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SIMONE MARIA DA SILVA LIMA

DATA ANALAYSIS OF NON-COMMUNICABLE CHRONIC DISEASES IN BRAZIL

Recife
2022

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Thesis presented to the Graduate Program in Management Engineering at the Federal University of Pernambuco, as a partial requirement for obtaining the title of Doctor of Philosophy (PhD) in Management Engineering.

Research area: Production Management.

Supervisor: Caroline Maria de Miranda Mota, PhD.

Co-supervisor: Xin Shi, PhD.

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EXAMINATION COMMITTEE

____

Prof. Dr. Caroline Maria de Miranda Mota (Supervisor)
Universidade Federal de Pernambuco

____

Prof. Dr Cristiano Alexandre Virgínio Cavalcante (Internal examiner)
Universidade Federal de Pernambuco

____

Prof. Dr Luciana Hazin Alencar (Internal examiner)
Universidade Federal de Pernambuco

____

Prof. Dr Fernando Luiz Cyrino Oliveira (External examiner)
Pontifícia Universidade Católica do Rio de Janeiro

____

Prof. Dr Clarice Sandi Madruga (External examiner)
Universidade Federal de São Paulo

To my mother, Josy, and my father, Severino (in memoriam).

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“Our greatest glory is not in never failing, but in rising every time we fall” (CONFUCIUS, 2022).

ABSTRACT

Non-communicable chronic diseases (NCDs) include illness that are not transmitted from person to person such as high blood pressure, diabetes and cancer. NCDs are collectively responsible for the majority of deaths in Brazil and worldwide. This thesis aims to evaluate non-communicable chronic diseases in the Brazilian population, considering demographic, geographic, and socio-economic characteristics. The thesis methodology comprises a multi-paper approach composed by statistical and decision-making applications in the health management context focused in NCDs. Data analysis strategies of cleaning, organizing, and modeling data were explored to extract useful patterns to support data-driven decisions. Information from cross-sectional population-based researches in Brazil was used, considering the health supplements of the National Household Surveys (PNAD) and the National Health Survey (PNS). These databases have the potential to be increasingly used, justifying scientific researches to evaluate large amount of Brazilian health information. Initially, a systematic literature review was executed summarizing previous researches on NCDs in Brazil. Thereafter, it was investigated trends in the prevalence of NCDs related to age and sex from a temporal perspective showing that NCDs are highly associated with aging. Additionally, in a multi-period analysis, it was observed that women have been more affected than men have. Furthermore, evaluating NCDs in a geographic perspective, from the proposed Chronic Disease Index (gCDI) it was detected that the South of Brazil concentrated more chronic diseases compared with the North. It was executed an overtime analysis of multimorbidity, that is the co-occurrence of two or more chronic diseases in the same person. It was noticed that the risk of multimorbidity was higher for women and illiterate, increasing with age. People with multiple chronic diseases consider their health worse compared with people without chronic illnesses, demonstrating a greater need for health assistance and hospitalization. At the end, an integrated health assessment was proposed from an outranking multicriteria decision model using multiple periods of time, considering objective and subjective perspectives of health, that can be used as an indicator for monitoring the population overtime. Effectively, quantitative data analysis in different periods can facilitated trends observations to support health management. For instance, it was detected a tendency of increased risk of chronic diseases in groups like women and a higher need for health appointments and hospitalizations in individuals with multiple chronic diseases. PNAD and PNS researches demonstrated to be valuable data sources about chronic diseases in Brazil. A better understating of health patterns might support policy-makers to improve preventative actions that significantly affect groups of people with chronic conditions and multimorbidity.

Keywords: non-communicable chronic diseases; multimorbidity; multicriteria evaluation; PROMETHEE method; factor analysis; logistic regression; multi-period data analysis.

RESUMO

As doenças crônicas não transmissíveis (DCNTs) incluem doenças que não são transmitidas de uma pessoa para outra, como pressão alta, diabetes e câncer. As DCNTs são coletivamente responsáveis pela maioria das mortes no Brasil e no mundo. Esta tese tem como objetivo avaliar as doenças crônicas não transmissíveis na população brasileira, considerando características demográficas, geográficas e socioeconômicas. A metodologia da tese compreende uma abordagem multi-paper formada por aplicações estatísticas e de apoio à decisão no contexto do gerenciamento da saúde com foco nas DCNTs. Estratégias de análise de dados de limpeza, organização e modelagem de dados foram exploradas para extrair padrões úteis para apoiar decisões orientadas por dados. Foram utilizadas informações de pesquisas transversais de base populacional no Brasil, considerando os suplementos de saúde da Pesquisa Nacional de Domicílios (PNAD) e a Pesquisa Nacional de Saúde (PNS). Essas bases de dados têm potencial para serem cada vez mais utilizadas, justificando pesquisas científicas para avaliar grande quantidade de informações em saúde no Brasil. Inicialmente, foi realizada uma revisão sistemática da literatura resumindo pesquisas anteriores sobre DCNTs no Brasil. A partir daí, investigou-se tendências na prevalência de DCNTs relacionadas à idade e sexo em uma perspectiva temporal mostrando que as DCNTs estão altamente associadas ao envelhecimento. Adicionalmente, em análise multi-período, observa-se que as mulheres são mais afetadas do que os homens. Além disso, avaliando as DCNTs em uma perspectiva geográfica, a partir da proposta do Índice de Doenças Crônicas (gCDI), detectou-se que o Sul do Brasil concentrou mais doenças crônicas em relação ao Norte. Foi realizada uma análise temporal de multimorbidade, que é a co-ocorrência de duas ou mais doenças crônicas na mesma pessoa. O risco de multimorbidade foi maior para mulheres e analfabetos, aumentando com a idade. Pessoas com múltiplas doenças crônicas consideram sua saúde pior em comparação com pessoas sem doenças crônicas, demonstrando maior necessidade de assistência à saúde e hospitalização. Ao final, foi proposta uma avaliação integrada da saúde a partir de um modelo de decisão muticritério de sobreclasificação utilizando múltiplos períodos de tempo, considerando perspectivas objetivas e subjetivas de saúde, que pode ser usado como indicador para monitoramento da população ao longo do tempo. Efetivamente, a análise de dados quantitativos em diferentes períodos de tempo pode facilitar a observação de tendências para apoiar a gestão da saúde. Por exemplo, foi detectado uma tendência de aumento do risco de doenças crônicas em grupos como as mulheres e observou-se uma maior necessidade de consultas de saúde e internações em indivíduos com múltiplas doenças crônicas. As pesquisas da PNAD e da PNS demonstraram ser valiosas fontes de dados sobre doenças crônicas no Brasil. Uma melhor compreensão dos padrões de saúde pode ajudar os formuladores de políticas a melhorar as ações preventivas que afetam significativamente grupos de pessoas com condições crônicas e multimorbidade.

Palavras-chave: doenças crônicas não transmissíveis; multimorbidade; avaliação multicritério; método PROMETHEE; análise fatorial; regressão logística; análise de dados multi-período.

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LIST OF ABBREVIATIONS

BLRM	Binary Logistic Regression Model
CD	Chronic Diseases
IBGE	Brazilian Institute of Geography and Statistics
gCDI	Geographic Chronic Disease Index
NCD	Noncommunicable disease
PNAD	National Household Surveys
PNS	National Health Survey
WHO	World Health Organization

CONTENTS

1 INTRODUCTION

Health is one of the main pillars of public policies in Brazil and broadly defined as a state of complete physical, mental and social well-being and not only related to the absence of diseases (WHO, 2020a). Health is a right guaranteed in the Brazilian federal constitution, based on Article 196: health is the right of all and the duty of the State, guaranteed by social and economic policies aimed at reducing the risks of illness and other hazards and at the universal and equal access to the actions and services for its promotion, protection and recovery (BRASIL, 1988).

For health management the focus is to deliver and to cause changes in organizations interested in improving the population health (HUNTER; BROWN, 2007). Health management activities include population identification, assessment of objectives in relation to quality and costs, risk stratification, as well as impact assessment and proposals for improving the quality and well-being of individuals (WHO, 2005).

Current health challenges comprise the treatment of chronic diseases that affect the lives of many individuals in the world. In particular, chronic non-communicable diseases (NCDs) which are illnesses that cannot be spread from person to person, such as heart disease, stroke, cancer, chronic respiratory diseases and diabetes. These diseases denote a very serious situation both for public health and for societies and economies affected (STEENKAMER et al., 2017).

Statistical and decision models can help health management processes by analyzing the context of the problem and the variables comprised. A decision analysis procedure includes a movement of the real word to a set of mathematical models. It can be an encounter of solutions in these models and a movement of abstract solutions back to physical operations in the real world (FRENCH et al., 2009). Therefore, these models can be constructed specifically to support decision making in public health management, based on multiple approaches, associating themes such as chronic diseases, multimorbidity (co-occurrence of two or more diseases), statistical analysis and decision theory.

1.1 JUSTIFICATION

The availability of resources in public management usually has large financial constraints, especially in underdeveloped countries where the basic needs are significant compared to the governmental financial possibilities. There is a technical need to manage resources efficiently in order to attend different groups. Large databases with diverse information about the population can be found in Brazil, such as the data provided by IBGE (IBGE, 2021). These databases have the potential to be increasingly used justifying scientific researches that can evaluate a large amount of information and can contribute to the innovation and development of public policies.

The Brazilian databases, even if collected for some other purpose, can be valuably used in academic researches. In this case, with the use of existing database in a different purpose, there is a substantial cost elimination as data will not need to be collected a second time (JAGADISH, 2015). On the other hand, large databases, need differentiated analysis techniques, for instance using the bases of statistical analysis and information technology. It is an inverted type of work, when the researcher first analyzes the database to decide after which studies can be performed and which will be the practical goal (HUANG et al., 2015). Finding the right databases, downloading and organizing the data requires a great deal of research time. For this thesis, particularly, an additional challenge was the use of multi-periods. It took extra work to find the possible variables to be studied that were present in the different health databases analyzed.

Large databases are worth nothing in a vacuum. Their potential value are only being reached when data is transformed into knowledge and used to drive decisions. To operate this evidence-based decision making, public and private organizations need efficient processes to turn large volumes of data into meaningful insights (GANDOMI; HAIDER, 2015). Thus, this study presents the construction of statistical and decision models to support decision-making in the context of health management, especially to support public policies for chronic non-communicable diseases (NCDs) prevention using existing open-source databases with national representative cross-sectional health information. It is estimated that cardiovascular disease, chronic respiratory disease, cancer, and diabetes are responsible for approximately 74% of deaths in Brazil (WHO, 2018).

Individuals with multiple chronic diseases have higher health care utilization, hospital admissions, and the costs are also substantial compared with the population without chronic diseases (BÄHLER et al., 2015; HAJAT; STEIN, 2018).

1.2 OBJECTIVE

In this section are presented the general and specific objectives of this thesis.

1.2.1 Main objective

The main objective of this study is to investigate trends and evaluate non-communicable chronic diseases in the Brazilian population, exploring statistical and decision models considering interconnected factors such as demographic information, territorial conditions, and socio-economic characteristics.

1.2.2 Specific objectives

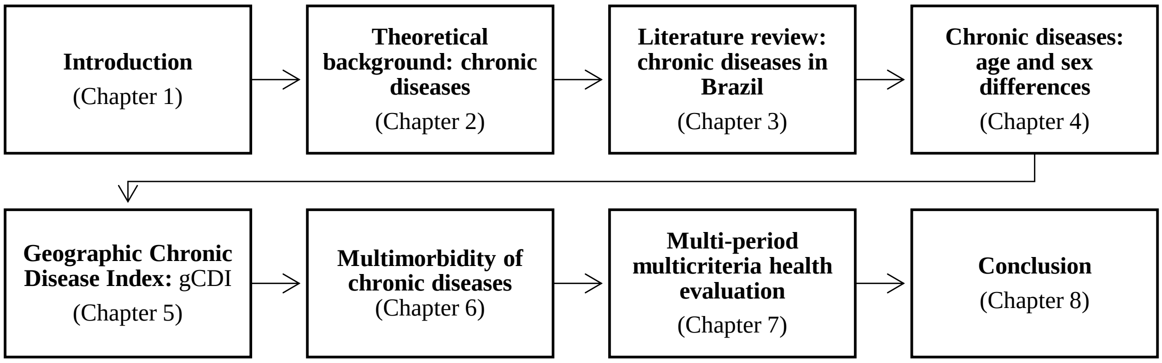
Five specific research objectives (RO) are stated below:

- RO1: To summarize previous researches on non-communicable chronic diseases in Brazil and to identify possible gaps in the existing knowledge for planning complementary researches;
- RO2: To investigate trends in the prevalence of non-communicable chronic diseases related to age and sex from a temporal perspective;
- RO3: To evaluate geographic distribution of non-communicable chronic diseases in the Brazilian territory and to propose an index methodology for a comprehensive assessment of the federative units of Brazil;
- RO4: To investigate dynamic distributions of socioeconomic, demographic, and health-related characteristics on multimorbidity in Brazil over an extended period of 15 years;
- RO5: To develop an outranking decision model to support health decision-making considering a temporal perspective.

1.3 THESIS STRUCTURE

In the next section, Chapter 2 presents basic health theoretical concepts related to chronic diseases. Chapter 3 presents a literature review about chronic diseases in Brazil. Chapter 4 provides an analysis about age and sex differences between men and women in relation to nine non-communicable chronic diseases: arterial hypertension (high blood pressure), arthritis/rheumatism, back/spine (column), bronchitis/asthma, cancer, chronic renal failure (kidney failure), depression, diabetes, and, heart disease. Chapter 5 proposes a geographic chronic disease index in order to evaluate the distribution of non-communicable chronic diseases in the Brazilian territory. Chapter 6 shows a temporal analysis of multimorbidity, that is the co-occurrence of two or more chronic diseases focused in the Brazilian inhabitants. Chapter 7 proposes a multi-period multicriteria outranking decision method with a real numerical example in the health context. At the end, Chapter 8 encompasses the discussion and conclusions of this thesis. Figure 1 presents the summary of the thesis structure.

Figure 1 - Thesis structure



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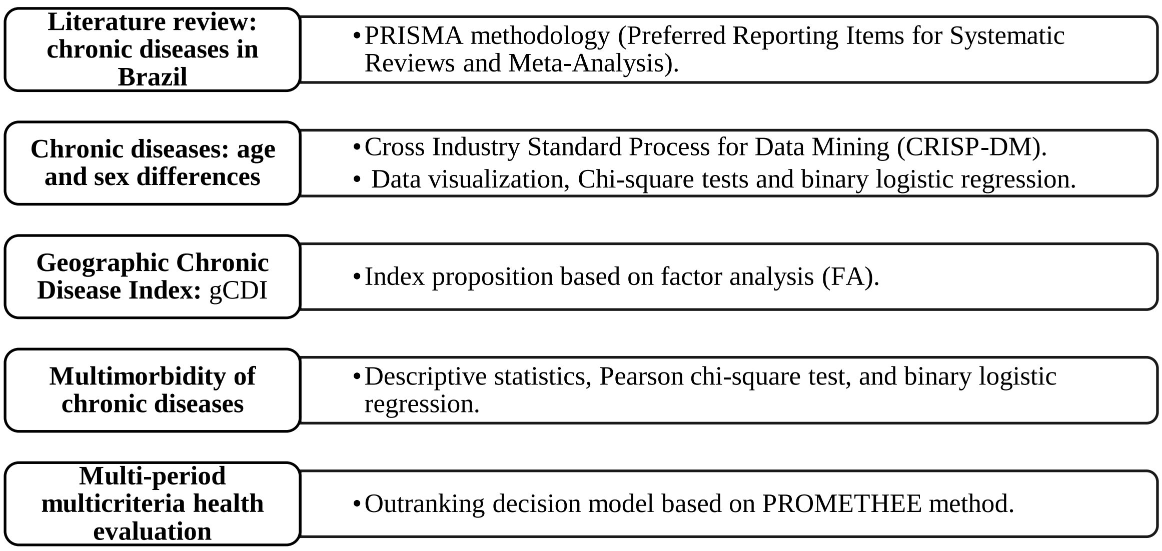
1.4 THESIS METHODOLOGY

The thesis is developed in a multi-paper approach, presenting research studies in the health management context focused in the assessment of non-communicable chronic diseases in Brazil. Figure 2 shows the main methodologies used in this thesis. Summarizing previous researches on non-communicable chronic diseases in Brazil, a systematic literature review was carried out taking into account the PRISMA methodology (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) (GALVÃO; PANSANI; HARRAD, 2015; LIBERATI et al., 2009). The databases used were Medline/PubMed, SciELO, Scopus and Web of Science. At the end, a qualitative synthesis and text analysis was performed for the relevant articles founded.

The prevalence of non-communicable chronic diseases related to age and sex were investigated from a temporal perspective, using as reference the Cross Industry Standard Process for Data Mining (CRISP-DM) (CHAPMAN et al., 2000), following six phases: (1) business understanding; (2) data understanding; (3) data preparation; (4) modelling; (5) evaluation; and (6) deployment. It was used the samples from The Brazilian National

Household Sample Survey (PNAD) and samples from the Brazilian National Health Survey (PNS). PNAD and PNS are cross-sectional population-based studies in Brazil that covers all states and regions of Brazil. PNAD provided health data only in 1998, 2003 and 2008. PNS was first performed in 2013 and the second data collection started in 2019. Data began to be made available in different stages between 2020 and 2021. PNAD 1998 had 344,975 participants, PNAD 2003 and 2008 had 384,834 and 391,868 participants respectively. PNS 2013 had 205,546 participants and PNS 2019 had 293,726 participants. PNS 2013 and PNS 2019 only had chronic disease information about individuals over 18 and 15 years old, respectively. PNAD includes data from participants of all ages. Data visualization, chi-square tests and binary logistic regression were applied to analyze chronic diseases' age and sex differences between men and women in the Brazilian population.

Figure 2 - Summary of the study's methodology



Source: The author (2022).

The geographic distribution of non-communicable chronic diseases in the Brazilian territory was evaluated and an index was proposed for a comprehensive assessment of the federative units of Brazil. This study used data from the Brazilian National Health Survey (PNS 2013). This research included a total sample of 60,202 individuals over 18 years old. Factor analysis (FA) was used to estimate an index to rank the geographic areas and to construct a summary view of non-communicable chronic diseases in Brazil.

Dynamic distributions of socioeconomic, demographic, and health-related characteristics on multimorbidity in Brazil were investigated in multiple periods. It was analyzed four cross-sectional population-based databases: PNAD 1998, 2003, and 2008 and the PNS 2013. The prevalence of multimorbidity was analyzed and modeled including arterial hypertension (high blood pressure), arthritis/rheumatism, back/spine (column), bronchitis/asthma, cancer, chronic renal failure (kidney failure), depression, diabetes, and, heart disease. Descriptive statistics, Pearson chi-square test, and binary logistic regression were carried out to assess the relationship between multimorbidity and the relevant risk factors.

It was developed an outranking decision model considering a temporal perspective based on the PROMETHEE method due to its non-compensatory characteristic and with an advantage of having relative easiness of use by decision makers for the context of public policies. In this study a numerical example is presented using five alternatives, four criteria and four periods. It used data from the PNAD 2003 and 2008, and from PNS 2013 and 2019. The methodology was built in five steps: (1) explaining the decision information scenario; (2) establishing the attribute weight determination and the decision-model of aggregation; (3) performing the decision-making ranking at each period; (4) presenting a comprehensive decision-making evaluation; and (5) review and finalization.

1.5 SOCIO-ECONOMIC AND ENVIRONMENTAL IMPACTS

Demographic, socio-economic and educational databases as those provided by the IBGE institute in Brazil can support a variety of health management processes. These data can be processed, analyzed and used in researches even if already collected for some purpose other than its initial plan, having an economic benefit from the elimination of costs and time in data collection.

Chronic diseases and multimorbidity indicate a great risk to human health, which can reduce people's quality of life and, consequently, cause serious situations such as disability and premature death. As it will be presented in this thesis, expressive information about chronic diseases in Brazil from a temporal view can indicate, for example, that people with multimorbidity seek more health services and have more cases of hospitalization. Furthermore, the subjective health assessment of individuals with multimorbidity was consistently worse than people without multiple chronic diseases. It was also observed that multimorbidity increases considerably with age and that the risk of multimorbidity is significantly higher among women and among people with no education. By analyzing the variety of different data periods, this study may have a positive impact towards a better understanding of socio-demographic patterns in chronic diseases and multimorbidity in Brazil to support plans related to health intervention and illness prevention.

Connected with the purposes of this study, it was explored statistical and decision models related to chronic diseases, including an environmental perspective on health by observing where people live. This assessment can contribute with the elaboration of public policies considering geographic variables to support the Brazilian population health.

2 THEORETICAL BACKGROUND: CRONIC DISEASES

Chronic conditions can be connected to a broad range of chronic and complex health conditions across the spectrum of illness, including mental illness, trauma, disability and genetic disorders. Chronic diseases are generally long-term and persistent, with a gradual deterioration of health and independence with complex and multiple causes (DEPARTMENT OF HEALTH, 2018). However, it can be found a tremendous variation in the possible illnesses included in the term “chronic disease” and also a variation in the time that a disease must be present to be considered as chronic (BERNELL; HOWARD, 2016).

For the World Health Organization (WHO, 2013), chronic diseases have a long duration and generally slow progression and they define four main groups including cardiovascular diseases, cancers, chronic respiratory diseases and diabetes (Table 1). Related to this definition can be seen the term ‘non-communicable chronic diseases (NCDs)’ in contraposition to ‘communicable chronic diseases’ that can be found referring to diseases that can spread from person to person through parasites, sexual contact or exchange of bodily fluids. For example, malaria or HIV/AIDS (AMELI, 2015). This thesis will be focused in studies related to NCDs.

Table 1 - Examples of non-communicable chronic diseases

Alzheimer’s disease	Cirrhosis	Insomnia
Arthritis	Congenital heart disease	Kidney disease
Asthma	Depression	Liver disease
Attention deficit hyperactivity disorder (ADHD)	Diabetes	Obstructive pulmonary disease (COPD)
Bipolar disorder	Epilepsy	Parkinson’s diseases
Cancer	Fibromyalgia	Peripheral arterial disease
Cerebral palsy	Fibromyalgia	Rheumatic heart disease
Cerebrovascular disease	Heart Disease	Tendonitis
Chronic Lung Disease	Hemophilia	Thrombosis and pulmonary embolism
Chronic pancreatitis	Hypertension (High Blood Pressure)	Tuberculosis

Source: Based on (BRASIL, 2011a; CIRINO, 2018; WHO, 2013).

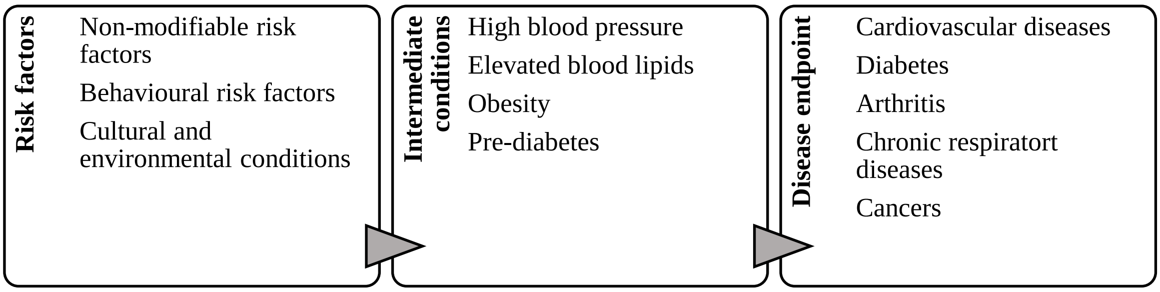
More specifically, cardiovascular diseases (CVDs) embrace coronary heart disease; cerebrovascular disease; peripheral arterial disease; rheumatic heart disease; congenital heart disease; deep vein thrombosis and pulmonary embolism. Chronic respiratory diseases include asthma; chronic obstructive pulmonary disease (COPD); respiratory allergies; occupational lung diseases and pulmonary hypertension (WHO, 2020b).

2.1 RISK FACTORS FOR NON-COMMUNICABLE CHRONIC DISEASES

In the health context, a risk factor can be defined as "*an aspect of personal behavior or lifestyle, an environmental exposure, or a hereditary characteristic that is associated with an increase in the occurrence of a particular disease, injury, or other health condition*" (CDC, 2012).

Modifiable risk factors or behavioral risk factors comprise risks that can be reduced or controlled by some intervention, such as physical inactivity, tobacco use, alcohol use, and unhealthy diets (WHO, 2013). On the other hand, non-modifiable risk factors can be related to age, gender, race, and family history. So, risks to chronic diseases are wide and may have their origins even before birth including genetics factors and even a fetal nutrition (HARDING, 2001). Additionally, some risks can be classified as intermediate or metabolic risk factors as elevated blood lipids, high blood pressure and glucose, and overweight/obesity (Figure 3).

Figure 3 - Common chronic diseases risk factors and conditions



Source: Based on (PUBLIC HEALTH AGENCY OF CANADA, 2018).

Cessation of tobacco use, reduction of salt in the diet, avoidance of harmful use of alcohol associated with consumption of fruits and vegetables, and regular physical activity has been shown to be effective in reducing the risk of cardiovascular disease (WHO, 2013). In addition, drug treatment of diabetes, hypertension and high blood lipids may be necessary to reduce cardiovascular risk and prevent heart attacks and strokes. Health policies that create conducive environments for making healthy choices affordable and available are essential for motivating people to adopt and sustain healthy behavior. Table 2 shows examples of risk factors for different chronic diseases.

