Global Epidemiology 8 (2024) 100171

Contents lists available at ScienceDirect

Global Epidemiology

journal homepage: www.sciencedirect.com/journal/global-epidemiology

Identification of population multimorbidity patterns in 3.9 million patients from Bogota in 2018

Carolina Saavedra-Moreno [a,b,*], Rafael Hurtado [c], Nubia Velasco [d], Andrea Ramírez [e]

[a] Faculty of Engineering, Universidad Nacional de Colombia, Bogotá, Colombia
[b] Faculty of Engineering, Universidad de Ibagué, Ibagué, Colombia
[c] Science Faculty, Universidad Nacional de Colombia, Bogotá, Colombia
[d] School of Management, Universidad de los Andes, Bogotá, Colombia
[e] Department of Epidemiology, UTHealth Science Center at Houston, School of Public Health, Center for Pediatric Population Health, Department of Pediatrics at McGovern Medical School, Houston, USA

ARTICLE INFO

Keywords:
Multimorbidity
Network analysis
Medical records
Healthcare systems
Colombia

ABSTRACT

Background: Multimorbidity has emerged as a challenge for health systems due to its association with adverse clinical outcomes. Given the limited information available on multimorbidity, particularly in low- and middle-income countries, this study characterizes multimorbidity patterns in the population of Bogotá, Colombia in 2018.

Methods: In a cross-sectional study, we analyzed 16 million medical consultation records from Bogotá reported in the National Service Delivery Records in 2018. Using network analysis, we quantified the prevalence of multimorbidity in the population and identified the most common associations between diagnoses, with data stratified by age, sex, and socioeconomic status.

Results: The study found that the prevalence of multimorbidity in the population was 44.2 %, increased with age, and was higher in women and in people affiliated to the contributory health scheme. Allergies and vasomotor rhinitis with asthma were common in young people. In women aged 19–39 years, obesity with hypothyroidism was common, while men in the same age group had obesity with dyslipidemia. In people aged 60 years and older, essential hypertension with dyslipidemia was the most common. In addition, some associations between diagnoses showed a higher association in people affiliated to the subsidized health scheme, with notable associations with trauma, especially in men.

Conclusion: Overall, the results provide valuable insights into multimorbidity in the population and highlight inequalities based on sociodemographic factors. Future research should investigate whether the lower prevalence of multimorbidity in vulnerable groups is related to biases in data collection or to underlying inequalities in healthcare access.

Introduction

Multimorbidity is a challenge for patients and healthcare systems worldwide. Research has shown that the coexistence of multiple medical conditions in individuals is associated with increased disability and functional impairment [1], reduced quality of life [2], and increased risk of mortality [3]. In health systems, multimorbidity is associated with poorer clinical outcomes, high resource utilization in both primary and specialist care [4], increased health expenditures and utilization of medical services [5], and higher rates of hospitalization and unplanned hospital admissions [6].

In Latin America and the Caribbean, the prevalence of multimorbidity is estimated to be between 35 % and 51 %, with an increasing trend over time [7]. Multimorbidity is a challenge for the health systems in these countries, as they face a rapid increase in the prevalence of non-communicable diseases, while at the same time dealing with communicable diseases (such as HIV, tuberculosis, and malaria) and issues related to maternal and newborn health, neonatal health and nutrition [8]. Many of these health systems are fragmented and have limited resources and infrastructure [9]. Like high-income countries, they have

* Corresponding author: Department of Logistics and Computer Science, Faculty of Engineering, Universidad de Ibagué, Carrera 22 Calle 67 B, Av. Ambala, Ibagué, Colombia.
E-mail address: carolina.saavedra@unibague.edu.co (C. Saavedra-Moreno).

https://doi.org/10.1016/j.gloepi.2024.100171
Received 11 March 2024; Received in revised form 8 October 2024; Accepted 11 October 2024
Available online 12 October 2024

traditionally organized their health services around the management of single diagnoses, which limits the understanding and care of multimorbidity, which requires multidisciplinary coordination [10].

Multimorbidity is commonly understood as the co-occurrence of two or more chronic conditions in an individual [11,12], although in some cases it is recognized more broadly as the presence of two or more concurrent health conditions, regardless of their chronicity [13–15]. While definitions may vary, the primary concern is the increased health care burden and treatment complexity associated with multimorbidity [16]. In this study, we adopt a broad definition of multimorbidity that considers the coexistence of multiple diseases or medical conditions in an individual [17], including both chronic diseases and injuries, to analyze its impact on population morbidity.

Information on the prevalence of multimorbidity and the most common combinations of conditions is essential for planning health services. However, despite the development of multimorbidity prevalence studies worldwide, results have been reported mainly for high-income countries [7]. According to Abebe et al. [18], prevalence studies in low- and middle-income countries are limited, coming mainly from Brazil, China, South Africa, India, Mexico, and Iran. In Colombia, the prevalence and patterns of multimorbidity have been partially studied, with one study characterizing clusters of chronic diseases with higher prevalence in a cohort of patients enrolled in one of the health schemes [19]. Under Law 100 of 1993, Colombia established a health insurance system with two main health schemes: contributory and subsidized. Membership in the contributory scheme is compulsory for those with formal employment or the financial means to pay, and their dependents. On the other hand, the subsidized scheme is aimed at people with limited resources and vulnerable groups.

