



Temporal Multivariate Structure of Disease Burden in Latin America (2000–2023): An HJ-Biplot and Clustering Approach

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Abstract. This study analyses the multivariate structure of the disease burden in Latin America between 2000 and 2023, employing HJ-Biplot and clustering techniques. Data from the Global Burden of Disease (GBD) project were employed, considering key indicators such as deaths, years of life lost (YLLs), years lived with disability (YLDs), disability-adjusted life years (DALYs), and incidence and prevalence rates. The data were organised and standardised, and the analysis was conducted across three sub-periods to identify changes in the epidemiological landscape. The results revealed two main axes: one associated with premature mortality, and the other with morbidity. The first dimension was dominated by mortality indicators, particularly YLLs and deaths, whilst the second dimension was concentrated around prevalence, YLDs and incidence. Furthermore, three groups of diseases with distinct patterns were identified: mortality-associated, morbidity-associated and mixed. The temporal analysis suggests a transition towards greater influence from chronic and disabling diseases. This study provides a comprehensive, multivariate perspective that facilitates an understanding of the complex patterns of disease burden and offers relevant evidence to inform public health decision-making in the region.

Keywords: HJ-Biplot, Burden of Disease, Multivariate Analysis, Clustering, Latin America.

1 Introduction

The analysis of the burden of disease is a key factor in understanding the health status of populations, as it incorporates dimensions such as premature mortality, disability and the loss of healthy life years. In this context, the HJ-Biplot is a multivariate analysis technique which simultaneously represents individuals and variables in a low-dimensional space whilst preserving the interpretability of both [1]. This capability enables complex structures in the data to be explored, patterns to be identified and relationships between epidemiological indicators to be detected, which is particularly useful in the

study of phenomena such as years of life lost (YLL), years lived with disability (YLD) and disability-adjusted life years (DALYs).

Despite global improvements in life expectancy, there are still significant challenges regarding the quality of life, particularly in regions such as Latin America, where communicable and chronic diseases coexist with conditions related to social determinants of health. Various studies have shown that a significant proportion of the population either dies prematurely or lives with long-term disability. This reflects inequalities in access to healthcare services and structural limitations within healthcare systems [2], [3], [4]. In this context, chronic diseases such as diabetes and cardiovascular disease remain significant causes of loss of healthy life years, while infectious and perinatal conditions continue to affect vulnerable populations disproportionately [5], [6], [7]. Furthermore, diseases such as dengue and leptospirosis, as well as other neglected infections, continue to have a significant impact in terms of years of life lost, particularly in contexts of poverty [8], [9].

At the same time, the increase in chronic, non-communicable diseases and lifestyle-related disorders has complicated the region's epidemiological landscape further. Cancer, particularly among women, remains one of the leading causes of loss of healthy life years, while conditions such as uterine fibroids, chronic low back pain, and neurodegenerative diseases like Parkinson's have shown an upward trend [10], [11], [12], [13], [14], [15]. Added to this are structural factors such as alcohol consumption, obesity, and failures in healthcare systems, which contribute to the increase in liver disease and preventable adverse events [4], [16]. Against this backdrop, the present study seeks to analyse the multivariate structure of disease burden in Latin America between 2000 and 2023 using HJ-Biplot and clustering techniques. Using Global Burden of Disease (GBD) data, the study examines relationships between key indicators such as deaths, DALYs, YLLs, YLDs, incidence and prevalence. A temporal approach based on sub-periods allows the identification of structural patterns and changes in disease patterns, as well as clusters of causes exhibiting similar behaviours.

Unlike previous studies, which analysed the burden of disease using isolated indicators or a single time period, this study uses the HJ-Biplot method, temporal stratification and cluster validation to examine how the multivariate structure of the burden of disease has evolved in Latin America over more than two decades. This analytical framework provides a comprehensive representation of the relationships between health indicators and disease groups, making it easier to identify structural changes over time.