Table 2 - Risk factors examples by chronic disease

Diabetes (type 2)	
• Overweight/obesity • Pre-diabetes • Advanced age • Physical inactivity • High blood pressure and/or high cholesterol • Family history of diabetes	• Belonging to certain high-risk ethnic populations • Having a history of gestational diabetes • Having other conditions which may include vascular disease, polycystic ovary syndrome, acanthosis nigricans and schizophrenia
Cardiovascular disease	
• Smoking • Lack of Exercise • Unhealthy Eating • High Cholesterol • Harmful use of alcohol	• High Blood Pressure (Hypertension) • Over-consumption of salt • Stress • Diabetes
Respiratory disease: asthma	
• Family history of allergy and allergic disorders (including hay fever, asthma and eczema) • High exposure of susceptible children to airborne allergens in the first years of life	• Exposure to tobacco smoke, including in utero exposure • Frequent respiratory infections early in life • Low birth weight and respiratory distress syndrome (RDS)
Respiratory disease: chronic obstructive pulmonary disease (COPD)	
• Smoking • Occupational exposure to dusts (e.g., coal dust, grain dust) and some fumes • Outdoor air pollution is associated with increased symptoms among those with COPD, including shortness of breath.	• Repeated childhood respiratory tract infections • Childhood exposure to second-hand smoke • Genetic deficiency of alpha-1-antitrypsin
Arthritis	
• Risk increases with age • Sex (most types of arthritis are more common in women) • Hormones (systemic lupus erythematosus - SLE) • Genetic-predisposition (RA, SLE, and AS) • Physical inactivity • Diet • Overweight/obesity	• Joint Injuries • Smoking • Occupation (certain occupations involving repetitive knee bending and squatting are associated with OA of the knee and hip) • Infection (it is a possible initiator for inflammatory types of arthritis, particularly RA)

Source: Based on (PUBLIC HEALTH AGENCY OF CANADA, 2018; WHO, 2020b).

Additionally, between different groups can be found differences about risks of chronic diseases. In the United States one study (BUTTORFF; RUDER; BAUMAN, 2017) establish for example that:

- Multiple chronic conditions (two or more chronic diseases simultaneously) are highest among older adults;
- Women are more likely than men to have multiple chronic conditions, as many women live longer than men do;

- The prevalence of multiple chronic conditions is higher in non-Hispanic whites than in other racial/ethnic groups (which may reflect differences in access to care, rather than in the actual prevalence of chronic disease);
- Those with more conditions have greater reported functional, social, and cognitive limitations

It is estimated that only smoking causes 2–21 % of all deaths in the world and produce 12% of the global disease burden in the European Region (SCHMIDT, 2016). The obesity is an epidemic problem that results in an increased prevalence of diabetes and hypertension. Cardiovascular and chronic respiratory disease mortality rates are challenging but these rates are declining probably as a consequence of tobacco control and improved access to primary care (SCHMIDT et al., 2011).

> A critical premise of epidemiology is that disease and other health events do not occur randomly in a population, but are more likely to occur in some members of the population than others because of risk factors that may not be distributed randomly in the population (CDC, 2012).

In Brazil, the National Health Survey (PNS) in 2013 found a prevalence of 12.5% of tobacco smoking, 14.9% in relation to an excessive alcohol consumption, 26.6% that do physical activity in leisure time and 41.8% that eats a recommended quantity of fruits and vegetables. Another research from telephone inquiries (VIGITEL) also carried out in 2013 found a prevalence of 11.3% of tobacco smoking, 16,4% that abuse of alcoholic beverages, 35.8% of people that do physical activities in leisure time and 23.6%; recommended intake of fruits and vegetables. All cases considered the adult population, with 18-year or older (MALTA et al., 2015a).

In the previously VIGITEL research (BRASIL, 2011b), 15.1% of the adults were smokers and the excess weight reaches 48.1% of the population, being practically doubled in the age groups of 18 to 24 years and 45 to 54 years for both sexes; 14.2% of the adult population did not perform physical activity, being the greatest physical inactivity in the age group of 65 or more years of age; and, the alcohol abuse was declared by 18.0% of adults, being considerably higher in men than in women, with 26.8% and 10.6%, respectively.

Additionally, on the risk factors related to food, the research showed that the regular consumption of fruits and vegetables was 29.9%, and in both sexes, the regular consumption of fruits and vegetables increased with age and with the level of schooling. 34.2% of the population is in the habit of consuming meats with excess fat, being more frequent in men than in women, with 45.5% and 24.5% respectively. 77% of the population reported having the habit of consuming soft drinks and artificial juices on at least one day of the week (BRASIL, 2011b).

2.2 SIDE EFFECTS, MORTALITY AND PREVENTION TO NON-COMMUNICABLE CHRONIC DISEASES

In a long term, diabetes can affect the eyes, nerves, heart, skin, digestion and increase, for example, the risk of strokes, cataracts, glaucoma and high blood pressure. The symptoms include increased thirst, frequent need to urinate, fatigue, blurred vision and tingling or pain in the hands, feet and/or legs (PIETRANGELO; CHERNEY, 2017).

In relation to cardiovascular diseases or heart diseases, one problem is that the patients might not be properly diagnosed until they have a stroke or heart attack, angina and heart failure. Other associated complications are aneurysm, aortic disease or peripheral artery disease. Cardiovascular symptoms can include for example a chest pain, chest pressure, shortness of breath, numbness, weakness or coldness in your legs or arms and neck pain (MAYOCLINIC, 2018; NHS, 2018a).

Respiratory disease has symptoms as breathlessness, chest pain, wheeze and stridor, dyspnea, cough and associated sputum production (LEACH, 2008). Asthma for example can cause the feeling of tiredness all the time, underperformance at or absence from work or school, stress, anxiety or depression, lung infections as pneumonia, delays in growth or puberty in children and asthma attacks (NHS, 2018b).

> Without significant investments now, 15 million people will continue to die each year from NCDs in the prime of their lives, between the ages of 30 and 70. And almost 800 000 people will die from suicide, the second leading cause of death among young adults (WHO, 2018) (p.7).

In 2016, non-communicable chronic diseases were collectively responsible for around 70% of all deaths worldwide (41 million of the world’s 57 million deaths). The majority of premature deaths, considered for people between 30 and 70 years, occurred in low- and middle-income countries (WHO, 2018). Tables 3 and 4 show comparative mortality related to NCDs.

In Brazil, it is estimated that non-communicable chronic diseases are responsible for most of the deaths in the country: cardiovascular diseases (28%), cancer (18%), chronic respiratory disease (6%) and diabetes (5%) (WHO, 2018).

Table 3 - Comparative proportional mortality

	Cardio-vascular disease	**Cancers**	**Chronic respiratory diseases**	**Diabetes**	**Other NCDs**	**Communicable, maternal, perinatal and nutritional conditions**	**Injuries**
Australia	28%	29%	7%	3%	23%	5%	6%
Brazil	28%	18%	6%	5%	17%	14%	12%
Canada	25%	31%	7%	3%	23%	6%	6%
China	43%	23%	9%	2%	13%	4%	7%
Germany	37%	26%	6%	3%	19%	5%	4%
India	27%	9%	11%	3%	13%	26%	11%
Japan	27%	30%	9%	1%	15%	13%	5%
Russian Federation	55%	19%	2%	1%	11%	5%	8%
South Africa	19%	10%	4%	7%	11%	40%	9%
United Kingdom	25%	28%	8%	1%	26%	8%	3%
United States of America	30%	22%	9%	3%	24%	5%	7%

Source: Based on (WHO, 2018).

Table 4 - Comparative NCD deaths

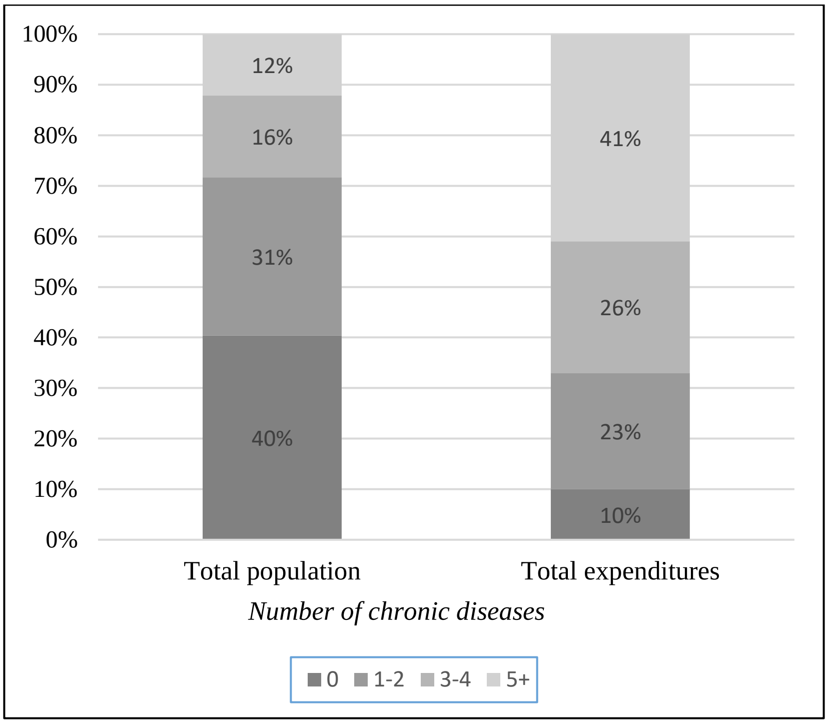
	Male	**Female**	**Male %**	**Female %**	**Total**
Australia	72 200	70 500	50,6	49,4	142 700
Brazil	516 800	458 500	53.0	47.0	975 300
Canada	112 700	113 500	49.8	50.2	226 200
China	4 975 000	4 284 000	53.7	46.3	9 259 000
Germany	406 900	432 700	48.5	51.5	839 600
India	3 313 000	2 682 000	55.3	44.7	5 995 000
Japan	549 000	531 300	50.8	49.2	1 080 300
Russian Federation	779 600	855 300	47.7	52.3	1 634 900
South Africa	137 100	132 400	50.9	49.1	269 500
United Kingdom	259 500	273 500	48.7	51.3	533 000
United States of America	1 242 000	1 232 000	50.2	49.8	2 474 000

Source: Based on (WHO, 2018).

In general actions to prevent chronic diseases focus in avoid the beginning of the illness, reduce the consequences and the mortality related to these diseases. Prevention can create conditions to support healthily behaviors and deliver "*healthier students to schools, healthier workers to employers and businesses, and a healthier population to the health-care system*" (BAUER et al., 2014) (p. 46).

Prevention can help to reduce the health costs related people with chronic diseases tend to use more the health service with a higher spending compared with the healthy population. For example, as showed in Figure 4, Americans with five or more chronic conditions represents 12% of the population but the total health care spending is about for 41% (BUTTORFF; RUDER; BAUMAN, 2017).

Figure 4 - Prevalence and spending by number of chronic conditions



Source: Based on (BUTTORFF; RUDER; BAUMAN, 2017).

In a literature review that included a summary about medical costs of non-communicable chronic diseases among adult Medicaid beneficiaries, in the US, it was estimated that the annual cost per patient (2015 U.S. dollars) were $3,219–$4,674 for diabetes, $3,968–$6,491 for chronic obstructive pulmonary disease, $989–$3,069 for asthma, $687 for hypertension-related (but total costs per hypertensive beneficiary ranged much higher), $29,271–$51,937 for heart failure, and $29,384–$46,194 for cancer in the 6 months following diagnosis (CHAPEL et al., 2017).

Even an obvious starting point is to focus on individual behavior or lifestyle, prevention needs to include the relative responsibilities in different spheres highly interdependent, including additionally formal and informal health workers, governments, and corporate entities (SCHMIDT, 2016).

> The point is that "lifestyle" implies degrees of freedom and the possibility of genuine opportunity and choice (…). It can be cynical to treat this "lifestyle" as voluntary and freely chosen if, for example, many of your role models smoke and if smoking in your social setting and challenging environment functions as a coping mechanism to relieve stress (SCHMIDT, 2016) (p.139-140).

Some actions to prevent chronic disease and encourage healthy behaviors with the collaboration between public and private sectors can include different strategies as community development; creating environments for living, working and relaxing; economic interventions; legislation and regulation; raising public awareness and engagement; strategic coordination, building partnerships and targeted interventions (GOV. OF WESTERN AUSTRALIA, 2016).

The world health organization (WHO) to prevent deaths from NCDs has a focus in reducing the tobacco use, physical inactivity, unhealthy diet and the harmful use of alcohol, which they consider the major risk factors for non-communicable diseases. In July 1998 established the Tobacco Free Initiative (TFI) giving international attention, resources and action on the global tobacco epidemic. Other action involves cost-effective policy options contained within the WHO Global Strategy on Diet, Physical Activity & Health and the Global NCD action Plan 2013 – 2020 as showed in Table 5 (WHO, 2018).

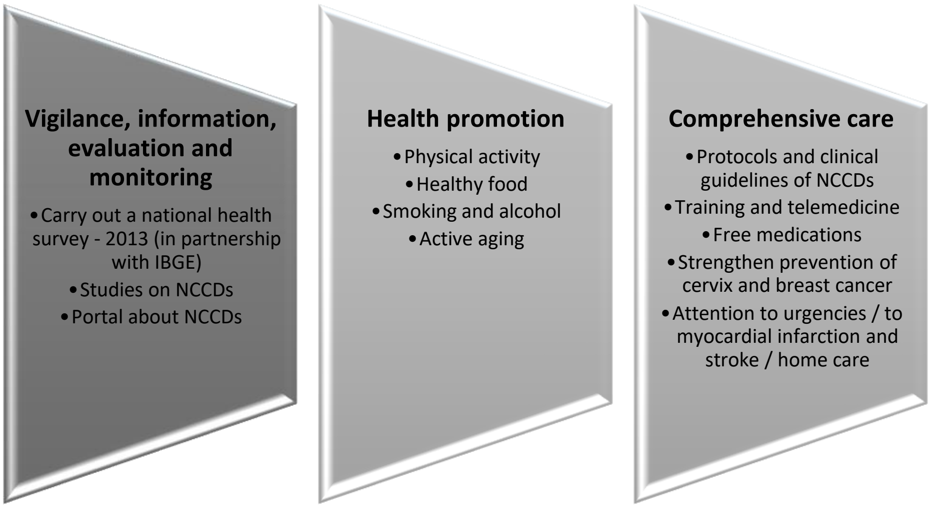
Table 5 - Objectives in the WHO global NCD action Plan 2013 – 2020

1	To raise the priority accorded to the prevention and control of non-communicable diseases in global, regional and national agendas and internationally agreed development goals, through strengthened international cooperation and advocacy
2	To strengthen national capacity, leadership, governance, multisector action and partnerships to accelerate country response for the prevention and control of non-communicable diseases
3	To reduce modifiable risk factors for non-communicable diseases and underlying social determinants through creation of health-promoting environments
4	To strengthen and orient health systems to address the prevention and control of non-communicable diseases and the underlying social determinants through people-centered primary health care and universal health coverage
5	To promote and support national capacity for high-quality research and development for the prevention and control of non-communicable diseases
6	To monitor the trends and determinants of non-communicable diseases and evaluate progress in their prevention and control

Source: Based on (BRASIL, 2011a).

Brazil developed a strategic action plan to prevent and control non-communicable chronic diseases organized by the Brazilian ministry of health in partnership with several ministries, educational and research institutions, health NGOs, medical entities, associations of people with chronic diseases, among others (BRASIL, 2011a).

Figure 5- Strategic action plan to prevent and control NCDs in Brazil



Source: Based on (BRASIL, 2011b).

The strategy had a focus in circulatory, cancer, chronic respiratory and diabetes and their common modifiable risk factors (smoking, alcohol, physical inactivity, unhealthy eating and obesity). This plan defines guidelines and actions related to vigilance, information, evaluation and monitoring of chronic diseases, health promotion and a comprehensive care of individuals as detailed in Figure 5 (BRASIL, 2011b).

3 LITERATURE REVIEW: CRONIC DISEASES IN BRAZIL

This chapter aims to address the research objective 1, summarizing previous researches on non-communicable chronic diseases in Brazil and identifying possible gaps in the existing knowledge for planning complementary research. It was executed a literature review focused in studies with data from population-based health surveys across the country. To identify relevant studies, the PRISMA recommendation was used as a methodology. A comprehensive search was performed in the Pubmed/Medline, SciELO, Scopus, Web of Science databases.

3.1 CONTEXTUALISATION

Population-based health researches can be developed to an initial purpose such as observing the use of tobacco, and might have potential to be used with another focus since it often contains relevant and representative socio-demographic information. As large databases are openly available, they become quite useful for exploratory researches, reducing time and costs in data collection. Working with large databases is a challenge because it often requires specific skills such as knowledge of database tools or statistical methodologies (DASH et al., 2019; GUPTA; RANI, 2019). There is a need for efficient processes to turn large volumes of data into meaningful insights (GANDOMI; HAIDER, 2015).

In countries like Brazil, with continental dimensions, the use of secondary population-based records with statistical samples including all states and regions can strongly assist the development of knowledge. Health surveys have been conducted in Brazil since the 70s (BARROS, 2008). Currently, health information can be provided for instance by the Ministry of Health (BRAZIL, 2021) or the Brazilian Institute of Geography and Statistics - IBGE (IBGE, 2021), including the supplements of the National Household Sample Survey (PNAD) and the National Health Survey (PNS) that are major national representative domiciliary health surveys in Brazil.

Population-based research can help to monitor individuals' health status as well as the health system performance (BARROS, 2008). Household surveys are an important source of data for a range of population health statistics, particularly in developing countries that often have scarce registration systems. For instance, one of the health challenges is the treatment of NCDs that affect the lives of many people in the world. It is a very serious situation, both for public health and for societies and economies affected by them (STEENKAMER et al., 2017).

3.2 METHODS

It was conducted a systematic review of the literature on chronic diseases in Brazil based on household health surveys. This study was carried out taking into account the PRISMA recommendation (Preferred Reporting Items for Systematic Reviews and Meta-Analysis). The PRISMA recommendation consists of a checklist with 27 items and a four-step flowchart focusing on ways in which authors can include items considered essential for transparent reporting of a systematic review (GALVÃO; PANSANI; HARRAD, 2015; LIBERATI et al., 2009). It was used Medline/PubMed, SciELO, Scopus and Web of Science databases.

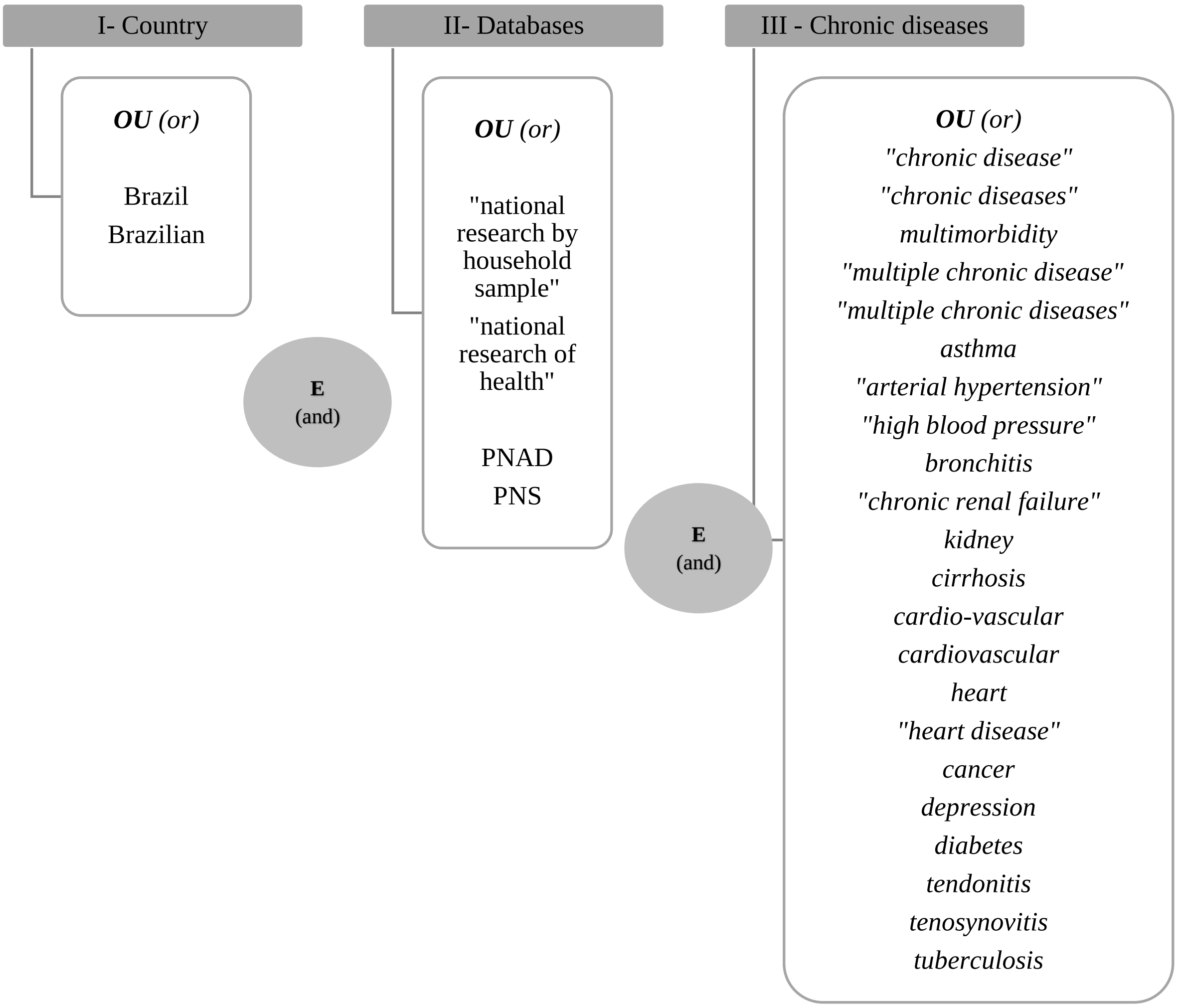
In Brazil, health surveys have been carried out since the 1970s (Barros, 2008). According to the research implemented, information on chronic diseases, collected from household surveys with a representative population base, including all regions and states of the country, has its data widely available from the health supplement of the Household Sample Survey-PNAD 1998, followed by the PNADs of 2003 and 2008 (PNAD, 2019), and by the National Health Survey-PNS in 2013 and 2019 (PNS, 2019). The VIGITEL survey (BRASIL, 2019) was also found with national population-based information on chronic diseases, but the survey was carried out through telephone interviews and not home visits, so it was not included in the focus of this literature review.

It was selected articles published between January 1998 and May 2020. The first health supplement in PNAD was distributed in 1998. It was included articles published in journals and excluded publications as abstracts, book chapters, conference articles, and editorials. It was considered articles in English and Portuguese languages. Figure 6 shows the keywords used.

Initially it was verified the duplication of the records taken from the databases observing the original title. Subsequently, title and abstract analysis were evaluated, excluding articles that did not address the review objective. Some articles were in the databases with both Portuguese and English titles, so a list of articles with their respective titles in English and Portuguese was made, when available, and duplicate cases were excluded.

After this screening process, the articles were subjected to full text reading. Articles that did not use the PNAD or PNS database were excluded, and articles that did not address the topic of chronic diseases were also excluded. At the end, a qualitative synthesis and text analysis was performed for the relevant articles after the previous screening stages. The organization and analysis of the articles were aided by Mendeley 1.19.4, JabRef 4.3.1, VOS Viewer 1.6.9, Microsoft Excel 2016 software.

Figure 6 - Search descriptors of the systematic literature review

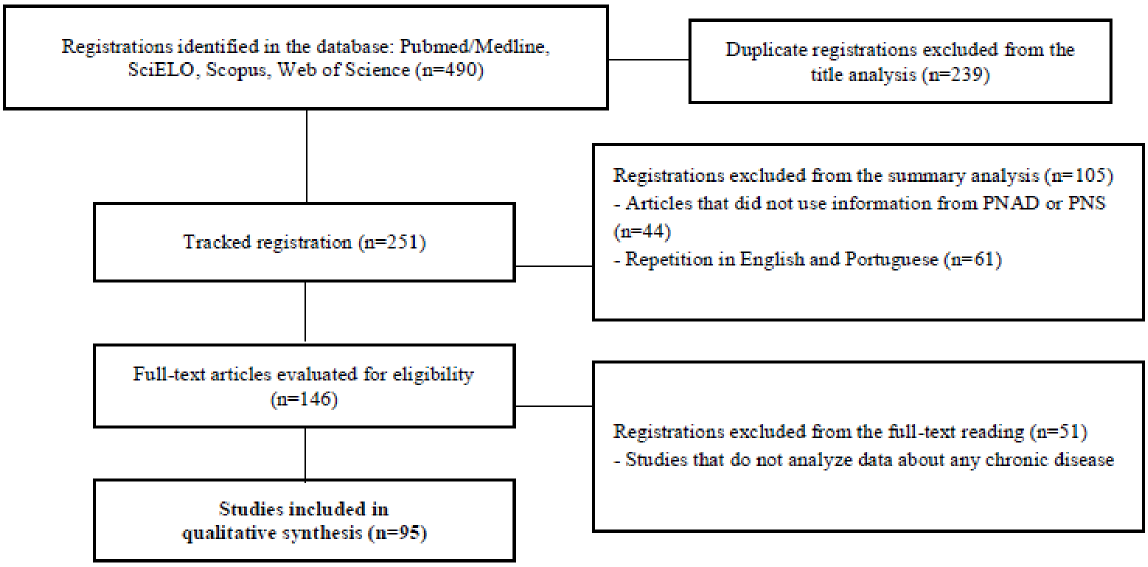


Source: The author (2022).

The search strategy identified a total of 490 records: Pubmed / Medline (64), SciELO (268), Scopus (107), Web of Science (51). It was found that 239 records were duplicated. A total of 251 records had their title and abstract revised. 44 articles were excluded because they did not meet the criterion of complete articles that used information from PNAD or PNS databases. Additionally, 61 articles were duplications with publications in Portuguese and English, resulting in 146 studies for full-text analysis.

After a critical analysis, 51 articles were excluded as they did not provide any data analysis about at least one chronic disease. For example, articles with themes such as eating habits, alcohol consumption, smoking, mammography or research methodologies. 95 articles were considered adequate for qualitative analysis and had their results systematized. The complete article selection process can be seen in Figure 7.

Figure 7 - Flowchart of the phases of identification, selection, eligibility and inclusion of articles on chronic diseases based on household health surveys in Brazil



Source: The author (2022).

