁVEIS CIRCUNSTÂNCIAS DE MORTE NÃO NATURAL (Informações de caráter estritamente epidemiológico)
48 Tipo: 1 Acidente; 2 Suicídio; 3 Homicídio; 4 Outros; Ignorado 9
49 Acidente do trabalho: 1 Sim; 2 Não; Ignorado 9
50 Fonte da informação: 1 Boletim de Ocorrência; 2 Hospital; 3 Família; 4 Outra; Ignorado 9
51 Descrição sumária do evento, incluindo o tipo de local de ocorrência
SE A OCORRÊNCIA FOR EM VIA PÚBLICA, ANOTAR O ENDEREÇO
52 Logradouro (rua, praça, avenida, etc.) — Código

VIII Cartório

53 Cartório — Código
54 Registro
55 Data
56 Município
57 UF

IX Localid. S/ Médico

58 Declarante
59 Testemunhas — A — B

Versão 01/10 - 2ª Impressão 11/2010

Annex II List of Garbage Codes (GCs)

Garbage Code Severity Level	ICD-10 Codes
Very High (Level 1)	A40, A40.0 - A40.3, A40.8 - A40.9, A41, A41.0 - A41.6, A41.8 - A41.9, A48.0, A48.3, A49.0 - A49.1, A59, A59.0, A59.8 - A59.9, A71, A71.0 - A71.1, A71.9, A74.0, B07, B07.0, B07.8 - B07.9, B30, B30.0 - B30.3, B30.8 - B30.9, B35, B35.0 - B35.6, B35.8 - B35.9, B36, B36.0 - B36.3, B36.8 - B36.9, B85, B85.0 - B85.4, B87, B87.0 - B87.4, B87.8 - B87.9, B88, B88.0 - B88.3, B88.8 - B88.9, B94.0, D50, D50.0, D50.9, D62, D62.0, D62.9, D63, D63.0, D63.8, D64, D64.1 - D64.4, D64.8 - D64.9, D65, D65.0, D65.9, D68, D69.9, E15 - E16, E50, E50.0 - E50.9, E64.1, E85.3 - E85.9, E86, E86.0 - E86.9, E87, E87.0 - E87.6, E87.8 - E87.9, F06.2 - F06.4, F07.2, F09, F09.0, F09.9, F17, F17.0 - F17.9, F20, F20.0 - F20.6, F20.8 - F20.9, F21 - F22, F22.0, F22.8 - F22.9, F23, F23.0 - F23.3, F23.8 - F23.9, F25, F25.0 - F25.2, F25.8 - F25.9, F26 - F28, F28.0, F29, F29.0, F29.9, F30, F30.0 - F30.4, F30.8 - F30.9, F31, F31.0 - F31.9, F32, F32.0 - F32.5, F32.8 - F32.9, F33, F33.0 - F33.4, F33.8 - F33.9, F34, F34.0 - F34.1, F34.8 - F34.9, F35 - F38, F38.0 - F38.1, F38.8, F39, F40, F40.0 - F40.2, F40.8 - F40.9, F41, F41.0 - F41.3, F41.8 - F41.9, F42, F42.0 - F42.2, F42.8 - F42.9, F43, F43.0 - F43.2, F43.8 - F43.9, F44, F44.0 - F44.9, F45, F45.0 - F45.4, F45.8 - F45.9, F46 - F48, F48.0 - F48.2, F48.8 - F48.9, F49, F51, F51.0 - F51.5, F51.8 - F51.9, F52, F52.0 - F52.9, F53, F53.0 - F53.1, F53.8 - F53.9, F54 - F55, F55.0 - F55.4, F55.8 - F55.9, F56 - F59, F60, F60.0 - F60.9, F61 - F62, F62.0 - F62.1, F62.8 - F62.9, F63, F63.0 - F63.3, F63.8 - F63.9, F64, F64.0 - F64.2, F64.8 - F64.9, F65, F65.0 - F65.6, F65.8 - F65.9, F66, F66.0 - F66.2, F66.8 - F66.9, F67 - F68, F68.0 - F68.1, F68.8, F69, F69.0, F70, F70.0 - F70.1, F70.8 - F70.9, F71, F71.0 - F71.1, F71.8 - F71.9, F72, F72.0 - F72.1, F72.8 - F72.9, F73, F73.0 - F73.1, F73.8 - F73.9, F74 - F78, F78.0 - F78.1, F78.8 - F78.9, F79, F79.0 - F79.1, F79.8 - F79.9, F80, F80.0 - F80.4, F80.8 - F80.9, F81, F81.0 - F81.3, F81.8 - F81.9, F82, F82.0, F83 - F84, F84.0 - F84.5, F84.8 - F84.9, F85 - F89, F89.0, F90, F90.0 - F90.2, F90.8 - F90.9, F91, F91.0 - F91.3, F91.8 - F91.9, F92, F92.0, F92.8 - F92.9, F93, F93.0 - F93.3, F93.8 - F93.9, F94, F94.0 - F94.2, F94.8 - F94.9, F95, F95.0 - F95.2, F95.8 - F95.9, F96 - F98, F98.0 - F98.6, F98.8 - F98.9, F99, F99.0, G06, G06.0 - G06.2, G07, G07.0, G08, G08.0, G32, G32.0, G32.8, G43, G43.0 - G43.9, G44, G44.0 - G44.2, G44.4 - G44.5, G44.8, G47, G47.0 - G47.2, G47.4 - G47.6, G47.8 - G47.9, G50, G50.0 - G50.1, G50.8 - G50.9, G51, G51.0 - G51.4, G51.8 - G51.9, G52, G52.0 - G52.3, G52.7 - G52.9, G53, G53.0 - G53.3, G53.8, G54, G54.0 - G54.9, G55, G55.0 - G55.3, G55.8, G56, G56.0 - G56.4, G56.8 - G56.9, G57, G57.0 - G57.9, G58, G58.0, G58.7 - G58.9, G59, G59.0, G59.8, G60, G60.0 - G60.3, G60.8 - G60.9, G62, G62.0 - G62.2, G62.8 - G62.9, G63, G63.0 - G63.6, G63.8, G64, G64.0, G65, G65.0 - G65.2, G80, G80.0 - G80.4, G80.8 - G80.9, G81, G81.0 - G81.1, G81.9, G82, G82.0 - G82.5, G82.9, G83, G83.0 - G83.5, G83.8 - G83.9, G89, G89.0 - G89.4, G91, G91.0 - G91.2, G91.4, G91.8 - G91.9, G92, G92.5 - G92.6, G92.9, G93.1 - G93.2, G93.4 - G93.6, G99, G99.0 - G99.2, G99.8, H00, H00.0 - H00.1, H01, H01.0 - H01.1, H01.8 - H01.9, H02, H02.0 - H02.9, H03, H03.0 - H03.1, H03.8, H04, H04.0 - H04.6, H04.8 - H04.9, H05, H05.2 - H05.5, H05.8 - H05.9, H06, H06.0 - H06.3, H07 - H09, H10, H10.0 - H10.5, H10.8 - H10.9, H11, H11.0 - H11.4, H11.8 - H11.9, H12 - H13, H13.0 - H13.3, H13.8, H14 - H15, H15.0 - H15.1, H15.8 - H15.9, H16, H16.0 - H16.4, H16.8 - H16.9, H17, H17.0 - H17.1, H17.8 - H17.9, H18, H18.0 - H18.9, H19, H19.0 - H19.3, H19.8, H20, H20.0 - H20.2, H20.8 - H20.9, H21, H21.0 - H21.5, H21.8 - H21.9, H22, H22.0 - H22.1, H22.8, H23 - H25, H25.0 - H25.2, H25.8 - H25.9, H26, H26.0 - H26.4, H26.8 - H26.9, H27, H27.0 - H27.1, H27.8 - H27.9, H28, H28.0 - H28.2, H28.8, H29, H30, H30.0 - H30.2, H30.8 - H30.9, H31, H31.0 - H31.4, H31.8 - H31.9, H32, H32.0, H32.8, H33, H33.0 - H33.5, H33.8, H34, H34.0 - H34.2, H34.8 - H34.9, H35, H35.0 - H35.9, H36, H36.0, H36.8, H37 - H39, H40, H40.0 - H40.6, H40.8 - H40.9, H41 - H42, H42.0, H42.8, H43, H43.0 - H43.3, H43.8 - H43.9, H44, H44.0 - H44.9, H45, H45.0 - H45.1, H45.8, H46, H46.0 - H46.3, H46.8 - H46.9, H47, H47.0 - H47.7, H47.9, H48, H48.0 - H48.1, H48.8, H49, H49.0 - H49.4, H49.8 - H49.9, H50, H50.0 - H50.6, H50.8 - H50.9, H51, H51.0 - H51.2, H51.8 - H51.9, H52, H52.0 - H52.7, H53, H53.0 - H53.9, H54, H54.0 - H54.9, H55, H55.0, H55.8, H56 - H57, H57.0 - H57.1, H57.8 - H57.9, H58, H58.0, H58.8 - H58.9, H59, H59.0 - H59.4, H59.8, H60, H60.0 - H60.6, H60.8 - H60.9, H61, H61.0 - H61.3, H61.8 - H61.9, H62, H62.0 - H62.4, H62.8, H65, H65.0 - H65.4, H65.9, H66, H66.0 - H66.4, H66.9, H67, H67.0 - H67.3, H67.8 - H67.9, H68, H68.0 - H68.1, H69, H69.0, H69.8 - H69.9, H71, H71.0 - H71.3, H71.9, H72, H72.0 - H72.2, H72.8 - H72.9, H73, H73.0 -