A relational approach used to study multimorbidity is Network Analysis (NA), which has previously been used to describe multimorbidity in populations of high-income countries, with some studies including sociodemographic factors such as sex [20,21], ethnic groups [22,23], and age [24]. As the lack of evidence on multimorbidity has implications for research and healthcare management in the region [7], this study provides information on the prevalence of multimorbidity in Bogota, the capital of Colombia, with more than seven million inhabitants in 2018. We analyzed 16 million records of medical consultations reported in the National Service Delivery Records, using NA and distinguishing the population by sociodemographic factors such as age, sex, and socioeconomic status related to health schemes. The main contribution of the study is to present patterns of multimorbidity in the population and disparities associated with the sociodemographic factors analyzed.

Methods

Study design

A population-based cross-sectional study was conducted in the city of Bogotá, the capital of Colombia. Multimorbidity networks were constructed at the population level by analyzing anonymized medical consultation records reported by healthcare providers to the Ministry of Health and Social Protection in 2018.

Settings and participants

The analysis focused on medical consultation records from Bogotá, the capital and largest city of Colombia. In 2018, the city had an estimated total population of 7,686,096 inhabitants, of which 52 % were female and 48 % were male [25]. The population was stratified by sex, age, and socioeconomic status. Patients of both sexes and all age groups were included. Age groups were defined to divide the population into four distinct life stages: childhood and adolescence (0–18 years), two 20-year intervals to capture different stages of adulthood, and individuals over 60 years to represent the elderly population. The study aimed to identify differences in the patterns of multimorbidity and to understand how the burden of multiple health conditions varies across life stages. Stratification by socioeconomic status was determined by health schemes, which, although not a direct measure of socioeconomic status, has been used previously for this purpose [26]. Other studies have found that the subsidized scheme tends to include the most economically disadvantaged population [27], suggesting that health schemes may reflect socioeconomic differences within the population.

Data sources

The data analyzed were records of medical consultations reported in the National Service Delivery Records (RIPS in Spanish) in 2018. These records contain information on health activities, are generated by health service providers, and include details such as the primary diagnosis and related diagnoses coded according to the International Classification of Diseases (ICD-10) for Colombia. The ICD-10 is a standardized system that categorizes the health status of individuals in terms of diseases, injuries, and reasons for consultation, using mutually exclusive categories. The RIPS database is the most widely used resource for health research in Colombia. However, it is important to note that this database has some limitations, particularly in terms of data quality, mainly because its primary function is to record the activities of healthcare providers for reimbursement purposes, which means that RIPS could provide limited clinical information, lacking details such as the duration of illness, its severity, or the criteria used by physicians to make a diagnosis [21]. Despite these limitations, it was possible to identify patterns of multimorbidity in the population due to the large sample size and the data cleaning process described in Appendix 1.

Study size

A total of 16,439,708 medical records of 3,896,717 individuals covered by contributory and subsidized schemes were analyzed. This sample represents all medical consultation records available from the Colombian Ministry of Health for Bogotá in the year 2018, after undergoing a thorough data cleaning process to remove incomplete or inconsistent entries (Appendix 1). Bogotá was selected for this study because it is the capital and the most populous city in the country, as well as a region where large migratory flows (forced and non-forced) from the regions are concentrated. The population of the subsidized scheme represented 7.29 % of the total population, suggesting underrepresentation and potential bias. However, it is important to note that in 2018, only 15.1 % of the population of Bogotá was enrolled in the subsidized scheme [28], and a previous study estimated that 35 % of them did not seek medical care when faced with a health problem [27]. This suggests that the available records provide a relevant but limited view of this population.

Analytical strategy, measures, and statistical analysis

We constructed multimorbidity networks, consisting of nodes representing medical diagnoses obtained from consultations and coded according to the ICD-10 classification system (Appendix 2). The edges in the networks represented the associations or links between pairs of nodes when they co-occurred in the same medical consultation. The process of constructing the networks is described in detail in Appendix 3.

The study followed these steps:

- From the patients' graphs (Appendix 3), the prevalence of multimorbidity was estimated by calculating the proportion of individuals with multiple coexisting medical conditions. This measure estimates the proportion of patients with at least one co-occurrence of two medical conditions, represented as an edge in each patient's multimorbidity network. We also examined population patterns of multimorbidity by analyzing the number of co-occurrences between

pairs of medical conditions (number of edges in the patient's multimorbidity network), measuring the proportion of patients with one to seven or more co-occurrences between medical conditions.