Among the 95 articles selected, 38 are published in English and Portuguese, 32 only in Portuguese and 25 only in English. There are different age groups, but most include individuals from 18 years old (47.4%) and there are articles with elderly only (14.7% only with participants with ages ranging from 60 and above, and 4.2% with elderly people with ages ranging from 65 and older). Regarding the methods, part of the publications showed the prevalence of diseases in associations with age, gender, region among other socio-demographic variables, as well as the detailing of behavioral variables related to health, such as medical visits or functional disability. The main statistical models used are Logistic Regression and Poisson Regression.

9.5% of the articles used the PNAD 1998 database, 8.4% of the PNAD 2003 and 9.5% of the PNAD 2008 (26 articles in total). 57.9% of the sample used data from PNS (55 articles in total). 12.6% of the articles used a combination of two or three PNADs (12 articles) and only 2.1% articles used a combination of PNAD and PNS chronic disease data (2 articles).

3.3 RESULTS AND DISCUSSION

The synthesis of the selected articles focused in chronic diseases in Brazil is divided in Tables 6, 7 and 8. The databases used, author information and year of publication are specified. Tables 6 and 7 summarize articles about specific chronic diseases and Table 8 shows publications focused in the prevalence of multiple chronic diseases and/or with the association with socioeconomic and behavioral factors (education, race, work, use of medicines, health services, etc.).

Arterial hypertension was the most investigated disease according to this literature review. It can be found a prevalence in different age groups and socio-conditions (ANDRADE, S. S. C. A. et al., 2015; BORGO et al., 2019; MALTA et al., 2016, 2018; MOREIRA et al., 2020; MOREIRA; MORAES; LUIZ, 2013; OLIVEIRA, B. L. C. A. et al., 2020) as well as in researches specifically with the elderly (BENTO, Isabel Cristina; MAMBRINI; PEIXOTO, 2020; NEVES et al., 2017) or addressing the issue of medications and medical consultations (FERREIRA, R. A.; BARRETO; GIATTI, 2014; MALTA; STOPA; ANDRADE; et al., 2015; MENGUE et al., 2015; MOREIRA; MORAES; LUIZ, 2011).

Only two studies bring comparisons using together 1998, 2003, and 2008 PNADs (LOBO, L. A. C. et al., 2017; MUNIZ et al., 2012). There are also studies with a combined view of hypertension and diabetes associated with health insurance (MENGUE et al., 2015), routine medical appointments (LOBO, L. A. C. et al., 2017), mobility (MALTA; DE OLIVEIRA; ANDRADE; CAIAFFA; et al., 2017), healthy eating (ROMERO et al., 2018), procurement of drugs by the popular pharmacy program of Brazil (ASSUNCAO; ABREU, 2017) and association of abdominal adiposity and body mass index (BEZERRA et al., 2018).

Table 6 - Chronic disease studies based on data from household health surveys in Brazil (PNAD/PNS) – Part 1

Chronic disease	N. of articles	Household survey	Author/year	Study information
Arterial hypertension	3	PNAD 2008	(FERREIRA, R A; BARRETO; GIATTI, 2014; MOREIRA; MORAES; LUIZ, 2011, 2013)	Study of hypertension in different age and socio-demographic groups, in addition to the analysis of the question of drugs and medical appointments of hypertensive individuals.
	9	PNS 2013	(ANDRADE, S. S. C. A. et al., 2015; BORGO et al., 2019; MALTA et al., 2016, 2018; MALTA; STOPA; ANDRADE; et al., 2015; MENGUE et al., 2015; MOREIRA et al., 2020; NEVES et al., 2017; OLIVEIRA, B. L. C. A. et al., 2020)	
	2	PNAD 1998 PNAD 2003 PNAD 2008	(LOBO, Larissa Aline Carneiro et al., 2017; MUNIZ et al., 2012)	
Arterial hypertension and diabetes	4	PNS 2013	(COSTA et al., 2016; FERREIRA, D. N.; MATOS; LOYOLA FILHO, 2015; NASCIMENTO-SOUZA; LIMA-COSTA; PEIXOTO, 2019; SZWARCWALD; SOUZA JUNIOR; et al., 2015)	Joint analysis of hypertension and diabetes involving topics such as health plans, routine medical consultations, mobility, healthy eating and obtaining medicines through the popular pharmacy program in Brazil.
	1	PNAD 1998 PNAD 2003 PNAD 2008	(NASCIMENTO et al., 2015)	
	1	PNAD 1998 PNAD 2003 PNAD 2008 PNS 2013	(CUNHA et al., 2019)	
Asthma	1	PNAD 2003	(WEHRMEISTER; PERES, 2010)	Information on the disease prevalence including socio-demographic factors such as age, sex, race, education, in addition to regional differences.
	1	PNS 2013	(MENEZES et al., 2015)	
	1	PNAD 1998 PNAD 2003 PNAD 2008	(WEHRMEISTER et al., 2012)	
	1	PNAD 2003 PNAD 2008 PNS 2013	(SANTOS, F. M. et al., 2018)	
Cancer	3	PNS 2013	(OLIVEIRA, M. M. et al., 2015; SILVA, Gulnar Azevedo e et al., 2016; WERNECK; COELHO-E-SILVA; et al., 2018)	Association between cancer prevalence and behavioral factors such as smoking and food consumption. Prostate and stomach cancers were the most commonly reported among men and breast and cervical cancer among women.
Chronic renal failure	1	PNAD 1998	(GODOY; NETO; RIBEIRO, 2007)	Relationship with other chronic diseases such as cardiovascular diseases and hypertension, and other health problems such as anemia, bone diseases, malnutrition, hepatitis type B and C. Association with socio-demographic factors such as income and education.
	1	PNS 2013	(MOURA et al., 2015)	
	1	PNAD 2008	(LEIVAS et al., 2018)	
	8	PNS 2013	(BARROS et al., 2017; CARPENA et al., 2019; LOPES et al., 2016; OLIVEIRA, G. D. et al., 2018; SILVA, Aline Natália; AZEREDO, 2019; SOUSA et al., 2019; STOPA et al., 2015; WERNECK; OYEYEMI; et al., 2018)	

Source: The author (2022).

Asthma is one of the most common chronic childhood diseases. Previous information on asthma prevalence is associated with socio-demographic factors such as age, gender, race, education, and regional differences (MENEZES et al., 2015; SANTOS, F. M. et al., 2018; WEHRMEISTER et al., 2012; WEHRMEISTER; PERES, 2010). It's worth pointing out, that there were changes in the question about this subject. In PNAD the question was “Has a physician or healthcare professional ever told you that you have bronchitis or asthma?” and in PNS was “Has any physician ever given you asthma diagnosis (or asthmatic bronchitis)?”.

Cancer is the second major cause of deaths in Brazil (after cardiovascular diseases) estimated 18% of all deaths (WHO, 2018). It was not found in previous studies with prevalence information overtime related to cancer (OLIVEIRA, M. M. et al., 2015; SILVA, Gulnar Azevedo e et al., 2016; WERNECK; COELHO-E-SILVA; et al., 2018) and cardiovascular diseases (GONÇALVES et al., 2019; VELASQUEZ-MELENDEZ et al., 2015) using PNAD/PNS data.

There are chronic renal failure studies from PNAD and PNS including the association with socio-demographic characteristics and other health problems such as cardiovascular diseases, arterial hypertension, anemia, susceptibility to infection, hepatitis type B and C, bone diseases, and malnutrition (MOURA et al., 2015).

Depression is a serious public health problem being a disorder that has accompanied humanity with serious consequences including suicide. The number of studies about depression is growing. It can be found associations with socio-demographic factors and risk behaviors (BARROS et al., 2017; CARPENA et al., 2019; LEIVAS et al., 2018; LOPES et al., 2016; OLIVEIRA, G. D. et al., 2018; SANTOS, Marcelo Justus; KASSOUF, 2007; SILVA, Aline Natália; AZEREDO, 2019; SOUSA et al., 2019; STOPA et al., 2015; WERNECK; OYEYEMI; et al., 2018). It was also found a recent study relating to diabetes and depression (BRIGANTI et al., 2019).

Diabetes was more explored in publications using only PNS data (BRACCO et al., 2020; DIDERICHSEN; ANDERSEN; MATHISEN, 2020; FERNANDES et al., 2020; ISER et al., 2015; MALTA; BERNAL; ISER; et al., 2017; MALTA et al., 2019; MALTA; ISER; CHUEIRI; STOPA; et al., 2015) than PNAD (VIEGAS-PEREIRA; RODRIGUES; MACHADO, 2008), showing prevalence rates, and associated factors as age, education smoking, or obesity.

Table 7 - Chronic disease studies based on data from household health surveys in Brazil (PNAD/PNS) – Part 2

Chronic disease	**N. of articles**	**Household survey**	**Author/year**	**Study information**
Depression	1	PNAD 2003	(SANTOS, Marcelo Justus; KASSOUF, 2007)	Association with behaviors such as physical activity, alcohol consumption, unhealthy eating, disease treatment, smoking, the time individuals watch TV and intimate partner violence. Issues such as socio-economic status, sex and age are also analyzed.
	1	PNAD 2008	(LEIVAS et al., 2018)	
	8	PNS 2013	(BARROS et al., 2017; CARPENA et al., 2019; LOPES et al., 2016; OLIVEIRA, G. D. et al., 2018; SILVA, Aline Natália; AZEREDO, 2019; SOUSA et al., 2019; STOPA et al., 2015; WERNECK; OYEYEMI; et al., 2018)	
Depression and diabetes	1	PNS 2013	(BRIGANTI et al., 2019)	Association with sex, obese, indigenous, divorced, widowed, and people with low educational level in the joint prevalence of depression and diabetes.
Diabetes mellitus	1	PNAD 2003	(VIEGAS-PEREIRA; RODRIGUES; MACHADO, 2008)	Relationship with age, education, mortality, smoking, overweight, hypertension and self-rated health.
	6	PNS 2013	(BRACCO et al., 2020; DIDERICHSEN; ANDERSEN; MATHISEN, 2020; ISER et al., 2015; MALTA; BERNAL; ISER; et al., 2017; MALTA et al., 2019; MALTA; ISER; CHUEIRI; STOPA; et al., 2015)	
Heart disease	2	PNS 2013	(GONÇALVES et al., 2019; VELASQUEZ-MELENDEZ et al., 2015)	Evaluation of self-reported behavioral factors such as smoking, BMI, physical activity and diet, in addition to biological factors, such as the diagnosis of dyslipidemia, diabetes and arterial hypertension.
Musculo-skeletal diseases	1	PNAD 2003	(RODARTE, R R P et al., 2012)	It encompasses studies related to spine problems / arthritis / rheumatism and tendonitis / tenosynovitis. Association with characteristics such as age, sex, low education, smoking, high salt consumption, heavy activities at work or at home, overweight and obesity.
	5	PNS 2013	(ASSUNCAO; ABREU, 2017; BEZERRA et al., 2018; MALTA; DE OLIVEIRA; ANDRADE; CAIAFFA; et al., 2017; OLIVEIRA, Camila Vasconcelos de Arruda et al., 2020; ROMERO et al., 2018)	
	1	PNAD 2003 PNAD 2008	(CAMARGOS, 2014)	
Tuberculosis	1	PNS 2013	(PINHEIRO et al., 2013)	Association with factors such as age, sex, family income per capita, health insurance and medical appointments.

Source: The author (2022).

Heart diseases encompass one of the major health risks in Brazil and causes of death in Brazil (WHO, 2018). It was not found in previous studies with multiple periods of time related to heart diseases/cardiovascular diseases (GONÇALVES et al., 2019; VELASQUEZ-MELENDEZ et al., 2015) using PNAD/PNS data.

Musculoskeletal problems also affect the lives of a large number of Brazilians (ASSUNCAO; ABREU, 2017; BEZERRA et al., 2018; CAMARGOS, 2014; MALTA; DE OLIVEIRA; ANDRADE; CAIAFFA; et al., 2017; OLIVEIRA, Camila Vasconcelos de Arruda et al., 2020; RODARTE, Rodrigo Ribeiro Pinho et al., 2012; ROMERO et al., 2018). Only one study on tuberculosis was found (PINHEIRO et al., 2013) whose main objective was to verify the association between demographic and socioeconomic variables as sex and age.

Table 8 - Studies including multiple chronic diseases divided by subject, based on data from household health surveys (PNAD/PNS)

Subject	**N. of articles**	**Author/year**	**Study information**
Color/Race	1	PNAD2008	(OLIVEIRA, B. L. C. A.; THOMAZ; SILVA, 2014)
Covid-19 risk	1	PNS 2013	(REZENDE et al., 2020)
Education	1	PNAD2008	(BESARRIA et al., 2016)
Functional disability	2	PNAD2003	(ALVES; LEITE; MACHADO, 2008, 2010)
	1	PNAD2008	(ANDRADE, K. R. C. et al., 2015)
	1	PNS2013	(COSTA FILHO et al., 2018)
Health condition: elderly	2	PNAD1998	(LIMA-COSTA et al., 2003; LIMA-COSTA; BARRETO, 2003)
	2	PNAD1998 PNAD2003	(LIMA-COSTA; LOYOLA FILHO; MATOS, 2007; VERAS, 2009)
	1	PNAD1998 PNAD2003 PNAD2008	(LIMA-COSTA et al., 2011)
Health self-assessment	2	PNS2013	(SZWARCWALD; DAMACENA; et al., 2015; THEME FILHA et al., 2015)
Health services	1	PNAD1998	(ALMEIDA, M. F. et al., 2002)
	1	PNS2013	(MALTA; BERNAL; LIMA; et al., 2017)
	1	PNAD2003 PNAD2008	(VERAS; PARAHYBA, 2007)
Medicines	2	PNS2013	(BENTO, I. C.; ANNE; SOUZA, 2019; TAVARES et al., 2015)
Metabolic syndrome	1	PNS2013	(RAMIRES et al., 2018)
Migraine	1	PNS2013	(PERES et al., 2019)
Prevalence of multiple chronic diseases	2	PNAD1998	(BELTRAO; SUGAHARA, 2002; LEITE et al., 2002)
	1	PNAD2003	(BARROS et al., 2006)
	5	PNS2013	(BERNAL et al., 2019; BOCCOLINI et al., 2017; LABRECQUE; KAUFMAN, 2019; MALTA et al., 2019; MALTA; STOPA; SZWARCWALD; et al., 2015; RZEWUSKA et al., 2017)
	1	PNAD2003 PNAD2008	(BARROS et al., 2011)
Relations with work and income	3	PNAD1998	(GIATTI; BARRETO, 2003; LIMA-COSTA; BARRETO; GIATTI, 2002; NERI; SOARES; SOARES, 2005)
	1	PNAD2003	(VIDAL; SILVANY NETO, 2009)
	1	PNAD2008	(MIQUILIN et al., 2015)
	1	PNAD1998 PNAD2003	(GIATTI; BARRETO; CESAR, 2008)
	1	PNAD1998 PNAD2003 PNAD2008	(GIATTI; BARRETO, 2011)
Smoking	1	PNAD2008	(TEJADA et al., 2013)

Source: The author (2022).

One part of the articles found in this literature review does not focus on the evaluation of a particular non-communicable chronic disease, but shows the health condition of Brazilians from the analysis of various illnesses. Table 8 provides a summary according to the main themes associated with NCDs such as Covid-19 risks, education, migraine, multiple chronic diseases and smoking.

3.3.1 Limitations

Undoubtedly, systematic literature review results are related to the choices made by researchers. It was attempted to mitigate the biases by using the PRISMA protocol. As detailed in the method section, the findings are based in researches from a certain period of time and based in articles from specific databases (Medline/PubMed, SciELO, Scopus and Web of Science), excluding conference articles, master's theses, etc. Additionally, the interpretation of selected articles and the organization of table it is a significant challenge.

The article selection was focused in articles that used health data from PNAD and PNS, given that chronic disease has extensive number of studies in different areas of knowledge. The systematic review limitations will always be present related to the criteria used, however, from this study an extensive general view of chronic diseases could be achieved, focused in studies related to chronic diseases in Brazil.

3.4 FINAL CONSIDERATIONS

According to the review executed, this is the first systematic study of publications on non-communicable chronic diseases that used household surveys conducted in Brazil, more specifically with data from the health supplement of the Household Sample Survey-PNAD and the National Health Survey-PNS.

According to Tables 7 and 8, in this review, 95 articles were included in the qualitative full-text analysis, comprising a variety of chronic diseases such as asthma, cancer, chronic kidney disease, heart disease, depression, diabetes, musculoskeletal diseases, hypertension, back problems and tuberculosis. The results obtained indicate that there is an emphasis in studies related to depression, diabetes and hypertension, due to the greater number of publications.

The analysis of the publications also showed that a part of the studies, did not address any chronic disease in particular, but showed the prevalence of several chronic diseases in the same study, sometimes focused on the association of multiple chronic diseases and socioeconomic and behavioral factors. Regarding the data used, most articles include information collected from the PNS (57.9%), followed by studies with surveys from the PNAD (27.4%) or designed from the combination of more than one database (14.7%).

Literature reviews are important and recognized as the cornerstone of evidence-based health care (PIEPER; MATHES; EIKERMANN, 2014). From the knowledge of the past, new studies and interventions on chronic diseases can be identified and/or improved. This systematic review helped to show a broad overview of studies that have already been carried out using data on chronic diseases collected through population-based household surveys in Brazil. This review also contributed to design new health studies related to chronic diseases in the Brazilian population that will be presented in the in the following chapters.

4 DEMOGRAPHIC DIFFERENCES OF CHRONIC DISEASES IN BRAZIL

This chapter aims to address the research objective 2, investigating trends in the prevalence of non-communicable chronic diseases. According to the literature review presented in the Chapter 3, there is a lack of chronic diseases studies in Brazil from a temporal perspective. For this study, it was specifically chosen to address differences related to age and sex, which is a topic with information available from other countries, however, with scarcity of temporal data of national representation of the Brazilian population.

4.1 CONTEXTUALISATION

The treatment of chronic diseases is one of the health challenges that affect the lives of several individuals in the world. It is a very serious situation, both for public health and for affected societies and economies (STEENKAMER et al., 2017). In Brazil, it is estimated that cardiovascular disease, chronic respiratory disease, cancer, and diabetes are responsible for approximately 74% of deaths (WHO, 2018). Consequently, the surveillance of chronic diseases and their risk factors becomes essential for the country's health (MALTA; SILVA; MOURA; MORAIS NETO, 2017).

In nations like Brazil, with continental dimensions, the use of national cross-sectional databases can strongly assist the development of scientific knowledge. Health surveys have been conducted in Brazil since the 70s (BARROS, 2008). Currently, valuable health information is underexplored by data analysis methodologies, as databases provided by the Ministry of Health (BRAZIL, 2021) or by IBGE - the Brazilian Institute of Geography and Statistics (IBGE, 2021), including the supplements of the National Household Sample Survey (PNAD) and the National Health Survey (PNS). Population-based research can help to monitor individuals' health status as well as the health system performance (BARROS, 2008).

In this study, it was evaluated tendencies related to nine non-communicable chronic diseases in Brazil: arterial hypertension (high blood pressure); arthritis/rheumatism; back/spine (column); bronchitis/asthma; cancer; chronic renal failure (kidney failure); depression; diabetes and heart disease. It was observed the prevalence of these diseases and trends in different periods and age groups including children, adolescents, adults, and the elderly. It was also analyzed temporal patterns related to the differences in the prevalence between men and women.

The sample was composed of data from the PNAD 1998, PNAD 2003, PNAD 2008, PNS 2013 and PNS 2019. These databases are the largest national health surveys in Brazil, including all regions and states. Household surveys are an important source of data for a range of population health statistics, particularly in developing countries that often have scarce registration systems. Temporal analysis in this article can help to visualize patterns related to sex and age in the prevalence of chronic diseases in Brazil that may be used to support planning and assessment of public health policies to prevent such illnesses.

4.2 METHODS

Studies using data mining methodologies have increased over the past decade (PLOTNIKOVA; DUMAS; MILANI, 2020) and still have a potential to be further explored due to the availability of population-based databases particularly in the health context (WANG; KUNG; BYRD, 2018). Our methodology took into consideration the Cross Industry Standard Process for Data Mining, the CRISP-DM (CHAPMAN et al., 2000). The life cycle of CRISP-DM consists of six phases that can move back and forth between different stages according project needs: business understanding, data understanding, data preparation, modelling, evaluation, and deployment.

Supporting the business understanding phase, it was carried out a systematic literature review to check related published articles as presented in Chapter 3. In the data understanding phase was collected open health data from the PNAD Household Sample Survey, more exactly, the supplements from 1998, 2003 and 2008, and the National Health Survey (PNS) carried out in 2013 and 2019 (IBGE, 2021). It was analyzed three PNAD databases in the years that the health supplement was available: 1998, 2003, and 2008 with 344,975, 384,834, and 391,868 participants respectively. PNS 2013 had 205,546 participants and 293,726 participants in PNS 2019. PNS had a sub-sample of 60,202 participants that answered questions about chronic diseases in 2013 and 94,114 in 2019.

In the data preparation phase, firstly, it was searched the common variables in PNAD 1998 composed by 443 variables, PNAD 2003 with 422 variables, PNAD 2008 with 783 variables, PNS 2013 with 942 variables, and PNS 2019 with 1,087 variables. PNAD and PNS microdata are available is the IBGE website (IBGE, 2022) with *.txt* files and dictionaries with details on variables. Initially each year's file was organized separately in the SPSS program. The common variables have been renamed to contain the same description and codes. For example, ‘yes’ and ‘no’ in a database could be ‘1’ and ‘3’ and in another year ‘2’ and ‘4’. It was necessary to standardize all common variables.

Secondly, these databases were integrated in a unique file also in SPSS. Variables with non-response rate over 25% missing values were excluded. It was created new variables from existing information in the database, as age group and region. Lastly, it was decided that variables related to chronic diseases would be evaluated, due to the importance of the topic and availability of relevant information. It was considered only illnesses that had information available in all databases. Consequently, nine chronic diseases were selected: arterial hypertension (high blood pressure); arthritis or rheumatism; back/spine (column); bronchitis or asthma; cancer; chronic renal failure (kidney failure); depression; diabetes and heart disease. In sequence, it was performed an exploratory data analysis and it was also calculated the diseases prevalence in different periods, age groups, and by sex.

Research methodologies used in other studies on chronic diseases were researched and the limitation of the types of variables in this study was also taken into account, since a large part of the data is composed of nominal and ordinal variables. Thus, the modelling and the multi-period evaluation were performed applying a chi-square test, considering a confidence level of 95% and a Binary Logistic Regression Model (BLRM). Logistic regression is a specific form of regression that can be used to predict and explain a categorical/nonmetric variable rather than a metric dependent measure. The independent variables can be metric or nonmetric. In the BLRM the dependent variable is dichotomous or binary (HAIR JR et al., 2014).

Applications using logistic regression in a diversity of disciplines can be found in the literature, including innumerous applications in health and related to chronic diseases (BRUCE; RIEDIGER; LIX, 2014; JIMÉNEZ-GARCÍA et al., 2011). The logistic regression model allows estimating the probability of occurrence of an event depending on the values of the independent variables. In the BLRM model the probability (of having or not having a disease) can be represented by the logistic function (Equations 1 and 2). The coefficients B_0, B_1, ... , B_p are estimated from the data set, by maximum likelihood method. It can be used for discrimination of two groups. If P(Y=1)>0,5, then, Y=1, or if P(Y=1)<0,5, then, Y=0 (BATISTA, 2015).

$$P\ (Y = 1) = \frac{1}{1 + e^{-g(x)}} \qquad (1)$$

$$g(x) = \alpha + B_1X_1 + \ldots + B_pX_p \quad (2)$$

In this study, binary logistic regression was used to compare differences by sex considering if each participant had one of the nine chronic diseases evaluated or not (yes/no questions for chronic diseases). It was analyzed the odds ratio (OR) that represents the ratio between the chance that an event occurs in one group and the chance that it occurs in another group. These methodologies demonstrated to be adequate mainly because they are capable of handling non-metric variables, one of the challenges of this study.

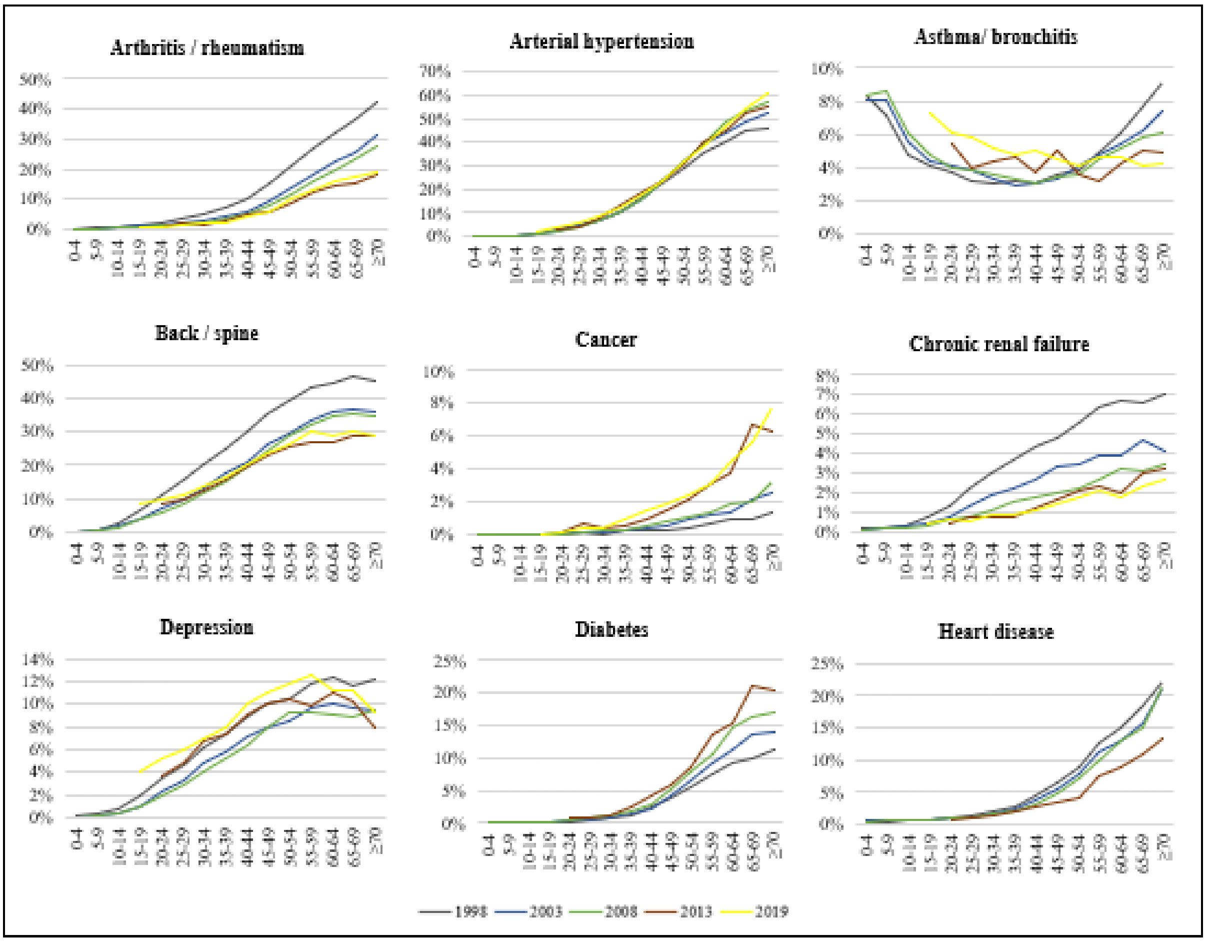
4.3 RESULTS AND DISCUSSION

This section is composed by the main trends related to age and sex, considering the case of Brazil.