	H73.2, H73.8 - H73.9, H74, H74.0 - H74.4, H74.8 - H74.9, H75, H75.0, H75.8, H76 - H79, H80, H80.0 - H80.2, H80.8 - H80.9, H81, H81.0 - H81.4, H81.8 - H81.9, H82, H82.1 - H82.3, H82.9, H83, H83.0 - H83.3, H83.8 - H83.9, H84 - H87, H87.6, H88 - H89, H90, H90.0 - H90.8, H91, H91.0 - H91.3, H91.8 - H91.9, H92, H92.0 - H92.2, H93, H93.0 - H93.3, H93.8 - H93.9, H94, H94.0, H94.8, H95, H95.0 - H95.4, H95.8 - H95.9, H96 - H99, I26, I26.0, I26.9, I31.2 - I31.4, I46, I46.0 - I46.2, I46.6, I46.8 - I46.9, I50, I50.0 - I50.4, I50.8 - I50.9, I51.7, I67.4, I76, I95, I95.0 - I95.1, I95.8 - I95.9, J69, J69.0 - J69.1, J69.8 - J69.9, J80, J80.0, J80.9, J85, J85.0 - J85.3, J86, J86.0, J86.9, J93, J93.0 - J93.1, J93.8 - J93.9, J94.2, J96, J96.0 - J96.2, J96.4 - J96.5, J96.8 - J96.9, J98.1 - J98.3, K00, K00.0 - K00.9, K01, K01.0 - K01.1, K02, K02.0 - K02.9, K03, K03.0 - K03.9, K04, K04.0 - K04.9, K05, K05.0 - K05.6, K06, K06.0 - K06.2, K06.8 - K06.9, K07, K07.0 - K07.6, K07.8 - K07.9, K08, K08.0 - K08.5, K08.8 - 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High (Level 2)	A14.9, A29, A30, A30.0 - A30.5, A30.8 - A30.9, A45, A45.9, A47 - A48, A48.8, A49, A49.3, A49.8 - A49.9, A61 - A62, A72 - A73, A76, A97, B08, B08.0 - B08.8, B09, B11 - B14, B28 - B29, B31, B31.9, B32, B32.3 - B32.4, B34, B34.0 - B34.4, B34.8 - B34.9, B61 - B62, B68, B68.0 - B68.1, B68.9, B73, B73.0 - B73.1, B74, B74.0 - B74.2, B76, B76.0 - B76.1, B76.8 - B76.9, B78, B78.0 - B78.1, B78.7, B78.9, B79, B80 - B81, B81.0 - B81.4, B81.8, B84, B92 - B94, B94.8 - B94.9, B95.6 - B95.8, B96, B96.0 - B96.8, B97, B97.0 - B97.3, B97.7 - B97.8, B98 - B99, B99.0, B99.8 - B99.9, D59, D59.4, D59.8 - D59.9, G44.3, G91.3, G93.0, G93.3, I10, I10.0, I10.9, I15, I15.0 - I15.2, I15.8 - I15.9, I27, I27.0, I27.2,