- From the population graphs, representative associations between pairs of medical conditions were identified considering the strength of the co-occurrence between pairs of diagnoses (weight of the edges). It was calculated using the prevalence measure P_{ij}. This measure is defined as the percentage of patients in whom diagnoses i and j occur together (Appendix 4). We excluded associations between medical diagnoses with an individual prevalence equal to or less than that of orphan diseases in Colombia, defined as one case per 5000 individuals according to Law 1438 of 2011. In addition, dental diagnoses were excluded due to their association with a separate care process within the health system.
- The most frequent diagnoses (nodes) in multimorbidity networks were identified using the weighted degree measure. This measure indicates the importance of a node based on its connections to neighboring nodes in the networks. For each age group, the three most common associations of the most frequent diagnoses (nodes) were also identified.
- The associations between medical diagnoses (edges) with the highest prevalence in the age groups were described. The prevalence of representative common associations between pairs of diagnoses was compared by sex in each age group, and by health scheme and sex in subgroups over 40 years of age, using chi-squared tests. The comparison was performed only for representative associations, defined in this study as those with prevalence rates higher than those typically observed for orphan diseases in Colombia. The assumptions of the chi-squared test were fully evaluated, ensuring that no expected cell count was less than 1 and that no more than 20 % of the expected cell counts were less than 5. Among the representative associations in males, 7 in the 40–60 age group and 8 in the over-60 group were excluded from the analysis because, in the subsidized health scheme, they did not meet the assumption that no more than 20 % of the expected cell counts were less than 5.

Results

Of the 3,896,717 individuals included in the analysis, 57.31 % were female, and 92.71 % were covered by the contributory scheme. The age distribution showed that 23.54 % of the individuals were younger than 18 years, 35.22 % were aged 19–39 years, 25.83 % were aged 40–60 years, and 15.41 % were older than 60 (Table 1). On average, women (4.53) and those in the contributory scheme (4.33) had a higher number

Table 1
Population characteristics by age, sex, and type of health scheme.

	Population[a]	Age (years)[b]	Number of consultations per patient (Median [Q1–Q3] (IQR))	Number of diagnoses per patient (Median [Q1–Q3] (IQR))	Prevalence of multimorbidity (Proportion of individuals with at least one co-occurrence of two medical conditions)[a]
Total population	3,896,717 (100 %)	34 [20–53] (33)	3 [1–5] (4)	3 [1–5] (4)	1,722,433 (44.20 %)
Age					
≤18	917,407 (23.54 %)	9 [4–14] (10)	2 [1–4] (3)	2 [1–4] (3)	290,269 (31.64 %)
19–39	1,372,283 (35.22 %)	28.79 (5.85)	2 [1–5] (4)	3 [1–4] (3)	543,722 (39.62 %)
40–60	1,006,496 (25.83 %)	49.83 (6.02)	3 [2–6] (4)	3 [2–6] (4)	508,752 (50.55 %)
≥60	600,531 (15.41 %)	70.97 (7.88)	5 [2–9] (7)	4 [2–7] (5)	379,690 (63.23 %)
0.5					
Sex					
Males	1,663,490 (42.69 %)	32 [17–51] (34)	2 [1–5] (4)	2 [1–4] (3)	670,046 (40.28 %)
Females	2,233,227 (57.31 %)	35 [21–53] (32)	3 [1–6] (5)	3 [2–5] (3)	1,052,387 (47.12 %)
0.5					
Type of health scheme					
Contributory	3,612,507 (92.71 %)	34 [20–52] (32)	3 [1–6] (5)	3 [2–5] (3)	1,614,581 (44.69 %)
Subsidized	284,210 (7.29 %)	36 [18–58] (40)	2 [1–3] (2)	2 [1–3] (2)	107,852 (37.95 %)
0.5					
Age-sex-type of health scheme					
40–60-Males-Contributory	373,345 (9.59 %)	49.74 (6.04)	3 [1–5] (4)	3 [1–5] (4)	170,889 (45.78 %)
40–60-Females-Contributory	561,672 (14.42 %)	49.79 (6.00)	4 [2–7] (5)	4 [2–6] (4)	306,362 (54.55 %)
40–60-Males-Subsidized	22,713 (0.59 %)	50.85 (5.96)	2 [1–3] (2)	2 [1–3] (2)	9049 (39.85 %)
40–60-Females-Subsidized	48,766 (1.26 %)	50.48 (5.92)	2 [1–3] (2)	2 [1–4] (3)	22,452 (46.05 %)
≥60-Males-Contributory	218,957 (5.62 %)	70.65 (7.6)	5 [2–9] (7)	4 [2–7] (5)	134,038 (61.22 %)
≥60-Females-Contributory	320,475 (8.23 %)	71.03 (8.03)	6 [3−10] (7)	5 [3–8] (5)	215,061 (67.11 %)
≥60-Males-Subsidized	22,408 (0.58 %)	71.44 (7.74)	2 [1–4] (3)	2 [1–3] (2)	10,606 (47.34 %)
≥60-Females-Subsidized	38,691 (0.99 %)	71.95 (8.17)	2 [1–4] (3)	2 [1–4] (3)	19,985 (51.66 %)

[a] The percentage in parentheses.

[b] Mean and Standard Deviation (SD) in parentheses for variables with mean/SD ratio > 2, median, first quartile (Q1) and third quartile (Q3) [Q1–Q3] in brackets, and interquartile range (IQR) in parentheses for variables with mean/SD ratio < 2.

of medical consultations. In the total population, 44.2 % had at least one co-occurrence of two medical conditions documented in their medical records, with a consistently higher prevalence among women than men in all age groups.