2 Disease burden

The burden of disease is a comprehensive approach that quantifies the impact of health problems on a population by combining mortality and morbidity within a single analytical framework. Developed within the context of the Global Burden of Disease (GBD) project, this approach integrates indicators such as years of life lost due to premature death (YLL), years lived with disability (YLD), and disability-adjusted life years (DALYs). This facilitates comparisons between diseases, regions, and time periods [17], [18]. These indicators not only allow the main causes of health loss to be

identified, but also enable inequalities in health systems to be analysed and public policy decisions to be guided, particularly in regions with high epidemiological heterogeneity, such as Latin America.

3 HJ-Biplot and multivariate analysis

The HJ-Biplot is a multivariate analysis technique that simultaneously represents the rows (individuals) and columns (variables) of a data matrix in a low-dimensional space while maintaining an adequate level of representation for both [1]. Unlike other Biplot variants, the HJ approach optimises joint interpretation, facilitating the analysis of relationships between variables using angles and the identification of similarities or differences between individuals through distances in the factor plane. This property makes the HJ-Biplot a particularly useful tool for exploring complex structures, detecting patterns, and analysing associations in multidimensional data. For example, it can be used to understand the interaction between multiple dimensions of health in an integrated manner, as is necessary when analysing epidemiological indicators of the burden of disease.

4 Reference works

The use of indicators such as disability-adjusted life years (DALYs) by various studies has provided a deeper understanding of the global and regional burden of disease, with the combining of premature mortality and disability into a single measure. This approach has revealed that, in many contexts, the leading causes of health loss have shifted from infectious diseases to chronic non-communicable diseases and mental health conditions. This reflects changes in epidemiological profiles and living conditions [8], [11], [14], [16]. Furthermore, inequalities in access to healthcare services and the quality of care continue to significantly influence the distribution of the disease burden, particularly in low- and middle-income countries [19].

In the case of children and young people, the literature highlights infectious diseases and perinatal conditions as significant factors contributing to the loss of healthy life years. For instance, respiratory syncytial virus (RSV) is a leading cause of DALYs in children under two in Latin America, due to mortality and long-term complications [6]. Similarly, preterm births continue to pose a significant challenge in regions with limited access to healthcare services, where associated complications lead to disability and infant mortality [7].

Furthermore, neglected diseases and emerging infections continue to have a significant impact on the region. Diseases such as leptospirosis and dengue fever impose a particularly high burden on vulnerable populations living in socio-economically disadvantaged conditions [8], [9]. Injuries caused by external factors, such as road traffic accidents, mainly affect young men of working age. This results in a significant loss of healthy life years, highlighting the influence of social and structural factors on health [20].

There has been a steady increase in the prevalence and impact of chronic non-communicable diseases in Latin America. Cancer, cardiovascular diseases, musculoskeletal disorders, and neurodegenerative diseases, in particular, have contributed to a significant loss of healthy life years [4], [10], [11], [12], [14], [15]. However, most of these studies have focused on descriptive analyses or specific diseases without taking a multivariate approach that integrates multiple health indicators. The present study therefore provides a complementary perspective by applying HJ-Biplot and clustering techniques to allow the simultaneous analysis of relationships between epidemiological variables and disease causes, and to identify structural patterns and relevant clusters in the context of the disease burden in Latin America.

5 Materials and Methods

5.1 Data source and variables

This study is based on data from the Global Burden of Disease (GBD) project, which provides internationally comparable estimates of mortality, morbidity, and risk factors. Records covering the period 2000–2023 for Latin America were used, taking into account key disease burden indicators such as deaths, disability-adjusted life years (DALYs), years of life lost due to premature death (YLLs), years lived with disability (YLDs), incidence and prevalence. These indicators allow for a thorough evaluation of both mortality and morbidity, enabling the combined analysis of the impact of diseases on the population.

All analyses were performed using R version 4.5.1 (R Foundation for Statistical Computing, Vienna, Austria). Data processing and visualisation were conducted using the tidyverse, ggplot2, ggrepel, patchwork and scales packages. HJ-Biplot analysis was performed using the MultBiplotR package, while cluster validation and clustering procedures were implemented with the cluster and factoextra packages. The database corresponds to the Global Burden of Disease (GBD) 2023 release, which was published by the Institute for Health Metrics and Evaluation (IHME).