4.3.1 Chronic diseases and age

Chronic diseases prevalence by age group can be seen in Figure 8, including five periods over 20 years in Brazil (1998 to 2019) and Figures 8 to 10 shows the prevalence divided by sex. Data from PNS 2013 is available only for individuals with 18 years old or more, and PNS 2019 for individuals with 15 years old or more. In general, chronic diseases grow with increasing age, except asthma/bronchitis that presents a higher prevalence for children/teenagers and the elderly population. Arthritis/rheumatism, back/spine problems, chronic renal failure, and heart diseases showed a trend of prevalence reduction until 2013. On the other hand, cancer, arterial hypertension, and diabetes were growing. In age groups under 50 years, depression showed a reduction between 1998 and 2008, growing again in 2013 and 2019.

Figure 8 - Prevalence of chronic diseases by age group over time



Source: The author (2022).

Arthritis/rheumatism include diseases that affect diseases that affect the joints. It can be observed growth with advancing age (Figure 8). The details of the percentages also can be observed in Table 9. On the other hand, asthma/bronchitis is a chronic disease that mostly affects children. For instance, 7.9% (7.8-8.1) of participants reported problems with arthritis/rheumatism and 4.9% (4.8-5.1) for asthma/bronchitis, considering data from PNS 2019 and individuals over 18 years old.

Arterial hypertension is one of the chronic diseases that most affect the Brazilian population (MOREIRA, J. P. L. et al., 2020; OLIVEIRA, B. L. C. A. et al., 2020). Our analysis found that the prevalence in 1998 was 16.5% (16.3-16.8), 18.0% (17.8-18.2) in 2003, 19.9% (19.7-20.1) in 2008, 22.3% (21.7-23.0) in 2013, and 26.9% (26.6-27.2) in 2019 (≥18 years old).

Table 9 - Overtime differences in chronic diseases prevalence in Brazilian adults (over 18 years' old)

	Arterial hypertension	**Arthritis/ rheumatism**	**Asthma/ bronchitis**	**Back / spine**	**Cancer**	**Chronic renal failure**	**Depression**	**Diabetes**	**Heart disease**
1998	**16.5(16.3-16.8)**	**12.5(12.3-12.8)**	**3.5(4.6-4.1)**	**26.4(26.1-26.7)**	**.33(.30-.35)**	**3.8(3.7-3.9)**	**7.5(7.3-7.7)**	**3.1(3.0-3.2)**	**5.8(5.7-6.0)**
Male	12.9(12.7-13.2)	9.1(8.9-9.4)	3.5(3.3-3.6)	23.4(23.0-23.8)	.31(.27-.35)	3.6(3.5-3.8)	4.5(4.3-4.7)	2.4(2.3-2.5)	4.6(4.5-4.8)
Female	19.9(19.6-20.2)	15.7(15.4-16.0)	4.6(4.5-4.8)	29.1(28.7-29.5)	.34(.31-.38)	3.9(3.8-4.1)	10.2(10.0-10.5)	3.7(3.6-3.8)	6.9(6.8-7.1)
p-value	<.001	<.001	<.001	<.001	.161	<.001	<.001	<.001	<.001
2003	**18.0(17.8-18.2)**	**8.7(8.5-8.9)**	**4.1(4.0-4.2)**	**19.3(19.0-19.5)**	**.61(.58-.65)**	**2.4(2.3-2.5)**	**5.9(5.8-6.1)**	**3.8(3.7-3.9)**	**5.3(5.2-5.4)**
Male	14.2(13.9-14.4)	5.7(5.5-5.8)	3.4(3.3-3.5)	16.4(16.1-16.7)	.48(.43-.53)	2.3(2.2-2.4)	3.1(3.0-3.2)	3.1(3.0-3.2)	4.3(4.2-4.5)
Female	21.5(21.3-21.8)	11.5(11.3-11.7)	4.7(4.6-4.9)	21.8(21.5-22.1)	.73(.68-.69)	2.5(2.3-2.6)	8.5(8.3-8.7)	4.5(4.4-4.6)	6.1(6.0-6.3)
p-value	<.001	<.001	<.001	<.001	<.001	.014	<.001	<.001	<.001
2008	**19.9(19.7-20.1)**	**8.0(7.8-8.1)**	**4.0(3.9-4.1)**	**18.7(18.5-19.0)**	**.79(.75-.83)**	**1.7(1.6-1.8)**	**5.8(5.6-5.9)**	**5.1(5.0-5.2)**	**5.4(5.3-5.5)**
Male	16.4(16.2-16.7)	5.0(4.8-5.1)	3.3(3.2-3.4)	16.2(15.9-16.5)	.73(.67-.78)	1.6(1.5-1.7)	3.2(3.1-3.3)	4.4(4.2-4.5)	4.7(4.6-4.9)
Female	23.0(22.7-23.3)	10.7(10.5-10.9)	4.7(4.5-4.8)	21.1(20.8-21.4)	.84(.80-.91)	1.8(1.7-1.9)	8.1(7.9-8.3)	5.7(5.5-5.8)	6.0(5.8-6.1)
p-value	<.001	<.001	<.001	<.001	.001	<.001	<.001	<.001	<.001
2013	**22.3(21.7-23.0)**	**6.4(6.1-6.8)**	**4.4(4.1-4.7)**	**18.5(17.8-19.1)**	**1.8(1.6-2.0)**	**1.4(1.3-1.6)**	**7.6(7.2-8.1)**	**7.1(6.7-7.5)**	**4.2(3.9-4.5)**
Male	19.1(18.2-20.0)	3.5(3.1-3.9)	3.6(3.2-4.0)	15.5(14.8-16.4)	1.6(1.4-1.9)	1.4(1.1-1.6)	3.9(3.5-4.4)	6.4(5.8-7.0)	3.9(3.5-4.4)
Female	25.2(24.4-26.1)	9.0(8.5-9.6)	5.1(4.7-5.6)	21.1(20.2-21.9)	2.0(1.8-2.3)	1.5(1.3-1.7)	10.9(10.3-11.6)	7.7(7.1-8.2)	4.4(4.0-4.8)
p-value	<.001	<.001	<.001	<.001	.028	.426	<.001	.004	.115
2019	**26.9(26.6-27.2)**	**7.9(7.8-8.1)**	**4.9(4.8-5.1)**	**21.1(20.8-21.5)**	**2.5(2.4-2.7)**	**1.4(1.3-1.5)**	**9.2(9.0-9.4)**	**8.8(8.6-9.0)**	**5.2(5.1-5.4)**
Male	22.7(22.3-23.1)	4.0(3.8-4.2)	3.9(3.7-4.1)	18.7(18.3-19.2)	2.1(2.0-2.3)	1.4(1.3-1.5)	4.6(4.4-4.8)	7.5(7.3-7.8)	4.8(4.6-5.0)
Female	30.5(30.1-31.0)	11.5(11.2-11.8)	5.8(5.6-6.0)	23.3(22.9-23.7)	2.9(2.8-3.1)	1.5(1.4-1.6)	13.3(13.0-13.6)	9.8(9.5-10.1)	5.6(5.4-5.8)
p-value	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001

Source: The author (2022).

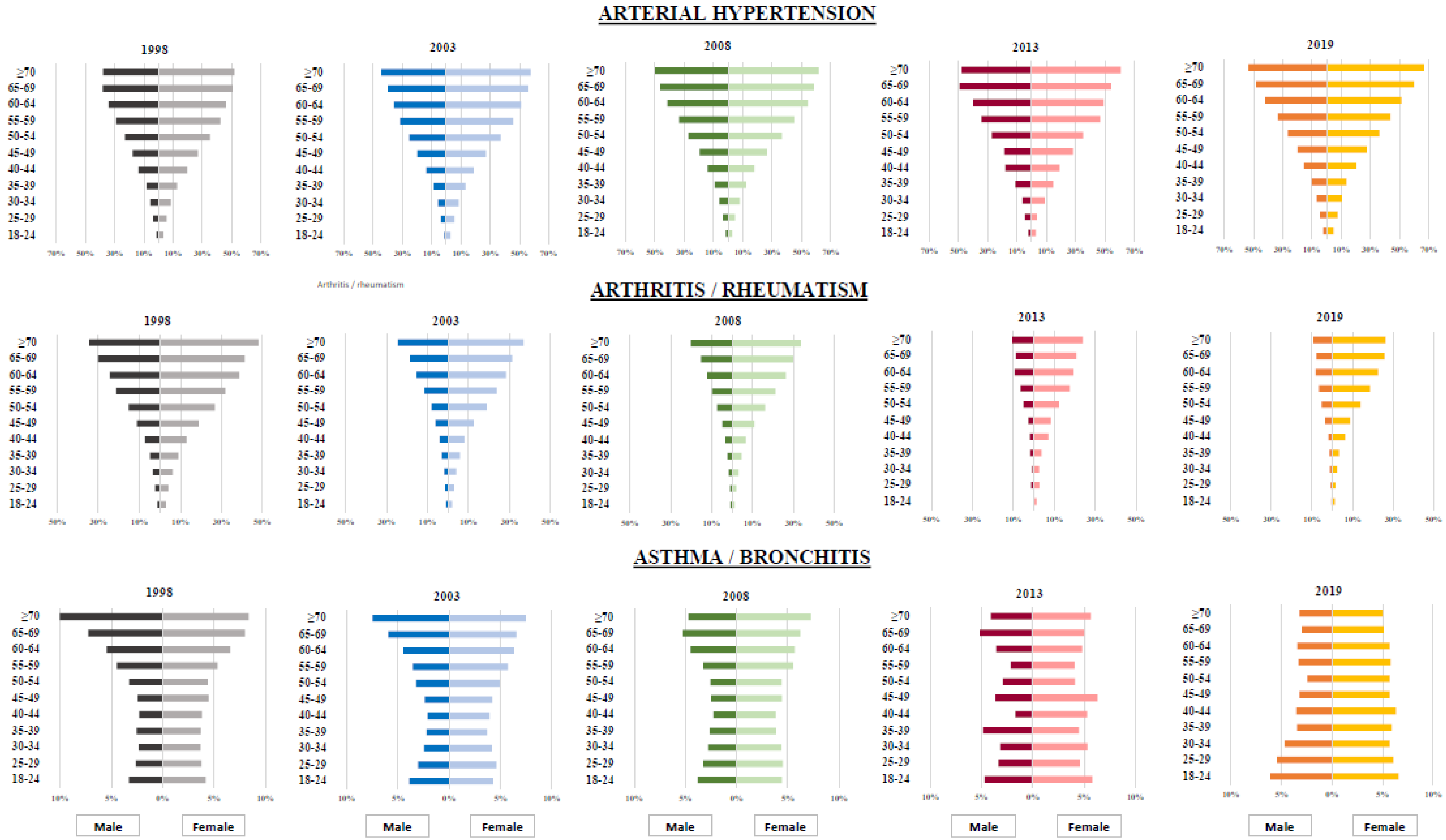
Chronic spine problems including chronic back pain, neck pain, lumbar pain, sciatica, and intervertebral discs, have the highest prevalence rates in Brazil after arterial hypertension, for instance with a prevalence of 21.1% (20.8-21.5), in 2019.

According to the results, the prevalence of cancer in the Brazilian population is increasing expressively over time, going from 0.33% (0.30-0.35) in 1998 to 2.5% (2.4-2.7) in 2013. The number of deaths related to cancer is also increasing in the last years. Cancer was responsible for 11.4% of all deaths in Brazil in 1990 rising to 18.2% in 2017 (BRAZIL, 2020).

Chronic renal failure prevalence is decreasing over time. In 1998, 3.8% (3.7-3.9) of Brazilians reported chronic renal complications, dropping to 1.4% (1.3-1.6) in 2013, and 1.4% (1.3-1.5) in 2019. On the other hand, depression and diabetes is showing an increasing trend since 1998. Depression prevalence rates increased from 7.5% (7.3-7.7) in 1998 to 9.2% (9.0-9.4) in 2019 and diabetes increased from 3.1% (3.0-3.2) in 1998 to 8.8% (8.6-9.0) in 2019.

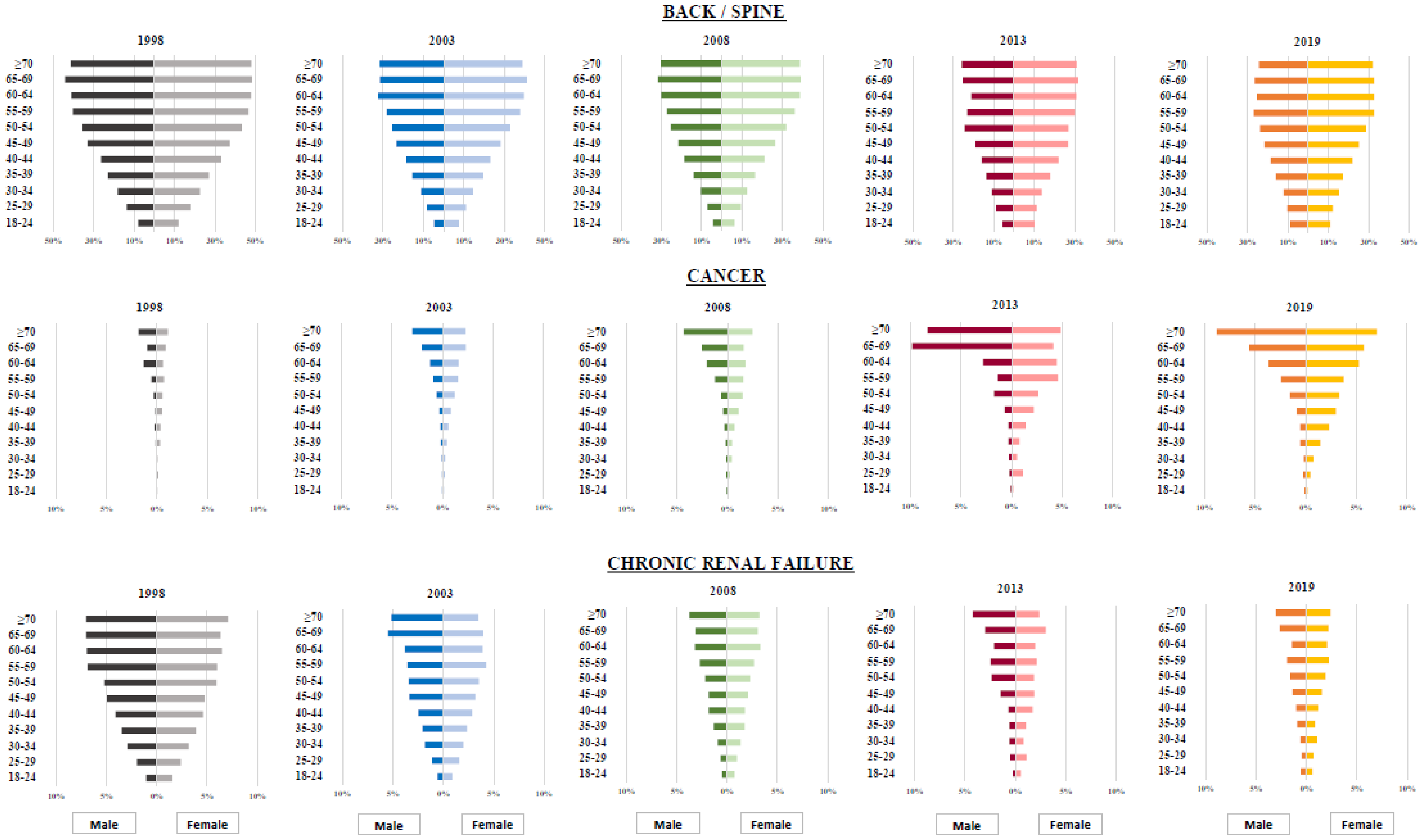
Heart diseases have less rates compared with arterial hypertension and musculoskeletal problems, however, comprehend one of the major health risks in Brazil, being responsible for approximately 28% of all country deaths (WHO, 2018). The prevalence showed a tendency of reduction until 2013: in 1998, 5.8% (5.7-6.0) of Brazilians reported heart problems; in 2003, 5.3% (5.2-5.4); in 2008, 5.4% (5.3-5.5); 4.2% (3.9-4.5) in 2013; and 5.2% (5.1-5.4) in 2019.

Figure 9 - Prevalence of chronic diseases by age group and sex overtime (Part A)



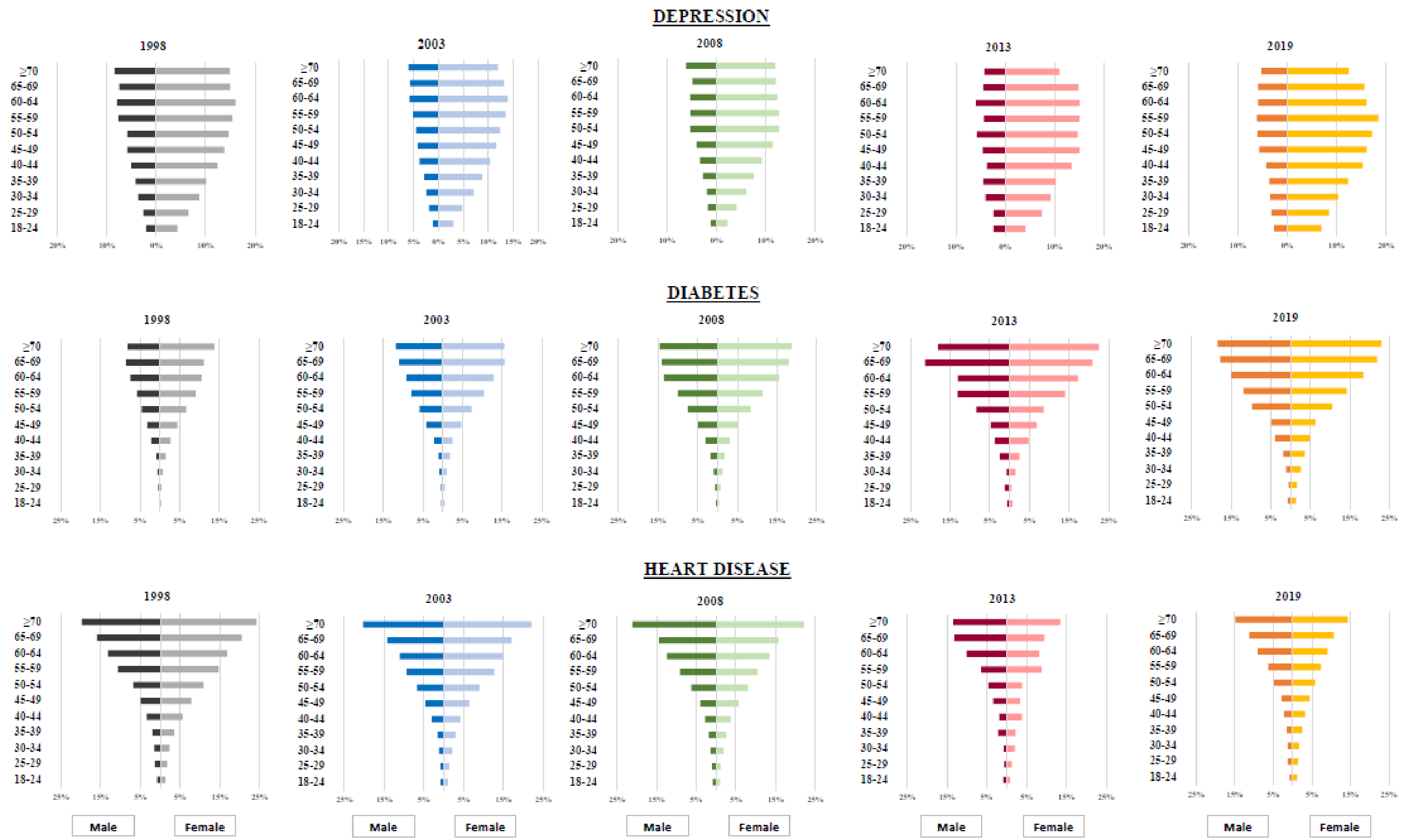
Source: The author (2022).

Figure 10 - Prevalence of chronic diseases by age group and sex overtime (Part B)



Source: The author (2022).

Figure 11 - Prevalence of chronic diseases by age group and sex overtime (Part C)



Source: The author (2022).

4.3.2 Chronic diseases and sex

It was observed that women were more affected by NCDs in Brazil over time. Nevertheless, variations can be observed when age groups are detailed (Figures 9 to 11). Overall, it was found significant statistical differences (p-value <0.05) between male and female groups for the nine NCDs evaluated in this study in multi-periods (Table 9).

It is significantly high the prevalence of depression in women, as well as arthritis/ rheumatism showed higher rates among women over time. Differences were not significant only to chronic renal failure and heart disease in 2013 and cancer in 1998 (Table 9). Some trends also were evidenced in the literature with studies that also suggested higher chronic disease prevalence in Brazil, for women with diseases as arterial hypertension (MALTA; STOPA; ANDRADE; et al., 2015) or diabetes (MALTA; BERNAL; ISER; et al., 2017).

Based on the logistic regression results, the odds ratio (OR) of nine chronic diseases between 1998 and 2019 are shown in Table 10. The odds of diseases for women are higher than that for men in all non-communicable chronic diseases evaluated, at all times. Arthritis/rheumatism and depression showed the highest differences. For instance, in 1998 the chance of having arthritis/rheumatism in the female group was 88% higher than that for the male group, showing a growth trend overtime, and women had about three times the odds to have depression compared with men (e.g., OR=3.2 in 2019).

4.3.3 Limitations

Even PNAD/PNS surveys considered an extensive research structure, probabilistic stages changed and the form of data collection have been updated over time as the question phrases (DAMACENA et al., 2015; IBGE, 2021; NASCIMENTO SILVA; PESSOA; LILA, 2002; PNS, 2013), even though the variables inform if the individual had a certain disease or not. It is a change to be considered but we believe that have not a high influence in this study. Nevertheless, our analysis expects to contribute with health management addressing an underexplored multi-period analysis in Brazil to assess at the same time different non-communicable chronic diseases prevalence, including differences by sex, extensively to different age groups, and from cross-country representative datasets.

Table 10 - Logistic regression results (OR 95% CI).

	Arterial hypertension	**Arthritis/ rheumatism**	**Asthma/ bronchitis**	**Back / spine**	**Cancer**	**Chronic renal failure**	**Depression**	**Diabetes**	**Heart disease**
1998									
Male	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Female	1.69 (1.65-1.73)	1.88 (1.83-1.93)	1.34 (1.28-1.40)	1.37 (1.34-1.39)	1.19 (1.03-1.39)	1.07 (1.02-1.12)	2.46 (2.38-2.55)	1.59 (1.51-1.67)	1.55 (1.49-1.60)
p-value	<.001	<.001	<.001	<.001	.0.22	.004	<.001	<.001	<.001
2003									
Male	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Female	1.67 (1.64-1.71)	2.17 (2.10-2.23)	1.42 (1.36-1.48)	1.43 (1.40-1.46)	1.53 (1.38-1.70)	1.07 (1.02-1.12)	2.91 (2.80-3.02)	1.48 (1.42-1.54)	1.45 (1.40-1.50)
p-value	<.001	<.001	<.001	<.001	<.001	.012	<.001	<.001	<.001
2008									
Male	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Female	1.53 (1.50-1.56)	2.27 (2.21-2.34)	1.42 (1.37-1.48)	1.38 (1.35-1.41)	1.18 (1.08-1.29)	1.11 (1.05-1.18)	2.71 (2.62-2.82)	1.34 (1.30-1.39)	1.30 (1.25-1.34)
p-value	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001
2013									
Male	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Female	1.35 (1.29-1.41)	2.64 (2.44-2.85)	1.52 (1.39-1.66)	1.36 (1.30-1.43)	1.36 (1.19-1.56)	1.08 (.93-1.25)	2.91 (2.69-3.15)	1.30 (1.21-1.40)	1.03 (0.94-1.13)
p-value	<.001	<.001	<.001	<.001	<.001	.300	<.001	<.001	.492
2019									
Male	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Female	1.50 (1.45-1.54)	3.14 (2.97-3.33)	1.51 (1.42-1.61)	1.32 (1.28-1.36)	1.40 (1.29-1.52)	1.07 (.96-1.20)	3.20 (3.04-3.37)	1.33 (1.27-1.40)	1.17 (1.10-1.24)
p-value	<.001	<.001	<.001	<.001	<.001	.209	<.001	<.001	<.001

Source: The author (2022).

4.4 FINAL CONSIDERATIONS

The central focus of this study was to analyze chronic diseases differences between age and sex from a temporal perspective. It was used the PNADs with health supplements carried out in 1998, 2003, and in 2008 combined with the National Health Survey (PNS) executed in 2013 and 2019.

Overall, chronic diseases grow with increasing age in a similar behavior over the years, except bronchitis/asthma since mainly affects children and the elderly. Chronic diseases as cancer and diabetes have shown an increase tendency in the last years. Diseases related to arthritis/rheumatism and back/spine showed a reduction trend until 2013, growing again in 2019. These problems need particular attention since they directly affect the physical well-being. Chronic renal failure is stable between 2013 and 2019. On the other hand, heart diseases increased in 2019. These problems need special attention since they are diseases among the leading causes of death in Brazil (BRAZIL, 2020).