The proportion of individuals with multiple co-occurrences of diagnoses (edges) increases with age and varies by sex and health scheme (Fig. 1). A higher proportion of women had at least one co-occurrence of two diagnoses in all age groups and health schemes (Table 1), except in the 0–18 age group, where no significant sex differences were observed ($p = 0.16$ and 0.91 for each health scheme). For both sexes and all age groups, a higher proportion of people with at least one coexisting condition was found in the contributory scheme than in the subsidized scheme. In the over-60 population enrolled in the contributory scheme, the proportion of people with seven or more co-occurrences between diagnoses was 16.58 % on average, compared with 3.20 % in the subsidized scheme (Fig. 1).

Among the most common diagnoses in people with multimorbidity by age, we found that allergic and vasomotor rhinitis were the most common diagnoses that co-occurred with others in people under 18 years of age (Table 2), and their three most common associations had a prevalence of less than 1 %. In the 19–39 age group, obesity was the most common diagnosis that co-occurred with others, while hypertension was the most common in those over 40. In those aged 60 years and over, associations with hypertension were mainly with non-communicable chronic diseases, which showed an increasing prevalence with age (Table 2).

Of the representative associations between diagnoses, 61 were identified as common across all age groups. The association of allergic and vasomotor rhinitis with asthma was most common in the 0–18-year age group, with prevalence decreasing with age (Table 3). The prevalence of the association between irritable bowel syndrome and functional gastrointestinal disorders was higher in the 19–39 age group. The association between obesity and dyslipidemia was higher in the 40–60 age group. In contrast, the association between obesity and hypothyroidism was more prevalent in those aged 60 years and over, and its prevalence increased with age (Table 3).

For most of the representative associations of common adult diagnoses by sex, a higher prevalence was observed in females. In those aged 0–18 years, males were 35 % more likely than females to have allergic rhinitis and vasomotor rhinitis associated with asthma (Table 4). In the age group 19–39 years, 80 representative associations with high prevalence were identified in men and 145 in women. The association

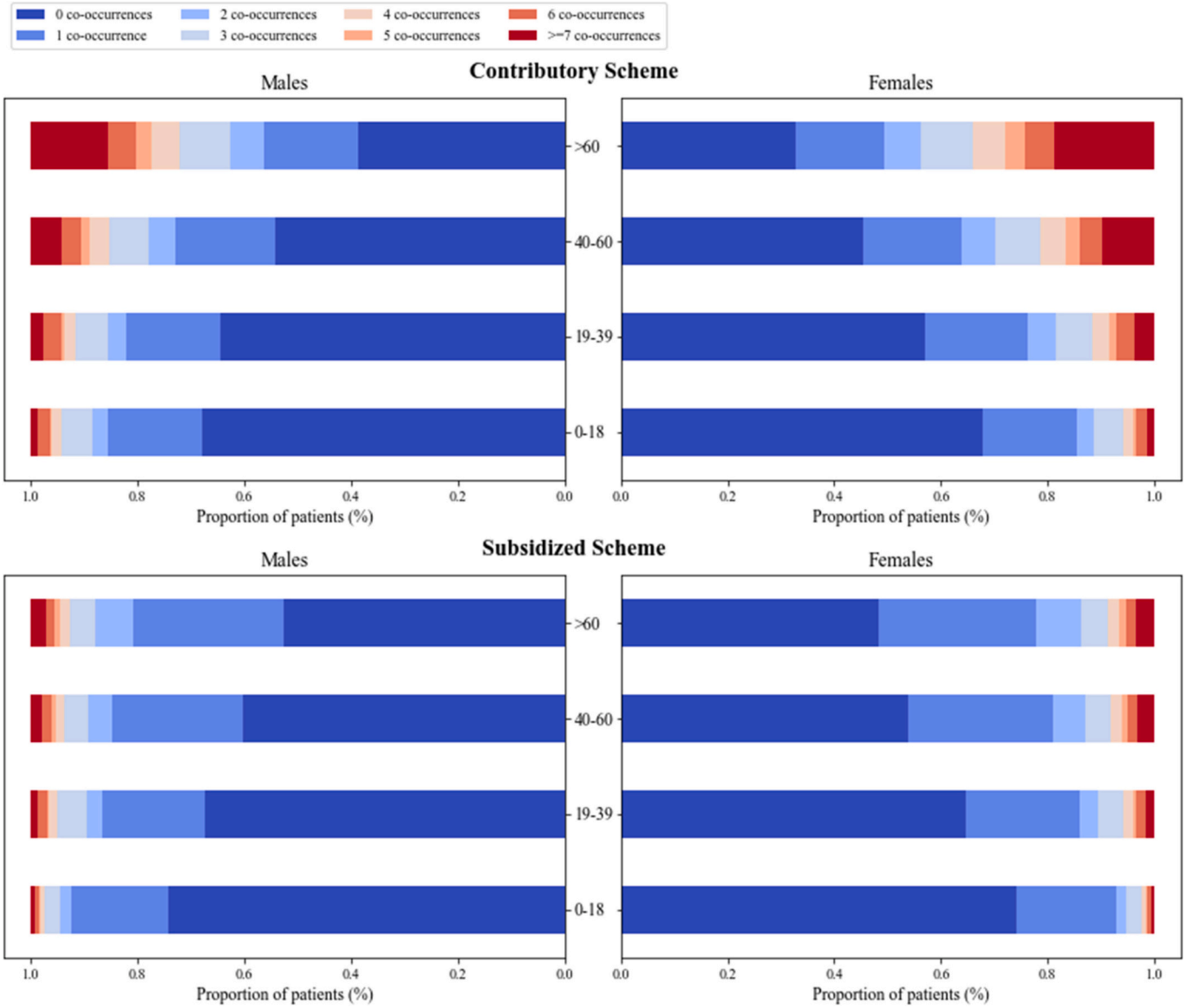

Fig. 1. Proportion of co-occurrence of diagnoses per patient stratified by age, sex, and health scheme.