5.2 Data pre-processing

The data were processed using techniques that transformed and aggregated them so that an analysis matrix could be constructed that was suitable for the multivariate approach. In particular, the data were reorganised using a pivot table, with each row representing a cause of disease and each column representing an epidemiological indicator. Average values of the indicators were calculated for each sub-period, reducing temporal variability and enabling a structural comparison between periods. Additionally, records with missing values were removed, and the variables were standardised to have a mean of zero and a variance of one in order to avoid scale effects between the different indicators.

5.3 HJ-Biplot analysis

A multivariate analysis was performed using the HJ-Biplot technique, which enables the relationships between variables and individuals to be visualised simultaneously within a two-dimensional space. This methodology was applied to three sub-periods (2000–2007, 2008–2015, and 2016–2023) separately, in order to analyse the temporal evolution of the disease burden structure. The factor coordinates of the variables and causes of disease were obtained based on the eigenvalue decomposition of the standardised data matrix, which facilitated the interpretation of patterns, associations and relative contributions within each analysed period.

5.4 Clustering analysis and validation

The k-means algorithm was applied to the coordinates obtained from the first two dimensions of the HJ-Biplot to identify groups of diseases with similar epidemiological profiles. The clustering procedure was implemented with 25 random initialisations ($nstart = 25$) to reduce the influence of local optima and improve the stability of the final partition. The optimal number of clusters for each sub-period was then evaluated using the average Silhouette coefficient. Silhouette analysis revealed heterogeneous solutions across the three sub-periods. However, a three-cluster solution was adopted for the main comparative analysis to ensure temporal comparability and to make it easier to interpret structural changes in disease burden.

The Silhouette coefficient was used to evaluate the internal consistency of the clustering solutions for each sub-period. Validation indicated that the two-cluster solution produced the highest average Silhouette coefficient in all three sub-periods (see Table 1). However, a three-cluster solution was adopted for the final analysis, providing a more detailed epidemiological characterisation of disease groups while maintaining consistent HJ-Biplot comparisons over time. This approach prioritises interpretability without substantially reducing cluster quality.

Table 1. Cluster validation using the Silhouette coefficient

Sub-period	Optimal number of clusters	Average Silhouette coefficient	Clusters used in the study
2000–2007	2	0.463	3
2008–2015	2	0.543	3
2016–2023	2	0.538	3

6 Results

6.1 Inertia and Quality of Representation

The results of the HJ-Biplot analysis show that the first two dimensions have high explanatory power across all sub-periods analysed. Notably, the cumulative variance explained by Dim1 and Dim2 is 69.40% for the period 2000–2007, 69.62% for 2008–2015, and 72.45% for 2016–2023. These values demonstrate that the two-dimensional representation captures a significant amount of the total variability in the data, enabling reliable interpretation of the relationships between disease burden indicators.

In all sub-periods, the first-dimension accounts for the largest proportion of variance, with respective values of 44.17%, 43.86% and 46.24%, suggesting that it represents the system under analysis's main structural gradient. The second dimension, meanwhile, accounts for between 25.23% and 26.21% of the variability, providing complementary information that enhances the ability to distinguish between patterns. Notably, the increase in cumulative explained variance in the most recent period (2016–2023) indicates a slightly clearer data structure, potentially associated with evolving epidemiological configurations. Overall, these results support the effectiveness of the HJ-Biplot in analysing the multivariate structure of disease burden in Latin America.