According to the results, women and elderly are groups more affected by chronic diseases in Brazil. The odds of having non-communicable diseases in the female group was continuously higher than that for the male group, mainly when it is observed diseases as arthritis/rheumatism or depression.

Regular national surveys can help to understand the epidemiological reality of the population from periodic cross-sections studies (WALDMAN et al., 2008). Monitoring chronic diseases and their risk factors is a challenge to be managed continuously in Brazil and worldwide (SCHMIDT, M. I. et al., 2011). Trends can help to indicate health policies priorities as well as new studies designs related to prevention strategies to non-communicable diseases. From the analysis of national-based databases such as PNAD and PNS, relevant information on the health of the population can be detected to assist health management in Brazil.

5 GEOGRAPHIC DISTRIBUTION OF CHRONIC DISEASES IN BRAZIL

This chapter aims to address the research objective 3, evaluating geographic distribution of chronic diseases in the Brazilian territory and proposing an index for a comprehensive assessment of the federative units of Brazil.

Health indexes can help to construct a summary view with a simplified version in a specific context. According to the literature researched, this study is the first to propose a global index of chronic diseases based on a statistical framework using factor analysis. From the quantitative methodology proposed, it was possible to provide a ranking of the states and use the results integrated with a geographical perspective. This chapter was the basis for the paper published by (LIMA; MOTA; MARINHO, 2022).

5.1 CONTEXTUALISATION

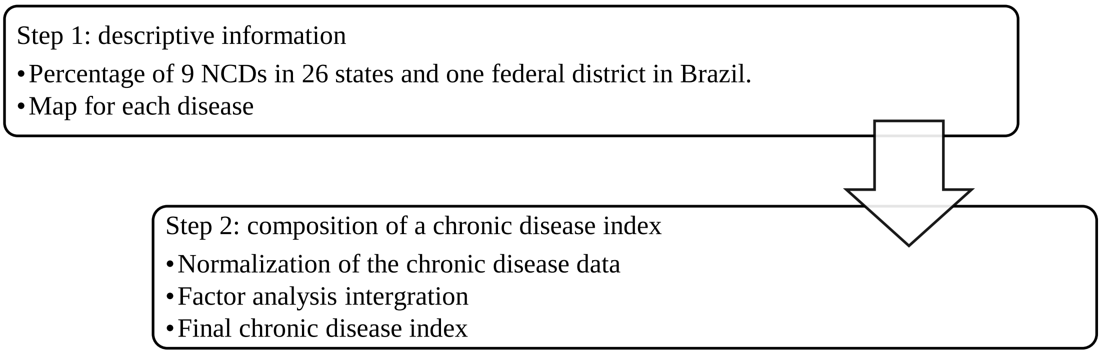
Health indicators represent summary measures that capture relevant information on different attributes and dimensions of the state of health or the performance of the health structure through different methodologies: direct counting, proportions and several index calculations (PAHO, 2018). Specifically related to chronic diseases, it was found some indexes with a focus on an individual risk analysis, aggregating the number of comorbid diseases and risk factors present in each person. For example, as showed by the Charlson Comorbidity Index-CCI, Chronic Disease Score and, Chronic Disease Index – CDI (CHARLSON et al., 2008; KORFF; WAGNER; SAUNDERS, 1992; MALONE et al., 1999; MCGREGOR et al., 2005; PAZ VAQUERO-HERRERO et al., 2017). In general, a higher score indicates that the person has more comorbid diseases and has more risk related to health care outcomes, as mortality or costs of medical care.

Another approach to evaluate chronic diseases is to establish an analysis involving behavioral risk, prevention practices and nutrition, as suggested for the Chronic Disease Indicators – CDI in US and the Canadian Chronic Disease Indicators – CCDI (BETANCOURT et al., 2017; HOLT et al., 2015). In this case, different indicators show the percentage of adults that are obese, the rate of newly diagnosed chronic diseases or life expectancy. However, it has not produced an index with all indicators together. The Milken Institute in the US (DEVOL et al., 2007) proposed a State Chronic Disease Index. This index ranked 50 states, grouping pulmonary conditions, hypertension, mental disorders, heart disease, diabetes, cancers and, stroke.

5.2 METHODS

This study examined the PNS database, which consists of a national and domiciliary study carried out through a partnership between the Brazilian Ministry of Health and the Brazilian Institute of Geography and Statistics (IBGE, 2022). The central focus of this study was to assess the variables that indicate if participants reported having or not one of the nine chronic diseases evaluated: arterial hypertension, arthritis/rheumatism, back/spine, bronchitis/asthma, cancer, chronic renal failure, depression, diabetes, and, heart disease. The PNS data collection was carried out in 2013 (DAMACENA et al., 2015). Two main steps were followed for this study (Figure 12):

Figure 12 - Main methodology steps



Source: The author (2022).

In the step 1, seeking to better visualize the distribution of the percentage of diseases in each map, it was implemented a division into groups using the Jenks classification method that is a possibility to minimize the group variance (SMITH; GOODCHILD; LONGLEY, 2018). It was used the QGIS program (QGIS, 2022) that is a free and open Geographic Information System.

In the step 2, firstly, it was performed normalization of the diseases proportions for each geographic unit (*xij*) according to Equation 3. Where *Yij* corresponds to the geographic unit score transformed into a scale between 0 and 1 representing the proportion of each state.

The 'i' maximum is 9 (number of chronic diseases) and the 'j' maximum is 27 (number of geographic units).

$$Y_{ij} = \frac{X_{ij}}{Max\ X_{ij}} \tag{3}$$

Accordingly:

- X_{ij} corresponds to the disease proportion ($i \geq 1$) per geographic unit ($j \geq 1$).
- Y_{ij} indicates the disease score ($i \geq 1$) per geographic unit (j ≥ 1).

Factor analysis (FA) was used to summarize the information of the nine chronic diseases analyzed. In this method, each factor is a linear combination of the original variables and also represent the underlying dimensions that summarize or account for the original set of observed variables (HAIR JR et al., 2014). The correlation between the original variables and the factors is represented by the factor loadings (l_i). The factor loadings extracted where used as a weight to compose the index (F_k). It was calculated a single index for each factor, based on Equation 4.

$$F_k = \frac{\sum |l_i| Y_{ij}}{\sum |l_i|} \tag{4}$$

Accordingly:

- F_k corresponds to each factor extracted ($k \geq 1$).
- l_i corresponds to the factor loading ($l \geq 1$) of each disease i ($i \geq 1$).
- Y_{ij} indicates the score of each disease ($i \geq 1$) per geographic unit ($i \geq 1$).

The proposed Geographic Index of Chronic Diseases (gCDI) is calculated considering the eigenvalues (E_k) as weights to aggregate the result of all factors (F_k). These eigenvalues (sum of squares) represent the amount of variance accounted for by a factor presented in a decreasing order representing the relative impact of each factor (HAIR JR et al., 2014). The final index (gCDI) was calculated based on Equation 5.

$$gCDI_j = \frac{\sum E_k F_k}{\sum E_k} \tag{5}$$

Accordingly:

- $gCDI_j$ is the aggregated index for each geographic unit j ($j \geq 1$).
- E_k corresponds to the eigenvalue of each factor F_k ($k \geq 1$).

For each of the 27 geographic units was calculated the gCDI index. At the end, it was constructed a map of Brazil and to better visualization the gCDI results were transformed into a scale between 0 and 1 (maximum division). In this study, the highest values indicate the areas with the greatest problems with chronic diseases.

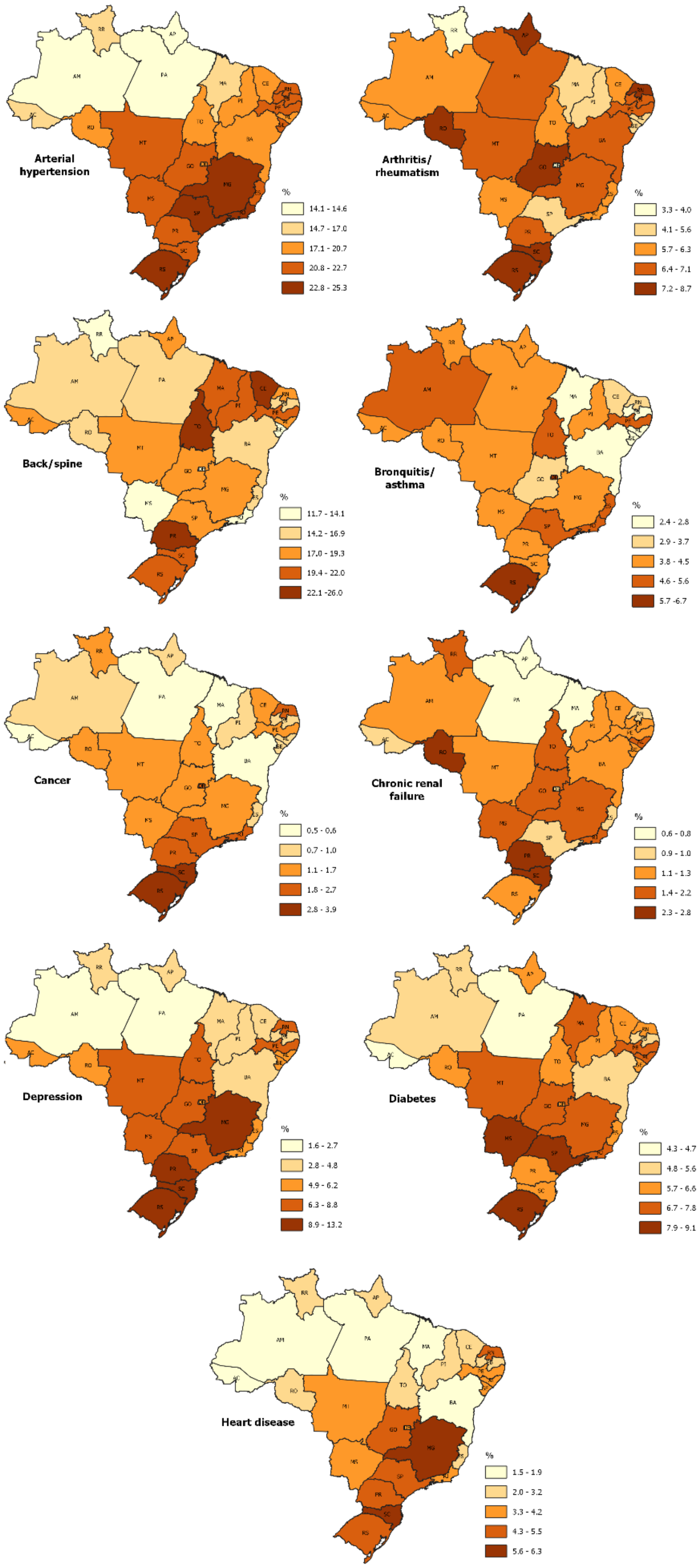
5.3 RESULTS AND DISCUSSION

Figure 13 shows a geographic representation of the chronic diseases: arterial hypertension, arthritis/rheumatism, back/spine, bronchitis/asthma, cancer, chronic renal failure, depression, diabetes, and, heart disease. Table 11 displays all proportions considered. The highest scores are in the darker areas representing federal units with more health problems related to respective chronic diseases. After testing different combinations, in this study, better visualization of the results was demonstrated with 5 groups for the 26 states and one Federal district of Brazil (27 geographic areas).

For arterial hypertension, depression, cancer, diabetes, and heart disease, it can be seen a considerable difference between the regions in Brazil: South areas have higher concentrations of these chronic diseases compared with the North. Arthritis and rheumatism, back problems, bronchitis and asthma, chronic renal failure have more diffuse distributions between regions of the country, even though, it is possible to verify similarities between close states.

It is important to be careful in interpreting the results. For example, in the South region, the elderly population is larger compared to the North and Northeast of Brazil, which can lead to a greater number of chronic diseases. In addition, in the South and Southeast regions, the average income and health insurance coverage is higher, which can lead also to higher rates of detection of chronic diseases. Another problem could be under-reporting in more remote areas.

Figure 13 - Proportion of chronic diseases by Brazilian federate units



Source: Based on (LIMA; MOTA; MARINHO, 2022).

Table 11 - Chronic diseases percentage (%) by Brazilian federal units

	Arterial hypertension			**Arthritis/ rheumatism**			**Back/ spine**			**Bronchitis/ asthma**			**Cancer**			**Chronic renal failure**			**Depression**			**Diabetes**			**Heart disease**		
Units	**%**	IC95%		**%**	IC95%		**%**	IC95%		**%**	IC95%		**%**	IC95%		**%**	IC95%		**%**	IC95%		**%**	IC95%		**%**	IC95%	
AC - Acre	**17.0**	15.0	19.3	**6.2**	4.7	8.1	**17.5**	14.9	20.5	**4.0**	3.0	5.4	**0.6**	0.3	1.3	**1.0**	0.6	1.8	**5.8**	4.6	7.3	**4.3**	3.1	6.0	**1.9**	1.3	2.6
AL - Alagoas	**19.7**	17.4	22.4	**5.0**	3.9	6.4	**18.0**	15.7	20.6	**2.6**	1.8	3.7	**0.8**	0.4	1.3	**2.0**	1.3	3.1	**6.2**	4.8	8.1	**7.8**	6.2	9.9	**3.5**	2.6	4.8
AM - Amazonas	**14.5**	12.8	16.3	**6.3**	5.2	7.7	**16.0**	13.7	18.6	**5.6**	4.5	6.9	**0.8**	0.4	1.4	**1.3**	0.8	2.1	**2.7**	2.0	3.6	**5.4**	4.3	6.9	**1.7**	1.3	2.4
AP - Amapa	**14.1**	11.7	16.9	**8.2**	6.5	10.2	**18.5**	15.2	22.4	**4.0**	2.9	5.7	**0.8**	0.4	1.6	**0.8**	0.4	1.5	**3.4**	2.2	5.1	**6.0**	4.4	8.0	**2.6**	1.7	4.1
BA - Bahia	**20.7**	17.6	24.2	**6.9**	5.3	8.8	**16.2**	13.4	19.4	**2.4**	1.6	3.5	**0.6**	0.4	1.2	**1.2**	0.6	2.1	**4.0**	2.9	5.5	**5.6**	4.5	7.0	**1.8**	1.3	1.6
CE - Ceará	**19.6**	17.5	21.8	**6.1**	5.0	7.6	**24.0**	21.5	26.8	**3.3**	2.6	4.1	**1.2**	0.8	2.0	**1.2**	0.7	2.0	**4.4**	3.4	5.6	**6.2**	5.0	7.8	**2.6**	1.9	3.6
DF - Distrito Federal	**20.0**	17.9	22.4	**4.0**	3.1	5.2	**11.7**	9.9	13.8	**6.0**	4.7	7.5	**2.7**	2.0	3.7	**0.9**	0.5	1.4	**6.2**	5.0	7.6	**6.3**	5.1	7.7	**3.5**	2.7	4.6
ES - Espírito Santo	**21.2**	18.4	24.3	**5.8**	4.4	7.5	**14.6**	12.1	17.7	**4.7**	3.2	6.9	**1.0**	0.6	1.6	**1.0**	0.5	2.1	**5.5**	3.9	7.6	**6.5**	4.9	8.6	**3.1**	2.1	4.6
GO - Goiás	**22.6**	20.2	25.1	**8.0**	6.7	9.6	**19.0**	16.9	21.3	**3.6**	2.7	4.7	**1.4**	0.9	2.1	**2.0**	1.4	3.1	**7.1**	5.8	8.6	**7.5**	6.0	9.3	**5.5**	4.4	6.9
MA - Maranhão	**15.0**	12.7	18.1	**5.5**	4.1	7.4	**21.5**	18.3	25.2	**2.5**	1.6	4.0	**0.5**	0.1	1.4	**0.8**	0.4	1.7	**3.8**	2.6	5.5	**7.2**	4.9	10.5	**1.6**	1.1	2.5
MG - Minas Gerais	**24.5**	22.0	27.2	**6.6**	5.3	8.3	**17.6**	15.2	20.3	**4.4**	3.3	5.8	**1.2**	0.7	2.2	**1.7**	1.0	2.8	**11.1**	9.3	13.2	**7.2**	5.8	8.8	**6.3**	5.0	7.9
MS - Mato Grosso do Sul	**21.5**	19.3	23.8	**6.2**	4.9	7.9	**14.1**	12.1	16.3	**4.1**	3.3	5.2	**1.1**	0.7	1.7	**1.8**	1.2	2.7	**8.8**	7.4	10.6	**9.1**	7.7	10.7	**4.2**	3.2	5.6
MT - Mato Grosso	**21.7**	19.4	24.2	**7.1**	5.6	9.0	**19.3**	16.8	22.1	**3.9**	2.8	5.4	**1.5**	1.0	2.4	**1.3**	0.6	2.7	**6.9**	5.3	9.0	**7.5**	5.9	9.5	**3.9**	2.9	5.3
PA - Para	**14.6**	12.5	16.8	**6.7**	5.4	8.3	**16.4**	13.6	19.7	**4.1**	3.2	5.3	**0.6**	0.3	1.2	**0.6**	0.3	1.2	**1.6**	1.1	2.3	**4.7**	3.3	6.6	**1.5**	1.0	2.3
PB - Paraiba	**22.3**	20.2	24.6	**6.9**	5.7	8.4	**16.9**	14.6	19.5	**2.8**	2.1	3.8	**0.9**	0.5	1.4	**1.1**	0.6	2.1	**4.8**	3.6	6.4	**5.0**	3.9	6.4	**3.1**	2.3	4.1
PE - Pernambuco	**22.3**	20.4	24.4	**6.6**	5.4	7.9	**20.2**	18.3	22.3	**5.0**	4.1	6.0	**1.2**	0.8	1.9	**1.2**	0.7	1.9	**7.2**	5.9	8.7	**7.0**	5.7	8.5	**3.7**	2.8	5.1
PI - Piauí	**20.4**	17.6	23.5	**5.0**	3.9	6.3	**21.0**	17.5	25.0	**4.3**	3.0	6.1	**0.8**	0.3	1.9	**1.1**	0.6	2.0	**3.9**	2.9	5.3	**6.1**	4.6	8.0	**2.8**	2.1	3.8
PR - Parana	**21.7**	19.3	24.4	**7.0**	5.7	8.7	**26.0**	23.1	29.2	**4.5**	3.5	5.9	**2.6**	1.7	3.9	**2.8**	1.8	4.3	**11.7**	9.5	14.4	**6.6**	5.1	8.7	**5.1**	3.9	6.7
RJ - Rio de Janeiro	**24.5**	22.6	26.4	**6.0**	5.0	7.1	**13.3**	11.7	15.0	**5.2**	4.2	6.4	**2.2**	1.7	3.0	**1.8**	1.4	2.5	**6.0**	5.1	7.1	**6.8**	5.8	7.8	**3.7**	2.9	4.6
RN - Rio G. do Norte	**21.2**	18.8	23.8	**8.0**	6.2	10.4	**17.9**	15.4	20.8	**3.7**	2.7	4.9	**2.1**	1.3	3.2	**0.9**	0.6	1.4	**6.9**	5.5	8.6	**6.2**	4.7	8.1	**4.7**	3.3	6.6
RO - Rondonia	**18.8**	16.4	21.5	**8.7**	7.1	10.7	**15.1**	12.2	18.6	**4.2**	3.1	5.8	**1.5**	0.9	2.4	**2.8**	1.8	4.2	**5.6**	4.3	7.4	**6.0**	4.3	8.2	**3.2**	2.3	4.5
RR - Roraima	**14.9**	12.7	17.3	**3.3**	2.4	4.6	**13.3**	11.1	16.0	**4.5**	3.4	6.1	**1.2**	0.7	2.0	**1.8**	1.0	3.0	**4.4**	3.4	5.9	**5.2**	3.9	7.0	**2.6**	1.7	3.8
RS - Rio G. do Sul	**25.3**	23.0	27.8	**7.8**	6.6	9.3	**22.0**	19.2	25.0	**6.7**	5.5	8.1	**3.3**	2.4	4.4	**1.2**	0.8	1.8	**13.2**	11.6	15.0	**8.0**	6.6	9.6	**5.3**	4.4	6.5
SC - Santa Catarina	**22.7**	19.1	26.8	**8.3**	6.3	10.8	**21.3**	18.1	24.8	**4.3**	3.1	5.8	**3.9**	2.7	5.6	**2.6**	1.7	3.9	**12.9**	10.0	16.4	**6.3**	4.9	8.1	**5.8**	4.4	7.6
SE - Sergipe	**21.5**	19.3	23.9	**5.1**	4.0	6.5	**13.6**	11.6	16.0	**2.8**	2.0	3.8	**0.9**	0.5	1.8	**1.2**	0.7	1.9	**6.2**	5.0	7.7	**6.6**	5.3	8.1	**3.3**	2.4	4.5
SP - Sao Paulo	**23.3**	21.7	25.0	**5.6**	4.9	6.4	**18.3**	16.8	19.8	**4.9**	4.1	5.8	**2.6**	2.0	3.2	**1.0**	0.8	1.4	**8.4**	7.3	9.6	**8.3**	7.3	9.5	**5.0**	4.1	6.1
TO - Tocantins	**20.0**	17.5	22.9	**6.1**	4.7	8.0	**23.2**	19.9	26.9	**4.9**	3.5	6.7	**1.7**	1.0	2.9	**2.2**	1.1	4.1	**7.1**	5.4	9.3	**6.6**	5.0	8.7	**2.9**	1.9	4.3

Source: The author (2022).

The Geographic Chronic Disease Index (gCDI) proposed is a combination of the nine chronic diseases in a unique number that can help to compare the global situation of chronic diseases by geographic unit. This combination was based on the factor analysis methodology and steps presented in Equations 3 to 5.

Some guidelines inherent to the application of the factor analysis method were evaluated (HAIR JR et al., 2014). The correlation between variables data presented values above 0.30. The Bartlett sphericity tests the hypothesis that the variables are not correlated. The Kaiser-Meyer-Olkin (KMO) tests the adequacy of sampling ranging from 0 to 1. The KMO values that indicate whether the analysis is appropriate differ from author to author and in general, values above 0.5 are acceptable. The values of Bartlett's sphericity and KMO tests are within the limits of acceptance, proving the adequacy of the data for the use of this method. Regarding the total variance explained, it was observed that the result was significantly satisfactory, obtaining a value higher than 70%. So, it is possible to affirm that the *gCDI* is an effective possibility to translate the original set of chronic disease proportions in a global index.

With the factorial loads and eigenvalues, it was computed the *gCDI* index. In a global evaluation of chronic diseases in Brazil, the units with higher scores represent the areas with major chronic disease problems, starting with Santa Catarina (SC), Paraná (PR) and Rio Grande do Sul (RS) in the South region. On the other hand, the lowest scores are in Pará (PA), Maranhão (MA), and Bahia (BA), in North/Northeast of Brazil. Figure 14 and Table 12 shows the final ranking of the *gCDI*.

Given the *gCDI* index it was possible to visualize that in an overall analysis, chronic diseases are more prevalent in the South of Brazil. Age distribution is an essential factor to consider for the increase in the rate of chronic illness in a given area. In the sample used in this study, it was observed more elderly in the South/Southeast of the country. The average rate of participants over 65 years old was 14.9% in South, and 15.4% in the Southeast. North, Northeast, and Midwest respectively presented an average of 9.5%, 12.9%, and 10.6% participants over 65 years old.

The evaluation of chronic disease is complex involving, in addition to the hereditary issue, lifestyle, and social behaviors (SCHMIDT, 2016). It is worth mentioning that the South and Southeast regions admit units of the federation with the best Human Development Index (HDI) levels in Brazil (ATLAS BRAZIL, 2013). Higher incomes tend to lead to more people having private health insurance that represent greater access to diagnosis (MELO et al., 2016) which may partly explain the greater record of chronic diseases in richer areas. A higher standard of living for the population can also lead to greater consumption of unhealthy food, increasing risk factors related to chronic diseases(BAUER et al., 2014). The association between chronic disease and the lifestyle of Brazilian individuals in South and Southeast regions from the results inferred by our geographic chronic disease index in Brazil can be better explored in future researches, preferably with an additional level of details about the location for each chronic disease.

Figure 14 - Chronic diseases distribution in Brazil based on gCDI index

Source: Based on (LIMA; MOTA; MARINHO, 2022).

Table 12 - Geographic Chronic Diseases Index ranking by Brazilian federal units

	Unit	Index		Unit	Index		Unit	Index
1	SC – Santa Catarina	1.000	10	MS – Mato Grosso do Sul	0.703	19	PB – Paraíba	0.582
2	PR – Paraná	0.964	11	PE – Pernambuco	0.700	20	RR – Roraima	0.570
3	RS – Rio Grande do Sul	0.942	12	MT – Mato Grosso	0.691	21	AM – Amazonas	0.567
4	MG – Minas Gerais	0.808	13	RN – Rio Grande do Norte	0.690	22	SE – Sergipe	0.557
5	GO - Goiás	0.787	14	DF –Distrito Federal	0.649	23	AC – Acre	0.551
6	TO - Tocantins	0.773	15	AL – Alagoas	0.627	24	AP - Amapa	0.546
7	RO – Rondonia	0.771	16	CE – Ceará	0.616	25	BA – Bahia	0.524
8	SP – São Paulo	0.750	17	ES – Espirito Santo	0.602	26	MA – Maranhão	0.472
9	RJ – Rio de Janeiro	0.745	18	PI – Piauí	0.592	27	PA – Pará	0.463

Source: The author (2022).

5.3.1 Limitations

The data used in this research was collected from the Brazilian National Health Survey (PNS) in 2013. The sample size considered a 95% confidence interval for estimates parameters in different geographic levels and population groups, based on the 2010 geographic census (SOUZA-JÚNIOR et al., 2015). Nevertheless, there are differences in the age distribution in the states. Consequently, one area with more elderly, for example, can have a higher percentage of residents with chronic disease. Additionally, PNS chronic disease data is based on self-reported information that can have different percentages compared to clinical diagnosis (WU et al., 2014). As all data used was collected with the same methodology, we believe that this not have an extensive impact in the final index.