Table 2
Most common diagnoses in multimorbidity networks by age group.

Age	Most common diagnosis in multimorbidity	Individual prevalence	Three diagnoses with the most common co-occurrences	
			Diagnosis	P_{ij}
≤18	Allergic and vasomotor Rhinitis	9.13 %	Asthma	0.78 %
			Nasal and sinus disorders	0.56 %
			Atopic dermatitis	0.35 %
19–39	Obesity	8.81 %	Dyslipidemia	0.56 %
			Hypothyroidism	0.45 %
			Back pain	0.40 %
40–60	Essential hypertension	15.00 %	Dyslipidemia	3.69 %
			Obesity	3.20 %
			Hypothyroidism	1.30 %
≥60	Essential hypertension	49.58 %	Dyslipidemia	11.36 %
			Hypothyroidism	7.96 %
			Non-insulin-dependent diabetes mellitus	7.28 %

Table 3
Prevalent common representative associations in each age group.

Common associations between diagnoses	Prevalence			
	≤18	19–39	40–60	≥60
Allergic and vasomotor rhinitis - Asthma	0.78 %	0.09 %	0.05 %	0.02 %
Irritable bowel syndrome - Functional bowel disorders	0.03 %	0.18 %	0.14 %	0.09 %
Obesity - Dyslipidemia	0.08 %	0.56 %	2.66 %	2.53 %
Obesity - Hypothyroidism	0.04 %	0.45 %	1.35 %	1.83 %

between obesity and dyslipidemia was more prevalent in men, with a 59 % higher prevalence (Table 4). In the 40–60 age group, 113 representative associations were more frequent in men and 347 in women. The association between essential hypertension and dyslipidemia showed small sex differences. Men were 3 % more likely to be affected than women, as supported by a significant *p*-value (0.0112) and a narrow confidence interval (1.01, 1.05) (Table 4). Also, the association between essential hypertension and obesity was more frequent in women; men were 20 % less likely to have this association, with an OR of 0.8. The extremely small p-value and the narrow confidence interval (0.78, 0.82) reinforce the results (Table 4). Among those aged 60 years and over, 199 representative associations had a high prevalence in men and 524 in women. The association between essential hypertension and chronic ischemic heart disease was more common in men, with a 152 % greater likelihood compared to women, whereas the prevalence of the association between essential hypertension and dyslipidemia was higher in women, men were 18 % less likely to have the association, with an OR of 0.82 (Table 4).

In the representative associations by health scheme and sex in people over 40, it was found that in most cases where significant differences in prevalence were found by health scheme ($p \leq 0.001$), higher values were found in the contributory scheme. In the subsidized scheme, the most common representative associations had a prevalence of less than 1.2 %. Associations with a higher prevalence in the subsidized scheme for the

Table 4
Common representative associations between diagnoses with higher prevalence by sex in each age group.

Common representative associations between diagnoses	Prevalence				
	M	F	*p*-value[a]	OR[b]	CI (95 %)[c]
0–18 years					
Allergic and vasomotor rhinitis – Asthma	0.90 %	0.67 %	<0.001	1.35	[1.29, 1.41]
Acute rhinopharyngitis - Atopic dermatitis	0.14 %	0.16 %	0.0021	0.85	[0.76, 0.94]
19–39 years					
Obesity - Dyslipidemia	0.71 %	0.45 %	<0.001	1.59	[1.52, 1.66]
Obesity - Back pain	0.35 %	0.44 %	<0.001	0.79	[0.74, 0.83]
40–60 years					
Essential hypertension-Dyslipidemia	3.75 %	3.65 %	0.0112	1.03	[1.01, 1.05]
Essential hypertension-Obesity	2.79 %	3.47 %	<0.001	0.80	[0.78, 0.82]
>60 years					
Essential hypertension-Chronic ischemic heart disease	5.25 %	2.15 %	<0.001	2.52	[2.45, 2.59]
Essential hypertension-Dyslipidemia	10.18 %	12.14 %	<0.001	0.82	[0.81, 0.83]

[a] Chi-squared test.
[b] Odds ratio.
[c] 95 % confidence interval of odds ratio.

40–60 age group included, in men, HIV with dyslipidemia, hypothyroidism and essential hypertension, and associations between leg, ankle and foot injuries and back pain with superficial chest injuries. In women, notable associations included chronic obstructive pulmonary disease with essential hypertension and dyslipidemia with obesity. For people aged 60 and over, fewer than 20 associations had a higher prevalence in the subsidized scheme for each sex.