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	T84.0 - T84.9, T85, T85.0 - T85.9, T86, T86.0 - T86.5, T86.8 - T86.9, T87, T87.0 - T87.6, T87.8 - T87.9, T88, T88.0 - T88.9, T90, T90.0 - T90.5, T90.8 - T90.9, T91, T91.0 - T91.5, T91.8 - T91.9, T92, T92.0 - T92.6, T92.8 - T92.9, T93, T93.0 - T93.6, T93.8 - T93.9, T94, T94.0 - T94.1, T95, T95.0 - T95.4, T95.8 - T95.9, T96, T96.0, T97, T97.0, T98, T98.0 - T98.3, TO7, W47 - W48, W63, W71 - W72, W76, W76.0 - W76.9, W82, W95 - W98, X07, X56, X59, X59.0 - X59.9, Y20, Y20.0 - Y20.9, Y21, Y21.0 - Y21.9, Y22, Y22.0 - Y22.9, Y23, Y23.0 - Y23.9, Y24, Y24.0 - Y24.9, Y25, Y25.0 - Y25.2, Y25.4 - Y25.9, Y26, Y26.0 - Y26.9, Y27, Y27.0 - Y27.9, Y28, Y28.0 - Y28.9, Y29, Y29.0 - Y29.9, Y30, Y30.0 - Y30.9, Y31, Y31.0 - Y31.9, Y32, Y32.0 - Y32.9, Y33, Y33.0 - Y33.9, Y34, Y34.0 - Y34.9, Y86, Y86.0, Y86.2, Y86.8, Y87, Y87.2, Y89, Y89.9, Y90, Y90.0 - Y90.9, Y91, Y91.0 - Y91.3, Y91.9, Y92, Y92.0 - Y92.9, Y93, Y93.0 - Y93.9, Y94 - Y98, Y98.0, Y99, Y99.0 - Y99.2, Y99.8, Y99.9
Medium (Level 3)	A01, A49.2, A64, A64.0, A99, A99.0, B55, B55.9, B89, C14, C14.0 - C14.3, C14.8 - C14.9, C26, C26.0 - C26.2, C26.8 - C26.9, C27 - C29, C35 - C36, C39, C39.0, C39.8 - C39.9, C42, C46, C46.0 - C46.9, C55, C55.0 - C55.1, C55.9, C57.9, C59, C6, C63.9, C68, C68.9, C75.9, C76, C76.0 - C76.5, C76.7 - C76.9, C77, C77.0 - C77.5, C77.8 - C77.9, C78, C78.0 - C78.8, C79, C79.0 - C79.9, C8, C80, C80.0 - C80.2, C80.9, C87, C97, C97.0, C97.9, C98 - C99, D0, D00, D00.0, D01, D01.4 - D01.5, D01.7, D01.9, D02, D02.4, D02.9, D07, D07.3, D07.6, D08 - D09, D09.1, D09.7, D09.9, D10, D10.9, D13, D13.9, D14, D14.4, D17, D17.0 - D17.7, D17.9, D18, D18.0 - D18.1, D19, D19.0 - D19.1, D19.7, D19.9, D20, D20.0 - D20.1, D20.9, D21, D21.0 - D21.6, D21.9, D28, D28.9, D29, D29.9, D30, D30.9, D36.0, D36.9, D37, D37.0, D37.6 - D37.9, D38, D38.6, D39, D39.0, D39.7, D39.9, D4, D40, D40.9, D41, D41.9, D44, D44.9, D48, D48.7, D48.9, D49, D49.0 - D49.1, D49.5, D49.7 - D49.9, D54, D75.9, D79, D85, D87 - D88, D90 - D99, E07.8 - E07.9, E08, E08.0 - E08.6, E08.8 - E08.9, E17 - E19, E34.9, E35, E35.0 - E35.1, E35.8, E37 - E39, E47 - E49, E62, E69, E87.7, E90, E90.0 - E90.9, E91, E91.0 - E91.9, E92, E92.0 - E92.9, E93, E93.0 - E93.9, E94, E94.0 - E94.9, E95, E95.0 - E95.9, E96, E96.0 - E96.3, E96.5 - E96.9, E97, E97.0 - E97.1, E97.3 - E97.9, E98, E98.0 - E98.9, E99, E99.0 - E99.1, E99.3, E99.5 - E99.9, F04, F04.0, F05, F05.0 - F05.1, F05.8 - F05.9, F06, F06.0 - F06.1, F06.5 - F06.9, F07, F07.0, F07.8 - F07.9, F08, F50, F50.8 - F50.9, G09, G09.0, G09.9, G15 - G19, G27 - G29, G33 - G34, G38 - G39, G42, G48 - G49, G66 - G69, G74 - G79, G84 - G88, G93, G93.8 - G93.9, G94, G94.0 - G94.2, G94.8, G96, G96.0 - G96.1, G96.8 - G96.9, G98, G98.0, G98.8 - G98.9, I00.0, I03 - I04, I14, I16, I16.9, I17 - I19, I29, I29.9, I44, I44.0 - I44.9, I45, I45.0 - I45.6, I45.8 - I45.9, I49, I49.0 - I49.5, I49.8 - I49.9, I51, I51.6, I51.8 - I51.9, I52, I52.0 - I52.1, I52.8, I53 - I59, I90, I91.9, I92 - I93, I93.9, I94, I96, I96.0, I96.9, I98.4, I98.8, I99, I99.0, I99.8 - I99.9, ID5.9, J02.9, J03.9, J04.3, J06, J06.9, J40, J40.0, J40.9, J47, J47.0 - J47.1, J47.9, J48 - J49, J49.9, J50 - J59, J71, J71.2, J72 - J79, J81.9, J83, J85.9, J87 - J89, J90.9, J93.6, J97 - J98, J98.0, J98.4 - J98.6, J98.8 - J98.9, J99, J99.0 - J99.1, J99.8, K31.9, K32 - K34, K39, K47 - K49, K53 - K54, K63, K63.0 - K63.4, K63.8 - K63.9, K69, K75, K78 - K79, K84, K87, K87.0 - K87.1, K88 - K89, K92, K92.9, K93, K96 - K99, L06 - L07, L09, L15 - L19, L31 - L39, L69, L77 - L79, N09, N13, N13.0 - N13.9, N24, N28.8 - N28.9, N38, N39.9, N40, N40.0 - N40.3, N40.9, N54 - N59, N66 - N69, N78 - N79, N84, N84.2 - N84.3, N84.8 - N84.9, N85, N85.0 - N85.9, N86, N88, N88.0 - N88.4, N88.8 - N88.9, N89, N89.0 - N89.9, N90, N90.0 - N90.9, N92, N92.0 - N92.6, N93, N93.0, N93.8 - N93.9, N94, N94.0 - N94.6, N94.8 - N94.9, N95.0, O08, O08.0 - O08.9, O17 - O18, O18.0, O19, O27, O37 - O38, O38.4, O39, O49, O50 - O59, O78 - O79, O93 - O95, O95.9, P06, P16 - P18, P30 - P34, P34.2, P40 - P49, P62 - P69, P73, P79, P82, P85 - P89, P96.9, P97 - P99, P99.9, Q08 - Q09, Q10, Q10.0 - Q10.3, Q19, Q29, Q36.0 - Q36.1, Q36.9, Q46 - Q49, Q88, Q89.9, Q94, Q99.9, R00, R00.0 - R00.2, R00.8 - R00.9, R01, R01.0 - R01.2, R07, R07.1 - R07.4, R07.8 - R07.9, R31, R31.0 - R31.2, R31.9, R31.9
Low (Level 4)	B54, B54.0, B64, B82, B82.0, B82.9, B83.9, E12, E12.0 - E12.9, E13, E13.0 - E13.9, E14, E14.0 - E14.9, G00, G00.9, G01, G01.0, G02, G02.0 - G02.1, G02.8, G03.9, I37.9, I42, I42.0, I42.9, I51.5, I64, I64.0 - I64.1, I64.9, I67, I67.8 - I67.9, I68, I68.8, I69, I69.4, I69.8 - I69.9, J07 - J08, J15.9, J17, J17.0 - J17.3, J17.8, J18, J18.0 - J18.2, J18.7 - J18.9, J19, J19.6, J22, J22.0, J22.9, J23 - J29, J64, J64.0, J64.9, P23, P23.5 - P23.6, P23.8 - P23.9, P37.3 - P37.4, R73, R73.0, R73.9, V87, V87.0 - V87.1, V87.4 - V87.9, V88, V88.0 - V88.1, V88.4 - V88.9, V89, V89.0 - V89.4, V89.9, V99, V99.0, Y09, Y09.0 - Y09.9, Y85, Y85.0, Y85.9, Y85.9