6.2 HJ-Biplot Analysis Across Subperiods

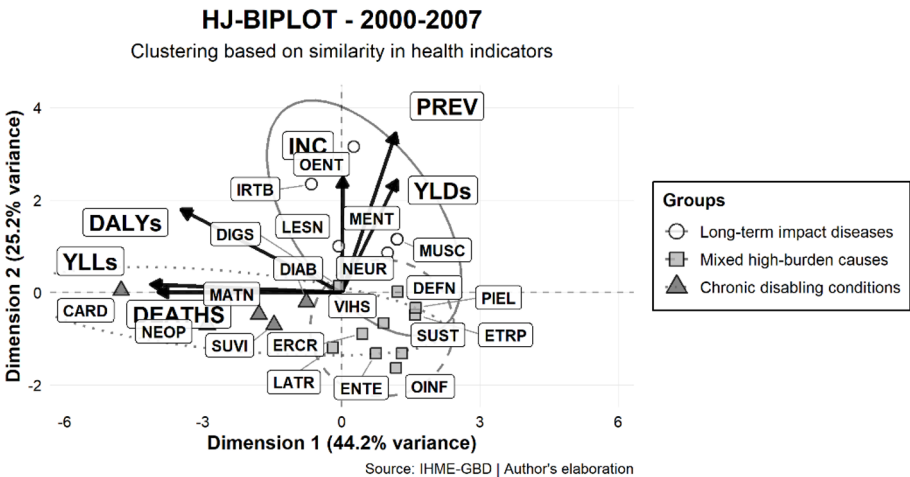


Fig. 1. HJ-Biplot of Disease Burden Indicators in Latin America (2000–2007)

The HJ-Biplot for the three sub-periods (Figure 1) reveals a consistent structure in the relationship between disease burden indicators and gradual changes in their configuration. In all three cases, the variables associated with mortality, particularly deaths and YLLs, are oriented in a similar direction along the first dimension, indicating a strong

correlation between these indicators. By contrast, YLDs, incidence and prevalence cluster mainly along the second dimension, reflecting their association with morbidity and the persistence of diseases. Meanwhile, DALYs occupy an intermediate position, suggesting their role as a bridge between premature mortality and disability.

In terms of time, the sub-period from 2000 to 2007 shows a clear distinction between

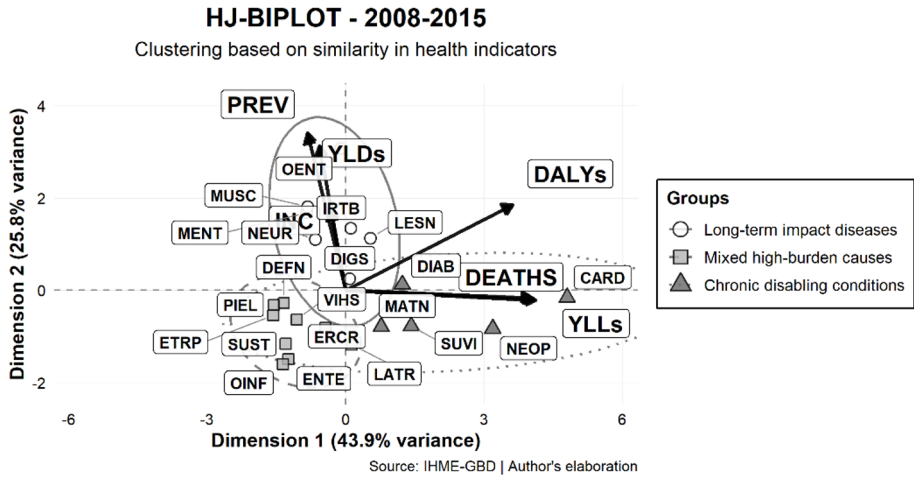


Fig. 2. HJ-Biplot of Disease Burden Indicators in Latin America (2008–2015)