Discussion

To the best of our knowledge, this study is the first in Colombia to identify patterns of multimorbidity in the population by analyzing medical consultation records of 3.8 million patients, including individuals of all ages and from the two main health schemes. The main findings of the study can be summarized as follows: 1) The prevalence of multimorbidity, defined as the proportion of individuals with at least one co-occurrence of two medical conditions, was 44.2 %; 2) the prevalence of multimorbidity increased with age and was higher in women and in people affiliated to the contributory scheme; 3) the most common diagnoses in people with multimorbidity varied by age group, with allergic and vasomotor rhinitis being prevalent in those under 18 years of age, obesity in the 19–39 age group and essential hypertension in those over 40 years of age; 4) some representative associations between diagnoses showed a higher prevalence in people affiliated to the subsidized scheme, with notable associations with trauma, especially in men.

The prevalence of multimorbidity of 44.2 %, obtained by calculating the proportion of individuals with at least one co-occurrence of two conditions directly from the patients' multimorbidity networks, falls within the range of 35–51 % reported in previous studies of the prevalence of multimorbidity in Latin America [7]. Although direct comparisons with previous reports are difficult due to differences in sample characteristics, medical diagnoses considered, and methods of estimating multimorbidity, the consistency of our findings suggests the potential for further research to validate the population-level measure of

multimorbidity prevalence. It could serve as a valuable reference point that can be easily estimated using patient medical records of medical consultations reported in the National Service Delivery Records.

The prevalence of multimorbidity increased with age and was higher in women and in people affiliated to the contributory scheme. The increase with age is consistent with the greater exposure to risk factors and chronic diseases, a pattern observed in older populations [29]. The higher rates in women may be due to their more detailed reporting of health problems and greater use of health services compared with men [30,31]. In this study, women had more consultations per patient in both health schemes. However, the finding of a lower prevalence of multimorbidity among individuals in the subsidized scheme was unexpected. Despite the known inverse relationship between multimorbidity and socioeconomic status [32,33], our results are consistent with previous research indicating higher incidence rates of both communicable and non-communicable diseases in the population affiliated to contributory scheme [34]. This discrepancy may be influenced by potential biases and variations in the quality of health records. Of note, the population of the subsidized scheme represented only 7.29 % of the study sample, which may indicate underrepresentation. The lower prevalence observed may be partly explained by this underrepresentation. Future studies should investigate whether these differences are due to differences between health schemes, patterns of health care use, or inherent biases in the medical records.

The most common diagnoses in people with multimorbidity were allergic and vasomotor rhinitis in those under 18, obesity in the 19–39 age group and essential hypertension in those over 40. This information is crucial for the management of multimorbidity, as these medical diagnoses contribute most to the overall burden of multimorbidity in different population subgroups. As a result, patients with these conditions are more likely to have additional medical problems and increased healthcare needs. In people over 18 years of age, the associations between circulatory diseases and endocrine, nutritional and metabolic disorders had the highest prevalence and showed an age-related increase. These findings are consistent with previous studies of multimorbidity in people over the age of 40 [3,18,35–37].

Although only a small number of representative associations between diagnoses (less than 20) showed a higher prevalence in people affiliated to the subsidized scheme (less than 2 %), notable associations between traumas were identified in men, probably related to accident care. This information is valuable for the development of clinical guidelines that accurately reflect the reality of multimorbidity in the population, ensuring that management strategies and treatment plans are aligned and avoiding conflicts or excessive medication use for patients. In addition, it provides insight for service organizations on how to effectively manage common associations between diagnoses, considering socio-demographic factors, ultimately leading to improved patient care and resource utilization within the healthcare system.

Limitations

The design of this study has some limitations that should be addressed. First, there is the potential for incidence-prevalence bias, a common problem in cross-sectional studies, because we are analyzing existing cases at a single point in time without considering the duration of conditions. This bias could affect the interpretation of the prevalence of multimorbidity, as individuals with long-lasting conditions are more likely to be included in the study. As such, the results may not fully reflect the true incidence of multimorbidity in the population.

Another limitation of this study is the potential for confounding, whereby the observed associations may be influenced by other unmeasured factors. For example, socioeconomic factors, access to health care, and lifestyle differences between populations enrolled in different health care systems could contribute to the observed differences in multimorbidity patterns. Although we adjusted for some factors, such as age and sex, it is possible that other confounders, such as comorbidities or health care utilization patterns, were not adequately considered. Future studies should aim to control for these variables more comprehensively to ensure that the observed associations are not unduly influenced by confounding factors.

Conclusion

This study provides valuable insights into multimorbidity in the population and highlights disparities based on socio-demographic factors such as age, sex and socio-economic status. This information is relevant for the planning of health services and developing targeted public health initiatives. The innovative network approach used in this study provides a valuable means of quantifying the prevalence of multimorbidity through the analysis of medical records within the healthcare system. A major strength of this study is the use of a large data set representative of the population of Bogotá. However, it is important to acknowledge certain limitations. The construction of the multimorbidity networks was based on medical consultation records from a one-year period, which meant that only diagnoses recorded during this period and for a specific type of service were included. In addition, the study is subject to the inherent limitations of data collection and quality. While this study focused on analyzing associations between pairs of diagnoses (edges) in the networks to address representative differences, future research could consider exploring other configurations, such as triads, to further define multimorbidity.