5.4 FINAL CONSIDERATIONS

Analyzing the maps of each disease, it was observed that arterial hypertension, cancer, depression, diabetes, and heart disease showed a clear difference between regions. South had a higher proportion of chronic diseases compared with the North of Brazil. Arthritis and rheumatism, back problems, bronchitis and asthma, and, chronic renal failure showed comparatively minor differences between regions. However, from the construction of the gCDI index it can be confirmed that in an overall analysis, the problem with chronic disease is bigger in the South of Brazil.

The use of spatial analyses can help to propose strategic interventions for certain regions through identification of geographic patterns (ECCLES; BERTAZZON, 2015; MACQUILLAN et al., 2017) or it can be used to monitor the occurrence of diseases, identifying clusters and detecting hotspots (MLACHA et al., 2017; NDIATH et al., 2014). The determination of indicators can make an important element of support for health decision making.

6 MULTIMORBIDITY IN BRAZIL

This chapter aims to address the research objective 4, investigating dynamic distributions of socioeconomic, demographic, and health-related characteristics on multimorbidity in Brazil over an extended period of 15 years, using descriptive statistic and a binary logistic regression methodology. The common concept about multimorbidity include the co-occurrence of two or more diseases within one person (AKKER; BUNTINX, 1996).

The association between the multimorbidity with socio, economic and demographic variables were explored in the literature (BARNETT et al., 2012; GARIN et al., 2016; PRADOS-TORRES et al., 2014; VIOLAN et al., 2014), nevertheless, there is yet a lack of studies with multimorbidity in low- and middle-income countries (XU; MISHRA; JONES, 2017), especially observing the Brazilian population, that is the focus of this study. This chapter was the basis for the paper published by (SHI et al., 2021).

6.1 CONTEXTUALISATION

Chronic diseases encompass a group of long-term illnesses with complex and multiple symptoms and lead to a gradual deterioration of health and loss of morbidities such as cancers, diabetes, cardiovascular and respiratory diseases (AUSTRALIAN HEALTH MINISTERS' ADVISORY COUNCIL, 2017). Chronic diseases are also called non-communicable diseases (NCDs) as they do not spread from person to person. NCDs are collectively responsible for about 70% of all deaths worldwide and the majority of those deaths occur in people between 30 and 70 years from low and middle-income countries (WHO, 2018).

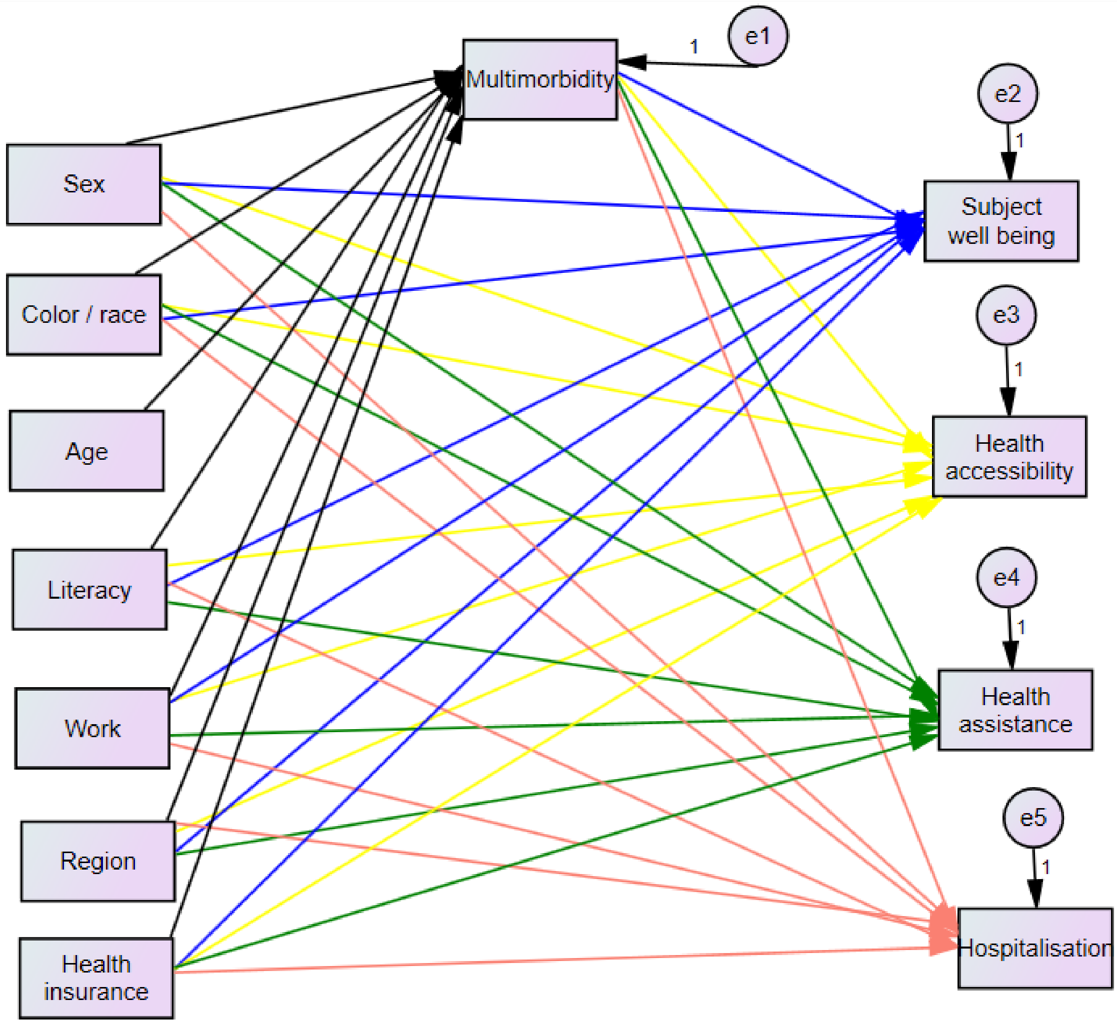
Different studies support the idea that interactions between chronic diseases can negatively affect health-related quality of life (FORTIN et al., 2004; NICE, 2016; WALLACE et al., 2015), being even more problematic to the older population (BUJA et al., 2018; GUISADO-CLAVERO et al., 2018; HUNGER et al., 2011). Patients with multimorbidity are at higher risk of safety issues such as polypharmacy, complex management regimens, increased healthcare utilization, more vulnerability due to poor health, limited health literacy and comorbidity of depression or anxiety (WALLACE et al., 2015; WHO, 2016). Multiple health conditions are more common in disadvantaged groups that contribute with health inequalities It is essential to take into account care of people with multimorbidity to improve safety in primary care (WHO, 2016).

6.2 METHODS

Cross-sectional national-based surveys were used from Household Sample Survey (PNAD) and National Health Survey (PNS). It was integrated the common variables from PNADs 1998, 2003, 2008 and PNS 2013.

Based on previous researches about non-communicable chronic diseases (as showed in Chapter 2 and 3) it was selected relevant variables in this context (Figure 15). The analysis of multimorbidity was conducted from three aspects, which are social-demographic, region, and utilization of health services.

Figure 15 - Statistical methodology using Binary Logistic Regression Models - BLRM



Source: The author (2022).

Descriptive analysis and data visualization were performed to identify differences in the participants' behavior. The sample was composed by 795,271 participants with 679,572 adults (18-59 years of age) and 115,699 elderly people (≥60 years of age). It was excluded 1.2% of individuals who did not answer all the questions about the 9 NCDs analyzed: back/column, arthritis/rheumatism, cancer, diabetes, bronchitis/asthma, high blood pressure (HBP, or hypertension), heart disease, chronic renal insufficiency (kidney failure), and depression. The other questions for analysis were mandatory in the surveys without any missing data (age, color/race, age, literacy, etc.).

Hypothesis testing, frequency analysis and Pearson chi-square test were used to evaluate the association with the occurrence of multimorbidity. Binary logistic regression models (BLRM) were applied for analyzing the impacts on multimorbidity. To estimate the association with multimorbidity, odds ratios (ORs) were computed with 95% CIs. P values (two-sided) with 95% CIs were used for evaluate statistical significance. The data was analyzed using SPSS Statistics software.

6.3 RESULTS AND DISCUSSION

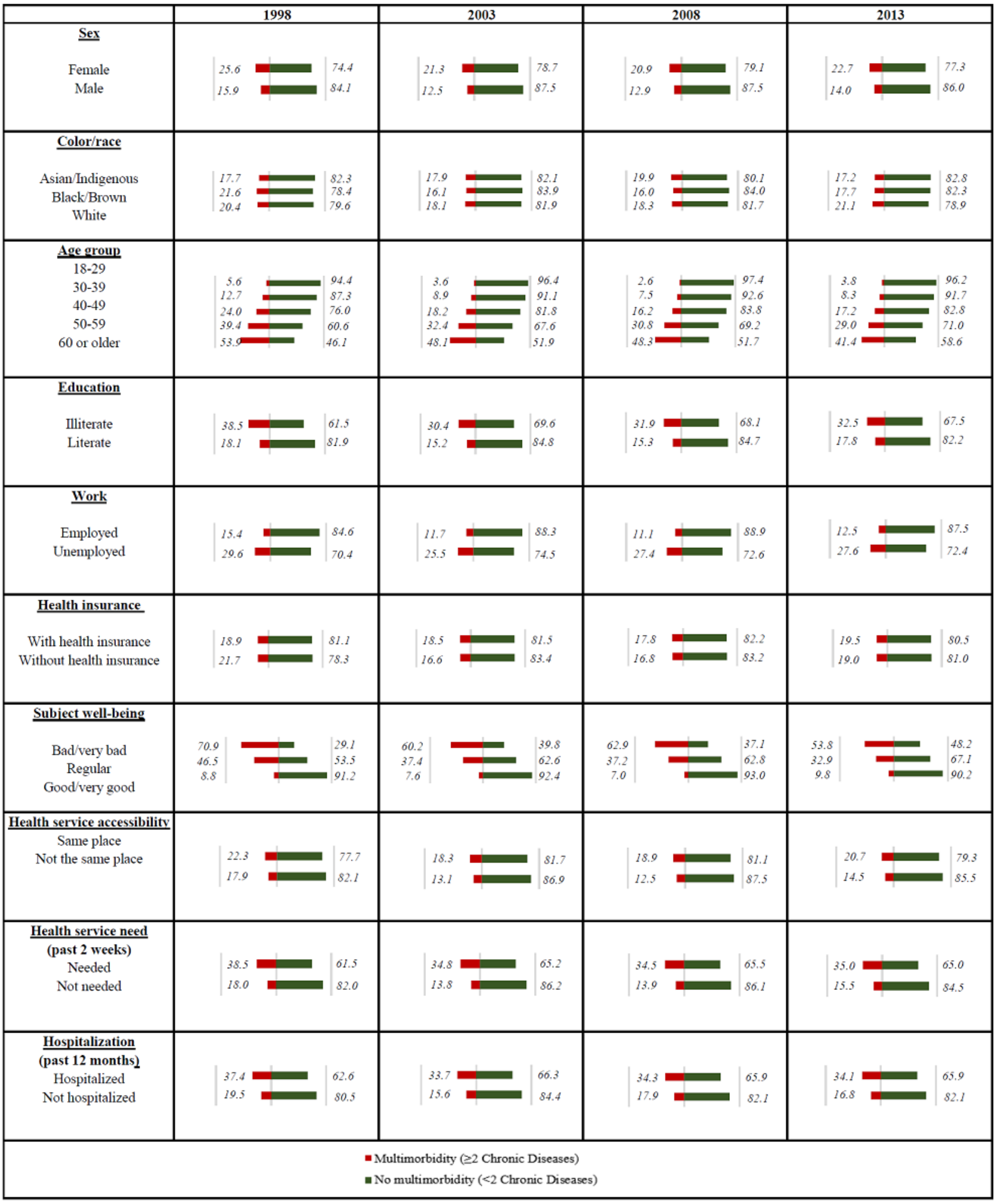
This section is composed by the descriptive analysis and logistic regression results.

6.3.1 Descriptive results

Figure 16 and Table 13 summarize the descriptive statistics of multimorbidity in Brazil according to gender, race, age, education, employment, and health characteristics.

Multimorbidity rate in Brazil was gradually reduced from 21.0% in 1998 to 17.1% in 2003 and 2008 but slightly increased to 19.1% in 2013. The female group shows a higher percentage of the population with multimorbidity (%) across all the cohorts and the multimorbidity of NCDs grows gradually with age. The illiterate population had a higher rate of multiple chronic diseases than that for the literate group in every single study period. The unemployed group has higher rates of multimorbidity in comparison with the group that has a job across the entire study period.

Figure 16 - Percentage of multimorbidity by year with sociodemographic, subjective well-being, and health service characteristics.



Source: (SHI et al., 2021)

Table 13: Descriptive summary table - multimorbidity overtime.

	No multimorbidity (<2CD)					Multimorbidity (≥ 2CD)				
	1998	**2003**	**2008**	**2013**	**Overall**	**1998**	**2003**	**2008**	**2013**	**Overall**
Sex										
Female	84,708	105,025	112,720	23,499	325,952	29,080	28,382	29,696	6,903	94,061
Male	87,161	106,158	112,423	18,222	323,964	16,487	15,158	16,680	2,969	51,294
Female	**74.4%**	**78.7%**	**79.1%**	**77.3%**	**77.6%**	**25.6%**	**21.3%**	**20.9%**	**22.7%**	**22.4%**
Male	**84.1%**	**87.5%**	**87.1%**	**86.0%**	**86.3%**	**15.9%**	**12.5%**	**12.9%**	**14.0%**	**13.7%**
Color/Race										
Asian/Indigenous	1,247	1,347	1,912	650	5,156	268	294	476	135	1,173
Black/Brown	78,838	106,613	120,796	24,031	330,278	21,744	20,449	23,029	5,167	70,389
White	91,784	103,223	102,435	17,040	314,482	23,555	22,797	22,871	4,570	73,793
Asian/Indigenous	**82.3%**	**82.1%**	**80.1%**	**82.8%**	**81.5%**	**17.7%**	**17.9%**	**19.9%**	**17.2%**	**18.5%**
Black/Brown	**78.4%**	**83.9%**	**84.0%**	**82.3%**	**82.4%**	**21.6%**	**16.1%**	**16.0%**	**17.7%**	**17.6%**
White	**79.6%**	**81.9%**	**81.7%**	**78.9%**	**81.0%**	**20.4%**	**18.1%**	**18.3%**	**21.1%**	**19.0%**
Age Group										
18-29	68,360	81,539	80,471	10,481	240,851	4,018	3,006	2,172	410	9,606
30-39	44,945	52,212	54,024	10,943	162,124	6,520	5,126	4,363	996	17,005
40-49	29,922	38,250	43,430	8,301	119,903	9,468	8,494	8,374	1,722	28,058
50-59	15,318	21,007	25,909	5,835	68,069	9,970	10,067	11,531	2,388	33,956
60 or older	13,324	18,175	21,309	6,161	58,969	15,591	16,847	19,936	4,356	56,730
18-29	**94.4%**	**96.4%**	**97.4%**	**96.2%**	**96.2%**	**5.6%**	**3.6%**	**2.6%**	**3.8%**	**3.8%**
30-39	**87.3%**	**91.1%**	**92.5%**	**91.7%**	**90.5%**	**12.7%**	**8.9%**	**7.5%**	**8.3%**	**9.5%**
40-49	**76.0%**	**81.8%**	**83.8%**	**82.8%**	**81.0%**	**24.0%**	**18.2%**	**16.2%**	**17.2%**	**19.0%**
50-59	**60.6%**	**67.6%**	**69.2%**	**71.0%**	**66.7%**	**39.4%**	**32.4%**	**30.8%**	**29.0%**	**33.3%**
60 or older	**46.1%**	**51.9%**	**51.7%**	**58.6%**	**51.0%**	**53.9%**	**48.1%**	**48.3%**	**41.4%**	**49.0%**
Education - literate										
Illiterate	18,991	22,008	19,540	3,151	63,690	11,881	9,599	9,137	1,516	32,133
Literate	152,878	189,175	205,603	38,570	586,226	33,686	33,941	37,239	8,356	113,222
Illiterate	**61.5%**	**69.6%**	**68.1%**	**67.5%**	**66.5%**	**38.5%**	**30.4%**	**31.9%**	**32.5%**	**33.5%**
Literate	**81.9%**	**84.8%**	**84.7%**	**82.2%**	**83.8%**	**18.1%**	**15.2%**	**15.3%**	**17.8%**	**16.2%**
Work										
Employee	111,826	137,278	153,164	25,245	427,513	20,301	18,194	19,149	3,604	61,248
Unemployed	60,043	73,905	71,979	16,476	222,403	25,266	25,346	27,227	6,268	84,107
Employee	**84.6%**	**88.3%**	**88.9%**	**87.5%**	**87.5%**	**15.4%**	**11.7%**	**11.1%**	**12.5%**	**12.5%**
Unemployed	**70.4%**	**74.5%**	**72.6%**	**72.4%**	**72.6%**	**29.6%**	**25.5%**	**27.4%**	**27.6%**	**27.4%**
Health insurance										
With insurance	46,956	53,940	60,527	12,445	173,868	10,917	12,251	13,066	3,023	39,257
Without insurance	124,913	157,243	164,616	29,276	476,048	34,650	31,289	33,310	6,849	106,098
With insurance	**81.1%**	**81.5%**	**82.2%**	**80.5%**	**81.6%**	**18.9%**	**18.5%**	**17.8%**	**19.5%**	**18.4%**
Without insurance	**78.3%**	**83.4%**	**83.2%**	**81.0%**	**81.8%**	**21.7%**	**16.6%**	**16.8%**	**19.0%**	**18.2%**
Subject well-being										
Bad/very bad	3,388	4,821	5,104	1,564	14,877	8,242	7,286	8,655	1,823	26,006
Regular	27,111	37,323	40,741	9,696	114,871	23,604	22,256	24,159	4,753	74,772
Good/very good	141,370	169,039	179,298	30,461	520,168	13,721	13,998	13,562	3,296	44,577
Bad/very bad	**29,1%**	**39,8%**	**37.1%**	**46.2%**	**36.4%**	**70.9%**	**60.2%**	**62.9%**	**53.8%**	**63.6%**
Regular	**53.5%**	**62.6%**	**62.8%**	**67.1%**	**60.6%**	**46.5%**	**37.4%**	**37.2%**	**32.9%**	**39.4%**
Good/very good	**91.2%**	**92.4%**	**93.0%**	**90.2%**	**92.1%**	**8.8%**	**7.6%**	**7.0%**	**9.8%**	**7.9%**
Health service accessibility										
Same place	177,865	160,767	158,197	30,727	467,556	33,826	35,920	36,775	8,004	114,525
Not the same place	54,004	50,416	66,946	10,994	182,360	11,741	7620	9,601	1,868	30,830
Same place	**77.7%**	**81.7%**	**81.1%**	**79.3%**	**80.3%**	**22.3%**	**18.3%**	**18.9%**	**20.7%**	**19.7%**
Not the same place	**82.1%**	**86.9%**	**87.5%**	**85.5%**	**85.5%**	**17.9%**	**13.1%**	**12.5%**	**14.5%**	**14.5%**
Health service need (past two weeks)										
Needed	19,467	26,009	27,458	6,211	79,145	12,168	13,865	14,467	3,338	43,838
Not needed	152,402	185,174	197,685	35,510	570,771	33,399	29,675	31,909	6,534	101,517
Needed	**61.5%**	**65.2%**	**65.5%**	**65.0%**	**64.4%**	**38.5%**	**34.8%**	**34.5%**	**35.0%**	**35.6%**
Not needed	**82.0%**	**86.2%**	**86.1%**	**84.5%**	**84.9%**	**18.0%**	**13.8%**	**13.9%**	**15.5%**	**15.1%**
Hospitalization (past twelve months)										
Hospitalized	11,444	13,631	14,170	2,589	41,834	6,826	6,926	7,394	1,340	22,486
Not hospitalized	160,425	197,552	210,973	39,132	608,082	38,741	36,614	38,982	8,532	122,869
Hospitalized	**62.6%**	**66.3%**	**65.7%**	**65.9%**	**65.0%**	**37.4%**	**33.7%**	**34.3%**	**34.1%**	**35.0%**
Not hospitalized	**80.5%**	**84.4%**	**84.4%**	**82.1%**	**83.2%**	**19.5%**	**15.6%**	**17.9%**	**16.8%**	**16.8%**
Total	***171,869***	***211,183***	***225,143***	***41,721***	***649,916***	***45,567***	***43,540***	***46,376***	***9,872***	***145,355***
% Total	***79.0%***	***82.9%***	***82.9%***	***80.9%***	***81.7%***	***21.0%***	***17.1%***	***17.1%***	***19.1%***	***18.3%***

Source: Based on (SHI et al., 2021).

Multimorbidity seems to have an influence on people's perception of health according to subject well-being evaluation. Individuals with multiple chronic diseases consider their state of health as bad or very bad more frequently than people without multiple chronic diseases, and this perception was worst in 1998. Overall, individuals with multiple chronic diseases do not tend to think about their health as good or very good. There is no substantive difference in the rate of multimorbidity between the group with or without health insurance in all periods studied. Participants usually attend the same place, doctor, or health service when one needs healthcare. The majority of the participants in the study also declared that they did not seek any health-related place, service or professional recently (considering the past two weeks from the moment of the interview), and inform that were not hospitalized in the last year. Pearson chi-square tests showed that multimorbidity was significantly associated with the risk factors considered over the 15-year period in Brazil ($P<.001$) except for health insurance in 2013. The covariates most associated with multimorbidity were age and subject well-being.

6.3.2 Statistical model

Table 14 shows the odds ratio (OR) of multimorbidity over the period 1998 – 2013 for adults, and Table 15 shows those estimations for the elderly group people with the binary logistic regression model (BLRM). Overall, the prevalence of multimorbidity is higher for women and increases with age. For instance, the odds of multimorbidity for female adults increased by 73% compared with males (OR=1.73) and the group between 50 and 59 had almost twelve times odds (OR=11.89) to develop multiple chronic diseases compared with the people between 18 and 29 years old.

The parameter estimations of BLRM analysis focused in the association between multimorbidity and health characteristics are shown in Tables 16 and 17.

In general, the participants without multiple chronic diseases naturally consider their health status as either good or regular. However, the individuals with multimorbidity responded that their SWB was almost ten times likely to be perceived as “bad/very bad” (adults OR=12.85 and elderly OR=8.35) than ‘good/very good’ in all study cohorts. The odds of individuals with multimorbidity utilizing the same healthcare unit were about 30% increased than the other people. In addition, the participants with multimorbidity showed 50% greater odds of needing health services (adults OR=2.73; elderly OR=2.16), and to be hospitalized (adults OR=2.29; elderly (OR=2.37) compared with non-multimorbidity groups.

Table 14 - Multimorbidity in Brazilian adults - BLRM results

ADULTS (18-59)	**1998**		**2003**		**2008**		**2013**		**overall**	
	[c]OR^{crude}	**[d]OR^{adjust}**	**OR^{crude}**	**OR^{adjust}**	**OR^{crude}**	**OR^{adjust}**	**OR^{crude}**	**OR^{adjust}**	**OR^{crude}**	**OR^{adjust}**
Gender										
Male	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Female	1.83	1.77 (1.72-1.83)	1.97	1.82 (1.77 -1.88)	1.79	1.60 (1.54-1.64)	1.88	1.79 (1.59 - 2.02)	1.86	1.73 (1.67 - 1.79)
		P<.001		P<.001		P<.001		P<.001		P<.001
Race/colour										
White	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Black/Brown	0.71	0.66 (0.52-0.83)	1.11	0.99 (0.82 - 1.21)	1.16	1.12 (0.95-1.33)	0.89	0.94 (0.60 - 1.47)	0.97	0.91 (0.76 - 1.08)
Asian/Indigenous	1.20	1.19 (1.14-1.23)	0.96	1.12 (1.08 - 1.16)	0.97	1.13 (1.09-1.67)	0.88	1.02 (0.91 - 1.15)	0.98	1.09 (1.05 - 1.13)
		P<.001		P<.001		P<.001		P=.891		P<.001
Age group										
18 to 29	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
30 to 39	2.54	2.66 (2.54-2.79)	2.71	2.80 (2.65 - 2.96)	2.98	3.10 (2.93-3.29)	2.32	2.41 (1.94 - 2.98)	2.61	2.70 (2.55 – 2.85)
40 to 49	5.56	5.92 (5.65-6.20)	6.13	6.32 (6.00 - 6.65)	7.12	7.29 (6.91-7.70)	5.60	5.69 (4.64 - 6.99)	5.95	6.08 (5.77 – 6.40)
50 to 59	11.37	11.61 (11.05-12.20)	13.29	13.14 (12.48 - 13.84)	16.42	15.86 (15.01-16.76)	10.23	10.13 (8.25 - 12.44)	12.18	11.89 (11.27 – 12.55)
		P<.001		P<.001		P<.001		P<.001		P<.001
Education										
Literate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Illiterate	2.30	1.39 (1.32-1.45)	1.84	1.20 (1.16 - 1.28)	1.94	1.23 (1.17-1.30)	1.83	1.13 (0.91 - 1.41)	2.02	1.34 (1.28 – 1.41)
		P<.001		P<.001		P<.001		P=.276		P<.001
Work										
Employee	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Unemployed	1.63	1.33 (1.29-1.38)	1.76	1.49 (1.44 - 1.54)	1.96	1.67 (1.61-1.73)	1.75	1.42 (1.26 - 1.60)	1.78	1.47 (1.42 – 1.52)
		P<.001		P<.001		P<.001		P<.001		P<.001
Region										
North	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Northeast	0.84	0.70 (0.64-0.77)	0.90	0.78 (0.72 - 0.85)	1.04	0.94 (0.87-1.02)	1.09	0.98 (0.83 - 1.15)	1.01	0.90 (0.85 – 0.95)
Southeast	0.66	0.59 (0.54-0.64)	1.07	0.91 (0.84 - 0.98)	1.30	1.16 (1.07-1.25)	1.32	1.20 (1.01 - 1.42)	1.10	0.99 (0.93 – 1.05)
South	0.84	0.80 (0.72-0.88)	1.35	1.23 (1.13 - 1.33)	1.59	1.48 (1.35-1.62)	1.87	1.74 (1.43 - 2.12)	1.42	1.35 (1.26 – 1.44)
Midwest	0.87	0.85 (0.77-0.94)	1.26	1.19 (1.10 - 1.30)	1.31	1.27 (1.16-1.39)	1.44	1.36 (1.14 – 1.62)	1.25	1.22 (1.15 – 1.30)
		P<.001		P<.001		P<.001		P<.001		P<.001
Health insurance										
With insurance	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Without insurance	1.26	1.29(1.25-1.35)	0.95	1.05(1.01-1.09)	1.04	1.10(1.06-1.15)	1.05	1.07(0.95-1.20)	1.06	1.12(1.08-1.16)
		P<.001		P=.015		P<.001		P=.267		P<.001

Source: Based on (SHI et al., 2021).