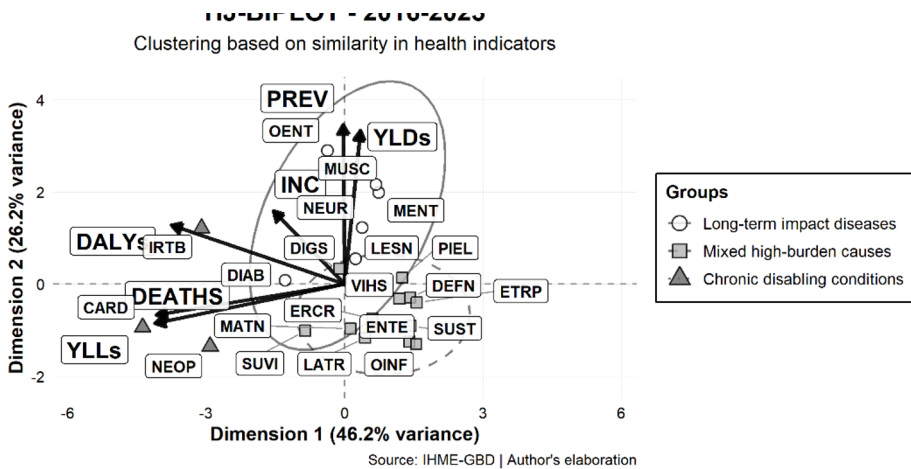


Fig. 3. HJ-Biplot of Disease Burden Indicators in Latin America (2016–2023)

mortality and morbidity indicators, with a relatively compact distribution of diseases. In contrast, the 2008–2015 period exhibits a greater dispersion of data points, indicating a more heterogeneous structure and complex interactions between the indicators. In the final sub-period (2016–2023), there is evidence of a greater concentration of causes around the morbidity axis, particularly in relation to YLDs, incidence and prevalence.

This suggests a greater prominence of chronic and disabling diseases. Overall, these results reflect an evolution in the structure of the disease burden in Latin America, characterised by a progressive transition from mortality-dominated patterns towards morbidity-influenced configurations.

6.3 Variable Importance

Analysis of the variables' contributions shows that the indicators associated with premature mortality carry the greatest weight in the multivariate structure in all sub-periods. YLLs are particularly influential, contributing around or more than 94% in all periods. This is followed by deaths and DALYs, which also show high values. This confirms that the first dimension is dominated primarily by mortality and years of life lost, forming the main structural axis of the system. Furthermore, the consistency of these contributions over time suggests that premature mortality continues to be a key factor in shaping the disease burden in Latin America.

Conversely, indicators pertaining to morbidity, especially prevalence and YLDs, have a more significant impact on the second dimension. Prevalence is the most influential variable on this axis, with values exceeding 64% in all sub-periods. This is followed by YLDs, and to a lesser extent, incidence. This pattern reinforces the interpretation of the second dimension as an axis associated with the persistence of diseases and disability. Furthermore, in the most recent sub-period (2016–2023), these variables continue to contribute significantly, suggesting that chronic and disabling conditions are becoming increasingly relevant in the structure of the disease burden. Overall, these results demonstrate clear differentiation between the mortality and morbidity components, as well as a shift towards greater morbidity influence on the region's epidemiological profile.

6.4 Clustering of Diseases

Cluster analysis based on the coordinates of the HJ-Biplot enables us to identify distinct patterns among the causes of disease in each sub-period. During the 2000–2007 period, diseases such as cardiovascular disease (CARD) and neoplasms (NEOP) contributed most to the first dimension, reflecting their strong association with premature mortality. By contrast, other causes, such as chronic respiratory diseases (ERCR), traffic injuries (LATR), and other infections (OINF), show a greater contribution to the second dimension, highlighting their relationship with morbidity and disability. Furthermore, some categories, such as substance use (SUST), show balanced contributions across both dimensions, suggesting a mixed pattern of mortality and morbidity.

A similar pattern persists in the sub-periods 2008–2015 and 2016–2023, albeit with slight variations in the magnitude of the contributions. Cardiovascular diseases and neoplasms continue to dominate the first dimension, establishing themselves as the leading causes of loss of life years. Conversely, conditions such as road traffic injuries (RTI), chronic respiratory diseases (CRD) and other infections (OINF) exert a greater influence on the second dimension, thereby reinforcing their association with disability. In the most recent period, greater stability in disease contributions is also evident,

suggesting a clearer structure within the identified groups. Taken together, these results demonstrate the existence of three groupings of diseases: those primarily associated with mortality; those primarily associated with morbidity; and those with mixed behaviour. This allows for a better understanding of the heterogeneity in the disease burden in Latin America.