Ethical approval and consent to participate

The project was evaluated by the Ethics Committee of the Secretary of Health of Bogotá (23−10−2020). The database records were received anonymously with a random code to protect the privacy of people included in the database.

Consent for publication

The authors declare their consent for publication.

Funding

This research received no external funding.

CRediT authorship contribution statement

Carolina Saavedra-Moreno: Writing – original draft, Validation, Methodology, Formal analysis, Conceptualization. **Rafael Hurtado:** Writing – review & editing, Validation, Methodology, Formal analysis, Conceptualization. **Nubia Velasco:** Writing – review & editing, Validation, Formal analysis, Conceptualization. **Andrea Ramírez:** Writing – review & editing, Validation, Methodology.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

The authors acknowledge the financial support received from the Universidad de Ibagué for CSM doctoral studies. The generous funding provided by the University has been instrumental in facilitating the progress of this research project and the preparation of the manuscript for submission. They would also like to express their sincere gratitude to the Centre of Excellence in Scientific Computing, Faculty of Science - HERMES, at the Universidad Nacional de Colombia, where the database was processed.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.gloepi.2024.100171.

References

[1] Ryan A, Wallace E, O'Hara P, Smith SM. Multimorbidity and functional decline in community-dwelling adults: a systematic review. Health Qual Life Outcomes 2015: 13. https://doi.org/10.1186/s12955-015-0355-9.

[2] Aiden H. Multimorbidity - Understanding the challenge. Richmond Group of Charities; 2018.

[3] Nunes BP, Thumé E, Facchini LA. Multimorbidity in older adults: magnitude and challenges for the Brazilian health system chronic disease epidemiology. BMC Public Health 2015;15:1–11. https://doi.org/10.1186/s12889-015-2505-8.

[4] Palladino R, Pennino F, Finbarr M, Millett C, Triassi M. Multimorbidity and health outcomes in older adults in ten European health systems, 2006–15. Health Aff 2019;38:613–23. https://doi.org/10.1377/hlthaff.2018.05273.

[5] Bähler C, Huber CA, Brüngger B, Reich O. Multimorbidity, health care utilization and costs in an elderly community-dwelling population: a claims data based observational study. BMC Health Serv Res 2015;15:1–12. https://doi.org/10.1186/s12913-015-0698-2.

[6] Payne RA, Abel GA, Guthrier B, Mercer SW. The effect of physical multimorbidity, mental health conditions and socioeconomic deprivation on unplanned admissions to hospital: a retrospective cohort study Rupert. CMAJ 2013;185:1–8. https://doi.org/10.1503/cmaj.121349/-/DC1.

[7] Huaquiá-Díaz AM, Chalán-Dávila TS, Carrillo-Larco RM, Bernabe-Ortiz A. Multimorbidity in Latin America and the Caribbean: a systematic review and meta-analysis. BMJ Open 2021;11:1–8. https://doi.org/10.1136/bmjopen-2021-050409.

[8] Oni T, Unwin N. Why the communicable/non-communicable disease dichotomy is problematic for public health control strategies: implications of multimorbidity for health systems in an era of health transition. Int Health 2015;7:390–9. https://doi.org/10.1093/inthealth/ihv040.

[9] Basto-Abreu A, Barrientos-Gutierrez T, Wade AN, Oliveira de Melo D, Semeão de Souza AS, Nunes BP, et al. Multimorbidity matters in low and middle-income countries. J Multimorbid Comorbidi 2022;12. https://doi.org/10.1177/26335565221106074. 263355652211060.

[10] Vinjerui KH, Bjerkeset O, Bjorngaard JH, Krokstad S, Douglas KA, Sund ER. Socioeconomic inequalities in the prevalence of complex multimorbidity in a Norwegian population: findings from the cross-sectional HUNT study. BMJ Open 2020;10:1–9. https://doi.org/10.1136/bmjopen-2020-036851.

[11] Valderas JM, Starfi B, Sibbald B, Salisbury S, Roland M. Defining comorbidity: implications for understanding health and health services. Ann Fam Med 2009;7: 357–63. https://doi.org/10.1370/afm.983.Martin.

[12] WHO. Multimorbidityvol. 47. Geneva: World Health Organization; 2017. https://doi.org/10.1097/01.NURSE.0000524761.58624.1f.

[13] Skou ST, Mair FS, Fortin M, Guthrie B, Nunes BP, Miranda JJ, et al. Multimorbidity. Nat Rev Dis Primers 2022;8:48. https://doi.org/10.1038/s41572-022-00376-4.

[14] Nicholson K, Makovski TT, Griffith LE, Raina P, Stranges S, van den Akker M. Multimorbidity and comorbidity revisited: refining the concepts for international health research. J Clin Epidemiol 2019;105:142–6. https://doi.org/10.1016/j.jclinepi.2018.09.008.