Table 15 - Multimorbidity in Brazilian elderly - BLRM results

ELDERLY (60+)	1998		2003		2008		2013		Overall	
	OR^crude	OR^adjust	OR^crude	OR^adjust	OR^crude	OR^adjust	OR^crude	OR^adjust	OR^crude	OR^adjust
Gender										
Male	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Female	1.81	1.60 (1.52-1.68)	1.78	1.56 (1.49 -1.64)	1.76	1.58 (1.51-1.65)	1.50	1.42 (1.22 - 1.65)	1.68	1.52 (1.44 - 1.60)
		P<.001		P<.001		P<.001		P<.001		P<.001
Race/colour										
White	1.00	1.00	1.00	1.00	1.00	1.00			1.00	1.00
Black/Brown	0.58	0.64 (0.47-0.85)	0.56	0.57 (0.43 - 0.75)	0.70	0.70 (0.57-0.87)	N/A	N/A	0.70	0.72 (0.57 - 0.91)
Asian/Indigenous	1.18	1.10 (1.03-1.17)	0.94	1.05 (0.99 - 1.11)	0.93	1.06 (1.01-1.11)	N/A	N/A	0.95	1.03 (0.97 - 1.09)
		P<.001		P<.001		P<.001				P<.001
Education										
Literate	1.00	1.00	1.00	1.00	1.00	1.00			1.00	1.00
Illiterate	1.49	1.32 (1.24-1.41)	1.11	1.15 (1.09 - 1.22)	1.05	1.12 (1.06-1.18)	N/A	N/A	1.18	1.23 (1.16 – 1.30)
		P<.001		P<.001		P<.001				P<.001
Work										
Employee	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Unemployed	1.79	1.55 (1.45-1.65)	1.98	1.70 (1.60 - 1.80)	1.90	1.66 (1.57-1.75)	1.54	1.42 (1.16 - 1.74)	1.76	1.53 (1.44 – 1.63)
		P<.001		P<.001		P<.001		P=.001		P<.001
Region										
North	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Northeast	0.88	0.84 (0.73-0.95)	0.83	0.82 (0.74 - 0.91)	0.87	0.83 (0.75-0.91)	1.38	1.34 (1.08 - 1.67)	1.06	1.01 (0.93 – 1.10)
Southeast	0.74	0.78 (0.69-0.89)	1.01	1.00 (0.90 - 1.11)	1.09	1.04 (0.94-1.14)	1.78	1.75 (1.40 - 2.18)	1.22	1.21 (1.11 – 1.33)
South	0.87	0.96 (0.84-1.11)	1.21	1.27 (1.13 - 1.42)	1.28	1.27 (1.14-1.41)	2.28	2.28 (1.77 - 2.92)	1.49	1.53 (1.39 – 1.69)
Midwest	0.89	0.96 (0.82-1.11)	1.16	1.20 (1.06 - 1.35)	1.22	1.20 (1.07-1.34)	1.64	1.63 (1.28 – 2.07)	1.29	1.31 (1.19 – 1.44)
		P<.001		P<.001		P<.001		P<.001		P<.001
Health insurance										
With insurance	1.00	1.00	1.00	1.00	1.00	1.00	1.00		1.00	1.00
Without insurance	1.27	1.14(1.07-1.22)	0.92	0.93(0.88-0.99)	0.85	0.87(0.82-0.92)	0.86	N/A	0.94	0.93(0.88-0.99)
		P<.001		P=.022		P<.001				P=.019

Source: Based on (SHI et al., 2021).

Table 16 - Association between multimorbidity, subjective well-being (SWB) and health service utilization for Brazilian adults - BLRM results

	ADULTS (18-59)	**1998**		**2003**		**2008**		**2013**		**overall**	
		[c]OR^{c}	**[d]OR^{adjust}**	**OR^{c}**	**OR^{adjust}**	**OR^{c}**	**OR^{adjust}**	**OR^{c}**	**OR^{adjust}**	**OR^{c}**	**OR^{adjust}**
Subjective well-being (bad/very bad)	Without multimorbidity	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	With multimorbidity	21.32	13.90(12.98-14.88)	17.29	12.81(12.01-13.65)	24.04	18.17(17.04-19.38)	12.08	10.02(8.30-12.10)	17.70	12.85(12.07-13.68)
			P<.001		P<.001		P<.001		P<.001		P<.001
Health service accessibility	Without multimorbidity	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	With multimorbidity	1.29	1.28(1.23-1.33)	1.45	1.32(1.26-1.38)	1.57	1.43(1.38-1.49)	1.42	1.33(1.17-1.52)	1.41	1.31(1.26-1.36)
			P<.001		P<.001		P<.001		P<.001		P<.001
Health service need	Without multimorbidity	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	With multimorbidity	2.90	2.67(2.57-2.77)	3.35	2.82(2.72-2.93)	3.42	2.98 (2.87-3.09)	3.06	2.62(2.33-2.94)	3.16	2.73(2.63-2.83)
			P<.001		P<.001		P<.001		P<.001		P<.001
Hospitalization	Without multimorbidity	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	With multimorbidity	2.28	2.22(2.11-2.33)	2.61	2.46(2.35-2.58)	2.71	2.64(2.52-2.77)	2.71	1.89(1.61-2.22)	2.40	2.29 (2.19-2.39)
			P<.001		P<.001		P<.001		P<.001		P<.001

[a]OR: Odds Ratio; [b]CI: Confidence Interval; [c]OR^{C}: Odds Ratio Crude; [d]Odds Ratio Adjusted: binary logistic regression model adjusted by multimorbidity, sex, colour/race, literacy, work, region and health insurance.

Source: Based on (SHI et al., 2021).

Table 17 - Association between multimorbidity, subjective well-being (SWB) and health service utilization for Brazilian elderly - BLRM results

	ELDERLY (60+)	**1998**		**2003**		**2008**		**2013**		**overall**	
		OR^c	**OR^{adjust}**	**OR^c**	**OR^{adjust}**	**OR^c**	**OR^{adjust}**	**OR^c**	**OR^{adjust}**	**OR^c**	**OR^{adjust}**
Subjective well-being (bad/very bad)	Without multimorbidity	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	With multimorbidity	11.66	11.49(10.41-12.69)	7.61	8.81(8.07-9.63)	7.60	9.16(8.43-9.96)	4.95	6.23(4.93-7.86)	7.24	8.35(7.69-9.07)
			P<.001		P<.001		P<.001		P<.001		P<.001
Health service accessibility	Without multimorbidity	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	With multimorbidity	1.36	1.38(1.30-1.48)	1.55	1.43(1.34-1.52)	1.51	1.43(1.35-1.51)	1.25	1.17(0.98-1.40)	1.38	1.30(1.23-1.38)
			P<.001		P<.001		P<.001		P=.079		P<.001
Health service need	Without multimorbidity	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	With multimorbidity	2.56	2.59(2.41-2.78)	2.78	2.62(2.47-2.79)	2.58	2.46(2.32-2.60)	1.81	1.71(1.44-2.02)	2.26	2.16(2.02-2.31)
			P<.001		P<.001		P<.001		P<.001		P<.001
Hospitalization	Without multimorbidity	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	With multimorbidity	2.32	2.32(2.14-2.52)	2.55	2.47(2.29-2.66)	2.46	2.39(2.23-2.56)	2.32	2.31(1.86-2.88)	2.43	2.37(2.21-2.56)
			P<.001		P<.001		P<.001		P<.001		P<.001

[a]OR: Odds Ratio; [b]CI: Confidence Interval; [c]OR^C: Odds Ratio Crude; [d]Odds Ratio Adjusted: binary logistic regression model adjusted by multimorbidity, sex, colour/race, literacy, work, region and health insurance.

Source: Based on (SHI et al., 2021).

6.3.3 Multimorbidity in Brazil

It is estimated that between 16% and 57% of adults in developed countries have multiple chronic conditions (HAJAT; STEIN, 2018). The Brazilian females had around 70% more chance of having multimorbidity than the male adults (OR=1.77). The ORs were considerably higher for women and grew with age in the period of 1998-2013.

Differences in multimorbidity occurrences between gender and the higher use of health care services by individuals with multimorbidity possibility will remain largely unchanged in the near future in Brazil, as the distribution between these groups is not expected to change (IBGE, 2021). Given the higher life expectancy for women (80.25 years in 2020 and 81.22 years in 2025) (IBGE, 2021), multiple CDs create additional expenses for the health care system (BUJA et al., 2018). Participants who self-declared as Black/Brown presented less chance of multimorbidity in comparison to those who self-declared as White in this study. Race is not entirely a determinant factor worldwide (TSAI et al., 2016), but it might reflect those social conditions and income are important factors associated with multimorbidity. Blacks/Browns in Brazil have lower income and less opportunity to access health insurance, and worse housing conditions (BRAZIL, 2017). Brazilian adults without education showed higher chance of developing multimorbidity. Socioeconomic factors as sex and education increase exposure to risks and may lead to a reduced awareness of health status and care.

Unemployment showed higher risk of multimorbidity and it is comparable to another Brazilian study (RZEWUSKA et al., 2017) in which the unemployed showed a greater prevalence of multimorbidity. Over the study period, the multimorbidity prevalence gradually increased in the South and declined in the North. Geographic analysis in complex and multi-factors can be explored in future studies can to better understand the distribution variations.

The analysis of health characteristics and behaviors has not been explored in previous multimorbidity Brazilian studies using data from PNAD and PNS. There was a significant relationship between the subject well-being (SWB) and multimorbidity for all four cohorts. Individuals with multimorbidity perceived their SWB to be much worse than that of other groups, even though no causal relationship could be established from cross-sectional surveys. Brazilians with multimorbidity used health services more frequently were hospitalized compared with the group without multimorbidity.

6.3.4 Limitations

Some survey questions changed over the time, yet this modification is unlikely to impact the study outcomes (e.g., “Any doctor ever gives you the diagnosis of…” to “Did any doctor or health professional say that you have…”. Moreover, modifications in the data collection methodology could influence the geographic evaluation and the calculation of prevalence of NCDs by region. Although self-reporting is widely used in public health research (WU et al., 2014), this could introduce bias in this type of study without medical documents, for example. This research evaluated the impact of multimorbidity on various outcomes that could lead to possible reverse causality and future studies are needed to address this issue.

6.4 FINAL CONSIDERATIONS

Different physical and mental morbidities were explored in previous studies in Brazil with, however restricted ages groups, geographic areas and number of participants. To the extent of the best knowledge, our study is the first study about multimorbidity in the Brazilian population integrating two national survey datasets in Brazil (PNAD and PNS). The total sample in this study includes 795,271 individuals and besides demographic aspects connect health issues as subject well-being, use of health assistance and hospitalization. The sample size and time variation analysis are central issues in this study.

Multimorbidity implies a great risk on human health, decreases people’s quality of life and consequently causes disability and death. Expressive information about co-occurrence of chronic diseases can contribute to visualize what has been happening in a temporal view. By analyzing the variety and uncertainty of the different period of data, this study could assist for the better understanding the patterns of multimorbidity in Brazil. The dynamic configuration developed to present the distribution of multimorbidity could support healthcare policies for intervention and prevention on multimorbidity in Brazil.

7 MULTI-PERIOD OUTRANKING-BASED DECISION-MAKING METHOD

This chapter aims to address the research objective 5, developing an outranking decision model to support health decision-making considering a temporal perspective. In the current literature, there is a lack in the multicriteria decision methods/analysis (MCDM/MCDA) adapted to multiple periods of time, even more when it is considered an outranking decision approach, based on peer-to-peer comparison between alternatives. In the health context, for example, a better understanding of chronic diseases patterns, connected with the development/adaptation of decision methods could support policies for prioritize intervention and prevention, ranking certain regions or vulnerable groups considering multiple years and diseases progress.

7.1 CONTEXTUALISATION

The triple aim of population health management is used focused in to realize improvements in population health and quality of care seeking cost reduction (STEENKAMER et al., 2017). In this context, prevention is essential when addressed problems related to chronic diseases, comprehending the most vulnerable groups, areas and the consequences for this complex health problem. The main question that directed the planning of this study was how to monitor and compare chronic diseases in different geographic areas, considering the changes and evolution of the health status of the population overtime? It was evaluated objective factors, as the presence of multiple chronic diseases and the need for hospitalizations and health assistance since it has been observed that chronic illnesses increase the risk of needing medical assistance and its related costs. Also considered a subjective perspective of individuals with their self-health assessment, observing that individuals with chronic diseases tend to consider their health worse compared to people without chronic diseases. Multicriteria methodologies can be an option in this context to support decision-making in this health context, especially outranking approaches that lead with non-compensatory aggregation in the evaluation of alternatives.

In recent years, different outranking approaches have been introduced into the field with practical applications such as project investment selection (YI; LI; ZHANG, 2021), energy efficiency (SOLA; MOTA; KOVALESKI, 2011), or social indicators (PEREIRA; MOTA, 2016). The majority of the current scholars mainly study outranking decision-making problems on a single time period. Consequently, data available from past times are not effectively used to support decision making. There is still a lot to be explored in multi-period and multi-criteria methodologies from the increasing availability of data in the context of the computational systems evolution and big data. When available data analysis using different periods of time is challenging, but also can lead to a more consistent decision making.

Adaptations of traditional multicriteria models can be an effective approach to assist multi-period decision making process. In real-world applications, one of the usual difficulties is to assign weights to attributes due the complex decision environment. Many researchers have successfully devoted special attention to this subject (SILVA, F. F. et al., 2021). Properly determining the time sequence weight is an additional challenge for evaluations using different periods of time (LEE et al., 2019; ZHANG, H. et al., 2019).

The design of this study considers an outranking decision-making methodology that considers a temporal perspective using a ROC weighted operator for multi-attribute (ALMEIDA FILHO et al., 2018) and focused on allocating weights based on the closeness of historical data to the latest information for multi-periods (YANG; HUANG, 2017).

The study was organized into four main sections. In this first section, an introduction and an overview of recent literature review on multi-period decision making. In the second section, the procedures and sequence of activities adopted are described. In the third section, a numerical problem and the main results are presented. In the fourth and last section, a conclusion of the multi-period health application is summarized.

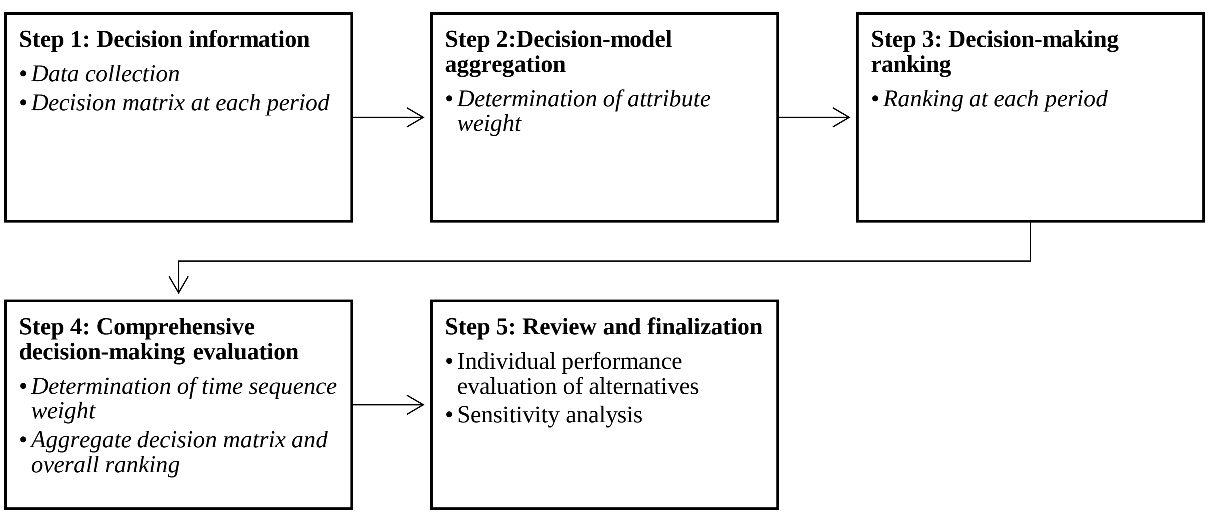
7.1.1 Multi-period multi-criteria methodologies

There is substantial literature on multicriteria decision problems, nevertheless, most studies focus on decisions under a single static time-sequence and overlook the historical information. According to the literature review, methods for decision problems concerning multi-period multi-criteria are underexplored. Even in articles published with multi-period methodologies, the assessment is performed for each period disconnectedly (WEI et al., 2020; ZHANG, L. et al., 2020). Studies can also be found with the assessment performed from an aggregation in a comprehensive decision-making matrix (YANG; HUANG, 2017; ZHANG, H. et al., 2019). The aggregation of data from different periods of time and the suitable choice of the weight of these periods are central approaches in the adaptation to multi-period decision methodologies. According to the literature review, just Frini and Ben Amor (2019) have proposed an outranking methodology with temporal aggregation through the MUPOM method in the context of sustainable development. For instance, in this application, criteria weights were based on the AHP method using a 9-point semantic scale and period weights were calculated considering each possible binary relation at each period. The related literature is composed of methods to dynamic stochastic problems (YANG; HUANG, 2017), triangular fuzzy numbers (DAI; ZHONG; QI, 2020; ZHANG, H. et al., 2019) and combining models like TOPSIS (LEE et al., 2019; WEI et al., 2020), AHP (FRINI; BEN AMOR, 2019) and multi-period evaluation proposals.

7.2 METHODS

In order to deal with the temporal information, this paper proposes a multi-criteria approach to monitor interconnect chronic diseases risk factors overtime. Different geographic areas will be alternatives in the decision problem representing specific city, states or divisions in a country, used to assess the status of population health. This study proposes a multi-period evaluation from an outranking decision-making approach using the PROMETHEE II method. The methodology was built in five stages, according to Figure 17.

Figure 17 - Multi-period methodology



Source: The author (2022).

Step 1: Decision information

The first step includes the procedure of planning, collecting, and analyzing relevant data for the specific problem. One of the challenges is to understand the big data analytics capabilities in the health context (WANG; KUNG; BYRD, 2018) as well as to find reliable databases available. Data understanding and preparation (collect, explore, clean, etc.) (MIKUT; REISCHL, 2011) involves phases that require a lot of time and need to be well structured to do not compromise the entire project. As the proposal comprises multiple periods of time, it is necessary to ensure that the selected variables are available for all periods of time.

In this study, it was found common and appropriate variables in the National Sample Household Survey (PNAD) of 1998, 2003 and 2008 and The National Health Research of 2013 (PNS). PNAD and PNS are extensive cross-sectional Brazilian researches with participants' health information from different geographic areas in Brazil.

The originals decision matrix is defined by X = $(x_{i,j})_{n\,x\,m}$, where x_{ij} represents the evaluation value of the j-th alternative on the i-th criterion, from different periods of time (t_1, $t_2, \dots, t_k$), as follows (Equation 6):

$$X_k = \begin{bmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{bmatrix} \tag{6}$$

Step 2: Decision-model aggregation

Following procedures for building multicriteria decision models (ALMEIDA, A.T. d. et al., 2015; ROY, 1991), preferential information over the set of criteria is required under the outline of an outranking approach (BELTON; STEWART., 2002). Additionally, time weighting must also be explored and defined, observing the data of multiple periods. At the end, we build our approach under the basis of the PROMETHEE II method (Preference Ranking Organization Method for Enrichment Evaluations), being able to produce a complete preorder of alternatives. PROMETHEE is a well-known MCDM method, being widely applied to support decision makers (AGARWAL et al., 2021; BEHZADIAN et al., 2010). It is an outranking-based method whose advantage is the simplicity in pairwise comparisons (BRANS; VINCKE; MARESCHAL, 1986).

7.2.1 Determination of attribute weight

In this step, it is executed the determination of weights that is a very relevant aspect in the multicriteria decision modeling process as well as the determination of concordance and discordance thresholds, when necessary. These aspects are already widely discussed in the literature on multicriteria decision-making (SILVA, F. F. et al., 2021). In this study, the determination of weights is associated with the assessment of each time period unconnectedly. In multi-periods problems, it will be necessary additionally the determination of the time sequence weight that will be presented in step 4.

Criteria weight are represented by a constant scale in which the sum of all values equals one. Accordingly, W = {w_1, w_2, ..., w_n} is the set of all weights in which $w_1, w_2, \ldots w_n \geq 0$. For this proposal we do not use concordance and discordance thresholds.

Different procedures can be used in order to represent the decision maker value system, as EW (Equal Weights), RS (Rank-Sum), RR (Reciprocal of the Rank) and ROC (Rank-Order Centroid). In this research, we used the ROC weighting (Equation 7) since the literature has already indicated that this methodology better respond to the structure of PROMETHEE II method (ALMEIDA FILHO et al., 2018). The ROC procedure was utilized to derive the related weights, which correspond to the coordinates averages that define the centroid (BARRON, 1992; BARRON; BARRETT, 1996).

$$Wi(ROC) = \frac{1}{n}\sum_{r=1}^{n}\frac{1}{r} \qquad (7)$$

Accordingly, n is the number of criteria, and r = 1, 2, ..., n is the ordered position of the criteria. Using the ROC procedure, it is possible to identify a single set of weights to be representative of all possible weight combinations that are permissible and consistent with the established linear constraints (AHN, 2011)

Step 3: Decision-making ranking

In this study, the alternatives were evaluated according to the criteria and their weights. Furthermore, an outranking relation was established for each period based on PROMETHEE method.

7.2.2 PROMETHEE method

PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluation) is a commonly method in multi-criteria decision making that uses pair-wise comparison to establish the outranking relation between the performance of alternatives (BEHZADIAN et al., 2010; BRANS; MARESCHAL, 2005). This method is based on building an outranking relation and to explore this relation to support the decision process (BRANS; MARESCHAL, 2002). The PROMETHEE I is applied for a partial ranking of the alternatives while the PROMETHEE II is applied for a complete ranking. The overview of the essential operating rules of PROMETHEE II is expressed by phase 1 to phase 4, in Table 18 (Equations 8 to 12).

Step 4: Comprehensive decision-making evaluation

In this step two main procedures need to be addressed: the period weights and the comprehensive decision-making evaluation of all information over time.

7.2.3 Determination of time sequence weight

The definition of weights in multicriteria decision problems considering multiple periods of time is still underexplored in the literature. It can be found studies integrating different methodologies with weights based on distances between the values of alternatives, linear programming results (DAI; ZHONG; QI, 2020; YANG; HUANG, 2017; ZHANG, H. et al., 2019), or considering the expert’s opinion (LEE et al., 2019). In the unique outranking multi-period method that we have knowledge (MUPOM) (FRINI; BEN AMOR, 2019), temporal aggregation is based in the analysis of the possible combinations of the binary relation that are computed at each period, determining the aggregated preference relation. There is no direct determination of weights as in the previous studies explored (DAI; ZHONG; QI, 2020; LEE et al., 2019; YANG; HUANG, 2017; ZHANG, H. et al., 2019)

Table 18 - Summary of phases for the PROMETHEE II method

Phase 1: Determination of deviations based on pair-wise comparisons. $F_j(a,b) = g_i(a) - g_i(b)$ (8) Where $F_i(a,b)$ denotes the difference between the evaluations of *a* and *b* on each criterion *j*.
Phase 2: Calculation of an overall or global preference index. $\forall$ a,b $\in$ A $\pi(a,b) = \sum_{j=1}^{n} F_j(a,b)\, w_j$ (9) Where $\pi(a,b)$ of *a* over *b* (from 0 to 1) is defined as the weighted sum for each criterion, and w_j is the weight associated with *j-th* criterion.
Phase 3: Calculation of outranking flows. $\emptyset^+(a) = \sum_{b \in A} \pi(a,b)$ (10) $\emptyset^-(a) = \sum_{b \in A} \pi(b,a)$ (11) Where $\emptyset^+(a)$ positive outranking flow, indicates the advantage of the alternative *a* over all other alternatives *b* in the set of alternatives *A*. $\emptyset^-(a)$ denote the negative outranking flow, indicating the disadvantage of the alternative *a* compared with all other alternatives *b* in the set of alternatives *A*.
Phase 4: Calculation of the net outranking flow. PROMETHEE II – complete rankings. $\emptyset(a) = \emptyset^+(a) - \emptyset^-(a)$ (12) Where $\emptyset(a)$ denotes the net outranking flow for each alternative (liquid flow).

Source: Based on (BRANS; MARESCHAL, 2005; BEHZADIAN et al., 2010).