7 Discussion

The results indicate that the multivariate structure of the burden of disease in Latin America remained relatively stable between 2000 and 2023, with a consistent separation between indicators related to mortality and those related to morbidity. In all three sub-periods, deaths and years of life lost (YLL) constituted the dominant components of the first dimension, whilst prevalence, years lived with disability (YLD) and incidence were primarily associated with the second dimension. This pattern is consistent with the epidemiological transition described in previous Global Burden of Disease studies, which point to a gradual shift from communicable diseases towards chronic non-communicable diseases as the main factors contributing to the loss of health in the population. Far from replacing mortality as a cause for public health concern, this transition reflects the coexistence of premature mortality and long-term disability as complementary dimensions of the burden of disease.

The temporal comparison also suggests that indicators related to morbidity became more significant during the most recent sub-period. The increased contribution of prevalence and DALYs (disability-adjusted life years) is consistent with demographic ageing and improvements in survival rates for chronic diseases. It is also consistent with the increased prevalence of chronic conditions observed across Latin America. Similar trends have been observed for cardiovascular diseases, cancers, diabetes, neurological disorders, and other chronic conditions. The impact of these conditions is increasingly reflected in years lived with disability rather than in mortality alone. Therefore, strategies that focus solely on reducing premature deaths may be insufficient to address the current epidemiological profile, emphasising the necessity of policies that reduce mortality and improve quality of life simultaneously.

From a methodological perspective, combining HJ-Biplot with temporal stratification and cluster analysis provided a comprehensive representation of the relationships between disease burden indicators and disease clusters. While the Silhouette criterion indicated that a two-cluster solution had the greatest internal consistency, a three-cluster configuration was chosen to allow for an epidemiological interpretation of disease profiles and to maintain comparability between sub-periods. This enabled diseases predominantly associated with mortality, diseases characterised mainly by disability and causes exhibiting mixed patterns to be identified. Such differentiation would be more challenging using conventional descriptive analyses or analyses based on a single indicator.

Several limitations should be borne in mind when interpreting the results. Firstly, the analysis was based on secondary data obtained from the 'Global Burden of Disease 2023' database. This database's estimates are derived from statistical models and

depend on the quality and availability of national health information systems. Furthermore, the study adopted an ecological approach and did not consider socio-economic, environmental, or healthcare access variables that could partly explain the observed patterns. Therefore, the identified associations should not be interpreted as causal relationships, but rather as multivariate patterns that contribute to our understanding of how the burden of disease has evolved in Latin America over the past two decades.

From a methodological perspective, the proposed analytical framework shows that combining HJ-Biplot, temporal segmentation and cluster validation is an effective way of exploring structural changes in complex epidemiological datasets. The framework can be extended to other geographical regions or applied to different public health indicators to facilitate comparative analyses over time.

8 Conclusions

This study analysed the multivariate structure of the disease burden in Latin America between 2000 and 2023 using HJ-Biplot and clustering techniques. The results revealed two distinct main axes: the first dominated by premature mortality indicators, such as deaths and years of life lost (YLLs); and the second associated with morbidity, represented by prevalence, years lived with disability (YLDs), and incidence. This configuration remained relatively stable across the three sub-periods analysed, confirming the structural consistency of the indicators in explaining the burden of disease.

From a temporal perspective, significant changes in epidemiological trend patterns can be observed. In the most recent sub-periods, a greater concentration of causes of illness has emerged around morbidity indicators, suggesting an increasing prevalence of chronic and disabling diseases. This is consistent with an epidemiological transition in the region, whereby a reduction in premature mortality is occurring alongside an increase in the prevalence of long-term conditions affecting the population's quality of life.

Finally, the clustering analysis revealed three distinct patterns: diseases primarily associated with mortality; conditions linked to morbidity; and causes exhibiting mixed behaviour. From a methodological perspective, combining HJ-Biplot with variable standardisation and analysis by sub-periods provides a robust tool for analysing complex epidemiological data. The results obtained in this study provide valuable insights into the dynamics of disease burden and could inform the development of public health policies aimed at reducing mortality and improving quality of life in Latin America.

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