[15] Van Den Akker M, Buntinx F, Knottnerus JA. Comorbidity or multimorbidity: what's in a name? A review of literature. Eur J Gen Pract 1996;2:65–70. https://doi.org/10.3109/13814789609162146.

[16] Gaspar A, Miranda JJ. Burden of treatment as a measure of healthcare quality: an innovative approach to addressing global inequities in multimorbidity. PLOS Glob Public Health 2022;2:e0000484. https://doi.org/10.1371/journal.pgph.0000484.

[17] Huntley AL, Johnson R, Purdy S, Valderas JM, Salisbury C. Measures of multimorbidity and morbidity burden for use in primary care and community settings: a systematic review and guide. Ann Fam Med 2012;10:134–41. https://doi.org/10.1370/afm.1363.

[18] Abebe F, Schneider M, Asrat B, Ambaw F. Multimorbidity of chronic non-communicable diseases in low- and middle-income countries: a scoping review. J Comorbid 2020;10. https://doi.org/10.1177/2235042x20961919. 2235042X2096191.

[19] Alfonso-Sierra E, Arcila A, Bonilla J, Latorre M, Porras A, Urquijo L. Situación de multimorbilidad en Colombia 2012–2016. Bogotá - Colombia: Ministerio de Salud y Protección Social - Banco Mundial; 2016.

[20] Kalgotra P, Sharda R, Croff JM. Examining health disparities by gender: a multimorbidity network analysis of electronic medical record. Int J Med Inform 2017;108:22–8. https://doi.org/10.1016/j.ijmedinf.2017.09.014.

[21] Hernández B, Reilly RB, Kenny RA. Investigation of multimorbidity and prevalent disease combinations in older Irish adults using network analysis and association rules. Sci Rep 2019;9:1–12. https://doi.org/10.1038/s41598-019-51135-7.

[22] Glicksberg BS, Li L, Badgeley MA, Shameer K, Kosoy R, Beckmann ND, et al. Comparative analyses of population-scale phenomic data in electronic medical records reveal race-specific disease networks. Bioinformatics 2016;32:101–10. https://doi.org/10.1093/bioinformatics/btw282.

[23] Kalgotra P, Sharda R, Croff JM. Examining multimorbidity differences across racial groups: a network analysis of electronic medical records. Sci Rep 2020;10:1–9. https://doi.org/10.1038/s41598-020-70470-8.

[24] Liu J, Ma J, Wang J, Zeng DD, Song H, Wang L, et al. Comorbidity analysis according to sex and age in hypertension patients in China. Int J Med Sci 2016;13: 99–107. https://doi.org/10.7150/ijms.13456.

[25] DANE. Proyecciones de población. https://www.dane.gov.co/index.php/estadisticas-por-tema/demografia-y-poblacion/proyecciones-de-poblacion; 2020.

[26] Hilarión-Gaitán L, Díaz-Jiménez D, Cotes-Cantillo K, Castañeda-Orjuela C. Desigualdades en salud según régimen de afiliación y eventos notificados al Sistema de Vigilancia (Sivigila) en Colombia, 2015. Biomédica 2019;39:737–47. https://doi.org/10.7705/biomedica.4453.

[27] Urdinola P, Bejarano Salcedo V, Espinosa O, Silva PLDN. Estudio de caracterización socioeconómica y demográfica de los afiliados al régimen subsidiado de salud, Colombia 2019-2020. Ens Econ 2023;33:85–116. https://doi.org/10.15446/ede.v33n63.104918.

[28] Ministerio de Salud y Protección Social. ?Qué es SISPRO? SISPRO- Sistema Integrado de Información de La Protección Social. https://www.sispro.gov.co/Pages/Home.aspx; 2019.

[29] Marengoni A, Angleman S, Melis R, Mangialasche F, Karp A, Garmen A, et al. Aging with multimorbidity: a systematic review of the literature. Ageing Res Rev 2011; 10:430–9. https://doi.org/10.1016/j.arr.2011.03.003.

[30] Murtagh KN, Hubert HB. Gender differences in physical disability among an elderly cohort. Am J Public Health 2004;94:1406–11. https://doi.org/10.2105/AJPH.94.8.1406.

[31] Bertakis KD, Azari R, Helms LJ, Callahan EJ, Robbins JA. Gender differences in the utilization of health care services. J Fam Pract 2000;49:147–52.

[32] Barnett K, Mercer SW, Norbury M, Watt G, Wyke S, Guthrie B. Epidemiology of multimorbidity and implications for health care, research, and medical education: a cross-sectional study. The Lancet 2012;380:37–43. https://doi.org/10.1016/S0140-6736(12)60240-2.

[33] St. John P, Tyas S, Menec V, Tate R. Multimorbidity, disability, and mortality in community-dwelling older adults Multi-morbidité, incapacité et mortalité chez les personnes âgées vivant dans la communauté. Research Web Exclusive Can Fam Physician 2014;60:272–80.

[34] Mora-Moreo L, Estrada-Orozco K, Espinosa O, Mesa-Melgarejo L. Characterization of the population affiliated to the subsidized health insurance scheme in Colombia. A systematic review and meta analysis. Int J Equity Health 2023;22:1–23. https://doi.org/10.1186/s12939-022-01818-x.