In this study, we have chosen to obtain the time-sequence weights prioritizing periods closer to present than to past (YANG; HUANG, 2017), adjusting the previously methodology applied to a dynamic stochastic decision-making method with multi-period evaluation. The preferences of the decision maker are used in the elicitation of weights of each period time degree (λ) of the time sequence weight vector. λ describes de degree of attention specified by the decision maker. Smaller values of λ indicates that higher is the importance given to more recent periods. As presented (YANG; HUANG, 2017), based on Euclidean distance, positive and negative ideal time-weight vectors are obtained (Equation 13 and 14) and the closeness of time-weight vector to the ideal time-weight vector can be calculated (Equation 15). According to the solution of a nonlinear programming problem (Equation 16), the weights of the periods can be found. A higher value of C indicates that more attention is being attached to recent information.

$$d(w(t_k), w(t_k)^+) = \sqrt{\sum_{k=1}^{p-1} w\ (t_k)^2\ + (1 - w\ (t_p))^2} \tag{13}$$

$$d(w(t_k), w(t_k)^-) = \sqrt{(1 - w\ (t_1))^2 + \sum_{k=2}^{p} w\ (t_k)^2} \tag{14}$$

$$C\ = \frac{d(w(t_k), w(t_k)^-)}{d(w(t_k), w(t_k)^+) +\ d(w(t_k), w(t_k)^-)} \tag{15}$$

$$max \quad C\ = \frac{\sqrt{(1 - w\ (t_1))^2 +\ \sum_{k=2}^{p} w\ (t_k)^2}}{\sqrt{\sum_{k=1}^{p-1} w\ (t_k)^2\ + (1 - w\left(t_p\right))^2 +\ \sqrt{(1 - w\ (t_1))^2 +\ \sum_{k=2}^{p} w\ (t_k)^2}}}$$

$$s.t. \qquad \lambda =\ \sum_{k=1}^{p} \frac{p-k}{p-1}\ w(t_k)\ , \tag{16}$$

$$\sum_{k=1}^{p} w(t_k) = 1,$$

$$\mathrm{w(tk)} \epsilon\ [0{,}1], \mathrm{k} = 1, 2, \dots, \mathrm{p}.$$

7.2.4 Decision matrix aggregation and overall ranking

Considering each decision matrix X_k (as presented in step 1) and adapting the aggregation procedure (YANG; HUANG, 2017), the multi-period evaluation is based on a weighted arithmetic average operator (Equation 17).

$$\sum_{k=1}^{p} w\,(t_k)\;\; x_{ij}(t_k) \tag{17}$$

Accordingly, $w(t_k)$ is the weight of the time sequence $t_k(k=1,\ 2,\ldots,p)$, $w(t_k)\ \epsilon\ [0,1]$, $\sum_{k=1}^{p} w(t_k)=1$. Thus, a comprehensive decision-making matrix can be defined and an overall evaluation of alternatives can be integrated into the final ranking by PROMETHEE II, as presented in step 3.

Step 5: Review and finalization

This final step is the opportunity to analyze the results, evaluate the individual performance of alternatives, execute sensitivity analysis and draw conclusions. Graphic information can help to understand conflicts that have to be solved in making a decision observing the distribution of criteria. GAIA plane uses a dimension-reduction technique based on principal components analysis (PCA) and the graph shows the first two main components (called U and V). Similar alternatives appear close to each other, criteria expressing conflicting preferences are represented by axes oriented in opposite directions and the longer the axis, the criterion has a more relative discriminating power (VPSOLUTIONS, 2013).

7.3 RESULTS AND DISCUSSION

Health needs multiple indicators to assess different perspectives. Health assessments can use both objective characteristics as the number of diseases as well as subjective measures such as self-rated health referring to an individual's judgment of one’s overall health status (ARAÚJO et al., 2018; DESALVO et al., 2006). For instance, subject well-being reported as “very good”, “good”, “fair”, “poor”, or “very poor”. This study will present an illustrative case of study related to health evaluation in different with a geographic perspective using real information from a national health research in Brazil.

7.3.1 Decision information

This study was designed to consider objective and subjective factors that influence public health risks. The model included health challenges as measures of multiple chronic diseases, hospitalizations and need of health assistance for the population. It was also considered the self-health assessment of individuals since the concepts about health consider "*health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity*" (WHO, 2020a).

Supposing that the set of alternatives is represented by 5 (five) geographic areas: A= $\{A_1, A_2, A_3, A_4, A_5\}$ (representing respectively the regions of Brazil: North, Northeast, Southeast, South, and Midwest). The criteria are the subject well-being informed bad/very bad (C_1), multiple chronic diseases (C_2), hospitalizations (C_3) and health assistance (C4). Criteria set C= $\{C_1, C_2, C_3, C_4\}$ and criteria weight W= $\{w_1, w_2, w_3, w_4\}$. Each geographic area represented by the five alternatives have data from four different years: $t_k = \{t_1, t_2, t_3, t_4\}$ (representing the years of 2003, 2008, 2013 and 2019). The time sequence weight is considered as $W_{tk} = \{w_{t1}, w_{t2}, w_{t3}\}$. Decision matrices in different periods are shown in Tables 19 to 22.

Table 19 - Decision matrix at period t1

	C_1	C_2	C_3	C_4
A_1	4.81	15.11	8.98	13.66
A_2	6.39	15.18	8.22	14.25
A_3	3.89	17.47	7.25	16.66
A_4	4.34	20.50	8.94	17.15
A_5	4.67	18.13	9.88	14.94

Source: The author (2022).

Table 20 - Decision matrix at period t2

	C_1	C_2	C_3	C_4
A_1	5.72	13.89	8.83	12.14
A_2	6.38	15.11	7.75	13.92
A_3	4.33	18.46	7.53	16.91
A_4	5.21	20.97	8.76	17.36
A_5	4.48	17.51	9.86	14.75

Source: The author (2022).

Table 21 - Decision matrix at period t3

	C_1	C_2	C_3	C_4
A_1	8.40	14.31	8.40	14.27
A_2	7.32	17.14	7.32	16.44
A_3	6.61	20.83	6.61	20.17
A_4	9.67	25.62	9.67	22.06
A_5	8.78	20.16	8.78	16.85

Source: The author (2022).

Table 22 - Decision matrix at period t4

	C_1	C_2	C_3	C_4
A_1	3.63	16.68	6.94	16.85
A_2	5.74	20.86	7.02	19.39
A_3	3.73	25.20	7.83	24.22
A_4	3.31	27.00	8.35	23.66
A_5	3.34	21.02	9.17	20.00

Source: The author (2022).

7.3.2 Decision-model aggregation

As previously detailed in the methodology, PROMETHEE II method was chosen for this study. The determination of attribute weight was performed based on ROC weights procedure (BARRON; BARRETT, 1996) the set of criteria weight $w= \{w_1, w_2, w_3, w_4\}$, where $w_1=0.5208$; $w_2=0.2708$; $w_3=0.1458$; $w_4=0.0625$. The order of criteria (C1, C2, C3, C4) was established by the knowledge of researchers, nevertheless, we suggest that this ordering is also carried out with decision makers specific to each problem evaluated.

7.3.3 Decision-making ranking

In this step, the PROMETHEE II method was executed with the support of the Visual PROMETHEE software (MARESCHAL, 2013) for each period of time (Tables 23 to 26). At the end, it was possible to find a ranking of the alternatives in four different periods of time (Table 27).

Table 23 - Outranking relations at period t1

	Phi	**Phi^+**	**Phi^-**
A_3	0.6354	0.8177	0.1823
A_5	0.0000	0.5000	0.5000
A_4	-0.0729	0.4635	0.5365
A_1	-0.2812	0.3594	0.6406
A_2	-0.2813	0.3594	0.6406

Source: The author (2022).

Table 24: Outranking relations at period t2

	Phi	Phi$^+$	Phi$^-$
A_3	0.5000	0.7500	0.2500
A_1	0.1146	0.5573	0.4427
A_4	0.0000	0.5000	0.5000
A_5	-0.2813	0.3594	0.6406
A_2	-0.3333	0.3333	0.6667

Source: The author (2022).

Table 25 - Outranking relations at period t3

	Phi	Phi$^+$	Phi$^-$
A_3	0.5000	0.7500	0.2500
A_5	0.5000	0.7500	0.2500
A_1	0.3333	0.6667	0.3333
A_2	-0.3333	0.3333	0.6667
A_4	-1.000	0.0000	1.0000

Source: The author (2022).

Table 26 - Outranking relations at period t4

	Phi	Phi$^+$	Phi$^-$
A_2	0.4791	0.7396	0.2604
A_3	0.1459	0.5729	0.4271
A_1	0.1146	0.5573	0.4427
A_5	-0.2813	0.3594	0.6406
A_4	-0.4583	0.2708	0.7292

Source: The author (2022).

Table 27 - Outranking relations per time period

Ranking	Period t1	Period t2	Period t3	Period t4
1	A3	A3	A2	A1
2	A1	A5	A3	A4
3	A4	A1	A1	A5
4	A5	A2	A5	A2
5	A2	A4	A4	A3

Source: The author (2022).

7.3.4 Comprehensive decision-making evaluation

Setting λ=0.4, that is time degree parameter (YANG; HUANG, 2017), presented in the step 4, the period weights calculated are t_1=0.255; t_2=0.218;.t_3=0; t_4=0.527. The next procedure is to find the aggregated decision matrix. A weighted arithmetic average operator under four different times were calculated, according to Equation 17. The comprehensive decision-making matrix is presented in Table 28. At the end, the alternatives are then ranked according to their overall performances (Table 29).

Table 28 - Weighted decision making matrix

	C_1	C_2	C_3	C_4
A_1	6.94	14.38	8.64	13.59
A_2	6.88	16.19	7.63	15.32
A_3	5.43	19.49	6.99	18.57
A_4	7.37	23.32	9.28	19.79
A_5	6.79	19.04	9.30	15.90

Source: The author (2022).

Table 29 - Comprehensive outranking relations and final ranking

	Phi	**Phi$^+$**	**Phi$^-$**
A_3	0.5000	0.7500	0.2500
A_2	0.2396	0.6198	0.3802
A_5	0.1146	0.5573	0.4427
A_1	0.0729	0.5365	0.4635
A_4	-0.9271	0.0365	0.9635

Source: The author (2022).

7.3.5 Review and finalization

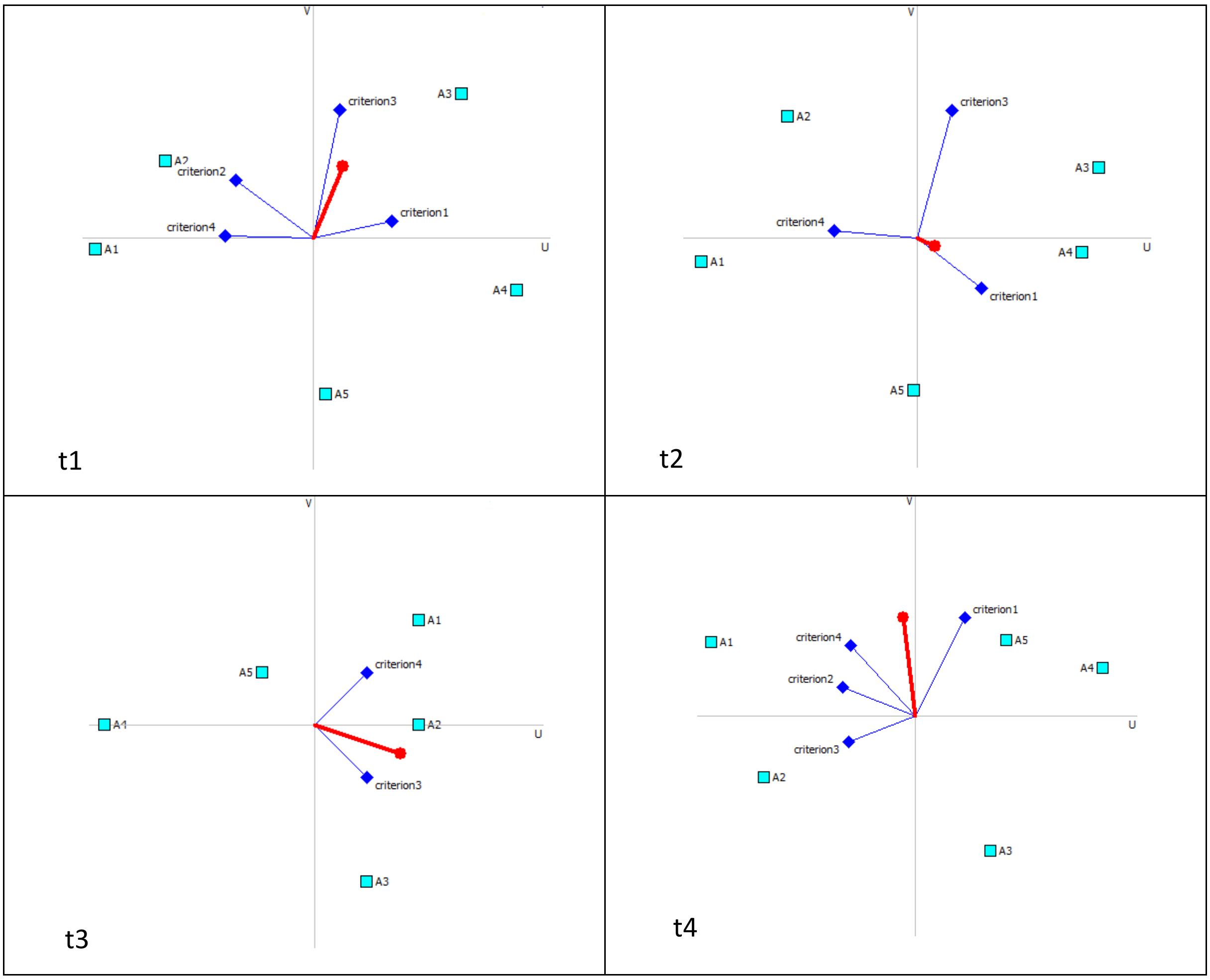
An individual assessment of the alternatives in each criterion was also performed through PROMETHEE-GAIA analysis showed in Figure 18 and Figure 19. For instance, observing period ‘t1’ it can be seen that criteria C1 (subject well-being) and C4 (health assistance) are communicating opposite preferences and that decision axis is more oriented to criterion 3 (hospitalization).

The criteria defined with greater relative importance (C1 and C2) was varied up or down by 5% as a scenario for sensitivity analysis. All alternatives admit the same ordering in relation even when we changed +5% in C1 and ±5% in C2. There was not a maintenance of all original ordering only when we reduced 5% in C1.

Further exploring sensitivity analysis evaluation, it was tested scenarios using different approaches of aggregation and weights. A simpler option that could be used is to average the values for each period to find an aggregated matrix. Thus, in a next step, the multi-criteria problem could be solved based on suitable multi-criteria methodologies that already can be found on the literature. However, this average decision that would be coherent for more stable data, since there will be loss of information if there is significant variation in the values of the alternatives in each time-period. For instance, for the data used in this study, there would be changes in the final order and only the first alternative would remain the same in the ranking.

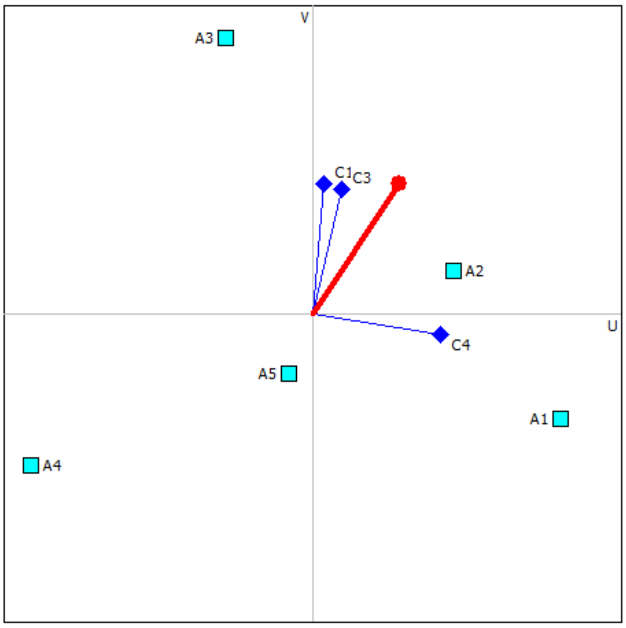
The assigned weights proved to have a relevant influence on the final ranking. For example, it may be of interest to the decision-makers to include a trend analysis, giving greater emphasis to specific periods. The methodology proposed in this article takes this into consideration, and there is a possibility of different levels of importance to more recent periods. Nevertheless, a subjective analysis of decision makers can be used to assign the weights for each period of time, simplifying calculations until the final ranking.

Figure 18 - Gaia plane by period (t1 to t4)



Source: The author (2022).

Figure 19 - Gaia plane considering the comprehensive evaluation



Source: The author (2022).

7.4 FINAL CONSIDERATIONS

An integrated health assessment can be a valuable indicator for monitoring the population over time. For example, public managers may be interested in comparing different geographic areas, such as neighborhoods, cities or states, ranking these areas or creating more homogeneous sub-groups. The results can orientate decisions including informative advertising campaign or the construction of a new health care unit. There is a gap to be explored in overtime problems that can often be proposed based on adaptations of existing decision models. The multi-period methodology proposed in this study used PROMETHEE II method. Additionally, it can be adapted to other multi-criteria decision approaches. Depending on the purpose of the assessment, weights and criteria need to be adjusted to best reflect the need for the context involved.

8 CONCLUSION

This chapter includes the central conclusions of the studies presented in the previous chapters.

8.1 CHRONIC DISEASES AND MULTIMORBIIDTY IN BRAZIL

This thesis evaluated non-communicable chronic diseases in Brazil, mostly arterial hypertension (high blood pressure), arthritis/rheumatism, back/spine (column), bronchitis/asthma, cancer, chronic renal failure (kidney failure), depression, diabetes, and, heart disease. Statistical and decision models were used considering interconnected factors such as demographic information, territorial conditions, and socio-economic characteristics.

Initially, a systematic literature review was performed to summarize previous researches on non-communicable chronic diseases, observing studies that analyzed data from population-based health surveys in Brazil. As presented in Chapter 3, it was possible to identify gaps in the existing literature, helping to design the studies presented in this thesis. The PRISMA recommendation was used as a methodology, including articles published between 1998 and 2020. A comprehensive search was completed in the Pubmed/Medline, SciELO, Scopus, Web of Science databases. 490 articles were analyzed and 95 relevant articles were selected for qualitative analysis. The results indicate that the main chronic diseases studied were depression, diabetes and hypertension, considering the large number of publications. The main themes are associated with the prevalence of diseases and their association with social, demographic, economic, regional and behavioral factors.

In Chapter 4, it was presented non-communicable chronic diseases differences related to age and sex showing trends from a temporal perspective. In general, chronic diseases showed similar behavior in relation to age. Predominantly, the prevalence of arthritis/rheumatism and back/spine problems has reduced between 1998 and 2013, increasing in 2019. On the other hand, cancer and diabetes showed a consistent growing trend. Depression has been increasing after 2003 as well. Patterns indicate that in Brazil, chronic non-communicable diseases consistently affect females over time. Information related to the prevalence of chronic diseases from population-based surveys can help to visualize the health-related situation in a temporal analysis, considering the Brazilian population.

Chapter 5 presented a geographic distribution of non-communicable chronic diseases in the Brazilian territory. The maps revealed patterns related to differences between regions of

Brazil. Arterial hypertension, depression, diabetes, and heart disease showed a considerable difference where South areas have higher chronic disease concentrations compared with the North. Arthritis/rheumatism, back problems, bronchitis/asthma, cancer, and chronic renal failure have more diffuse distributions between the five regions of Brazil, even though, it is possible to verify similarities between close states. It was also proposed a Chronic Disease Index (gCDI). This index can be visualized as an initial exploratory phase to evaluate the geographic distribution of chronic diseases for different states of a country or different neighborhoods in a city. Comparative results are key to show possible chronic disease distribution patterns highlighting critical areas. Indexes connected with geographic information can be used as a basis for government decision planning in projects to structure public spending or educational campaigns to prevent chronic diseases, focusing, for example, on reducing behavioral risk factors as smoking, alcohol consumption, physical inactivity, unhealthy diet, and obesity.

In Chapter 6, it was investigated dynamic distributions of socioeconomic, demographic, and health-related characteristics on multimorbidity in Brazil, which is the co-occurrence of multiple chronic diseases. In summary, it was found that multimorbidity rate in Brazil was 21.0% in 1998, 17.1% in 2003 and 2008, 19.1% in 2013. Multimorbidity odds ratio (95% CI) was 1.7 times higher in women (OR=1.73; 95%CI: 1.67-1.79) and 1.3 times higher among illiterates (OR=1.34; 95%CI: 1.28-1.41). Multiple chronic diseases grow considerably with age in Brazil. For instance, people between 50 and 59 years of age and above had about twelve times more chance of multimorbidity than adults between 18 and 29 years of age (OR=11.89; 95%CI: 11.27-12.55). Similarly, seniors with multimorbidity had more than twice the chance of receiving health assistance in community services or clinics (OR=2.16; 95%CI: 2.02-2.31) and to be hospitalized (OR=2.37; 95%CI: 2.21-2.56). People with multimorbidity often rate their subjective well-being worse than people without multiple chronic diseases (OR=12.85; 95%CI: 12.07-13.68 for adults). These patterns are similar across all four cohorts analyzed (1998 to 2013). A better understating of why there are differences in the prevalence of multimorbidity across different social groups would help to shape new strategies to accommodate different preventative activities to health care services.

Considering a public manager interested in broadly evaluate different health attributes of a certain population, a multicriteria decision method can support this task even considering multiple periods of time. It was proposed in Chapter 7, a multi-period multicriteria outranking methodology to support health decision-making considering a temporal perspective. It was considered four health attributes: subject well-being, multiple chronic diseases (multimorbidity), cases of hospitalizations and health assistance, observing four time periods. From the proposed multi-stage methodology, it is possible to rank geographic areas in each period, and also to perform an overall assessment of these five areas using an outranking approach based on PROMETHEE method. Different approaches found in the literature evaluate multi-criteria decision problems assuming that data did not change over time. However, public policy managers often face problems that need the evaluation of the past to plan the future as resource allocation activities. The comparison of geographic areas or specific groups overtime can support the planning of public policies, observing health trends and patterns over time.

8.2 MAIN CONTRIBUTIONS OF THE THESIS

Temporal analyzes can help to visualize patterns, such as observations related to sex and age in the prevalence of chronic diseases in Brazil, as presented in Chapters 3 and 4 of the thesis. A gap in the study of multi-temporal chronic diseases in Brazil was detected using population-based surveys such as the health supplements of the National Household Sample Survey (PNAD) and the National Health Survey (PNS). Household surveys are an important source of data for a range of statistics on the health of individuals, especially in developing countries that often have sparse record systems.

The determination of health indicators can be an important element to support decision-making in public management, as the index proposed in Chapter 5. Health indicators can be used as summary measures with relevant information about certain attributes and dimensions of individuals' health or in relation to the performance of the health system. According to the literature review, there is a lack of studies with a quantitative methodology to assess chronic diseases integrated with a geographic perspective.

According to the literature review carried out, the study demonstrated in Chapter 6, is the first to explore the temporal changes of multimorbidity over an extended period of 15 years, integrating the PNAD and PNS health databases, representing the largest sample in Brazil (795,271) of research on multimorbidity in adults and the elderly and, in addition to demographic aspects, relate health issues to the subject's well-being, use of health care and hospitalization.

Lastly, most studies involving multicriteria decision, and more specifically outranking methods, focus on problems using a single period of time. Consequently, available data from previous periods may not end up being used effectively to support decision-making. There is still a lot to be explored in multicriteria/multi-period methodologies, from the growing availability of big data in the context of the evolution of computer systems. Adaptations of traditional multi-criteria models can be an effective approach to assist in the multi-period decision-making process as proposed in the Chapter 7 of this thesis, with the integration of multi-aggregation methodologies and the PROMETHEE method.

Furthermore, it is worth mentioning that researches including data analysis and available databases (e.g., PNAD/PNS) can have a positive economic impact reducing costs in data collection. Substantial information can be extracted for existing datasets. It is expected that open data increase progressively more from the evolution of information technology, being this a great opportunity to scientific community.

The assessment of patterns in the health context can have a direct impact in the improvement of public policies, knowing the past to plan a better future. For instance, scarce resources can be direct to more vulnerable groups driven by data. As presented in this thesis, it is possible to detect socio-economic groups with more risk of chronic diseases, including environmental and geographic characteristics. This generated information can be used to support the planning and decision making in health management context using multi-periods of data.

8.3 LIMITATIONS AND FUTURE WORKS

Initially it was executed a literature review study about chronic diseases in Brazil. Systematic literature review results have limitations related to the criteria selected and time period. PRISMA recommendation was used to help to reduce possible biases. The search used Medline/PubMed, SciELO, Scopus and Web of Science and excluded publications as abstracts, book chapters, conference articles, and editorials. The thematic about chronic disease is extensive. Therefore, other limitation is that the search was concentrated in articles that used health data from PNAD and PNS. Future literature reviews related to chronic diseases in Brazil can add other datasets in the scope of research, even if they do not have a national coverage.

The identification of diseases can be also a limitation. It was considered the information provided by the participants and not a clinical diagnosis. All this self-reported data can undergo information bias. Additionally, some questions changed between PNAD and PNS. This can be a restriction for the studies using overtime data. For example, in PNAD the question was like

“Has any doctor ever given you the diagnosis of…” changing in PNS to “Did any doctor or health professional say that you have…”. In the variables that were used in this thesis, the question variations did not demonstrate to have influence in the final meaning and results. The smaller the changes and maintenance of the questions, the better for research in multiple periods. It would be even better to have a longitudinal representative survey with the same participants for observation in future studies.

Nevertheless, the overall distribution of diseases (e.g., by sex and age) reveal consistent patterns. On the other hand, it was observed differences in the age distribution when it was looked deeper the diseases by federative units/states. In this case, one area with a much older population, for example, can have a higher percentage of residents with chronic disease and have impact in the analysis. For instance, in the multimorbidity study, the results are presented for adults and elderly separately trying to reduce possible biases. It would be interesting to have other studies with more detailed data on the spatial perspective, as states are the smallest geographical areas provided by PNAD and PNS.

It was also evaluated the impact of multimorbidity on various outcomes that could lead to possible reverse causality (e.g., multimorbidity and work). Future studies can also be outlined to address this issue with in-depth studies. Future research might benefit from also to include more data from newest versions from PNS.

Even with the advantage of access to a large database representative of the Brazilian population, the lack of information is a limitation for more analysis as the surveys were designed primarily for other purposes. For instance, about the economic aspect, in the PNAD and PNS questionnaires there are questions about income but the dataset available presents considerable missing data. For example, having a health insurance was used as an indicator of better economic status. Other associations could be better executed in future studies if the participants income is available.

Another requirement for future studies is to have decision support methods able to lead with multiple periods of time, including the adaptation and the combination with traditional statistical tools. In this big data time, it is essential to innovate and construct options to lead efficiently with data analysis.

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