

ARTICLE / INVESTIGACIÓN

Statistical Analysis of Mortality by Non-Communicable Diseases (NCDs) and food supply in Ecuador, 1990-2017

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Abstract: An unhealthy diet is a risk factor for non-communicable diseases (NCDs). Data on the average protein supply and meat products between 1990-2017 consumed by the Ecuadorian population are collected. The HJ-Biplot method is used to identify clusters with MultiBiplot software to obtain a two-dimensional representation of the data in the plane along with the quality of representation of the variables and the total variance explained. This work aims to determine how much the source of protein, animal or vegetal, influences the amount of death caused by non-communicable diseases such as Cardiovascular diseases and Diabetes Mellitus. Finally, a Hierarchical Cluster Analysis is carried out with the food supply related to those diseases. It can be concluded that NCD mortality is primarily explained by the average protein supply of animal and meat products in Ecuador.

Key words: Ecuador, Non-Communicable Diseases, Cardiovascular disease, Diabetes, HJ-Biplot, food, proteins

Introduction

By 2030, the UN Sustainable Development Goals aim to reduce premature mortality from non-communicable diseases (NCDs) by a third¹. The most common is cardiovascular disease (CVD) which is responsible for an estimated 17.8 million deaths in 2017, and more than three quarters were in low-income and middle-income countries^{2,3}. While, Diabetes mellitus (DM) has become one of the most pressing and prevalent diseases in the last few decades and now is the seventh leading cause of death worldwide, with 5.2 million deaths globally and a mortality rate of 82.4 per 100,000⁴.

Furthermore, tobacco, harmful alcohol use, unhealthy diet, and physical inactivity are the four behavioral risk or lifestyle factors that drive CVD epidemic^{3,5,6}. An unhealthy diet is a modifiable risk factor for CVD, as well as DM, overweight, and obesity, are essential risk factors⁷.

There are strategies to reduce the high mortality rate, including accelerated tobacco control, salt reduction, healthy diets and physical activity, reduction of harmful alcohol consumption, and access to essential drugs and technologies^{8,9}. These strategies aim to reduce the number of premature deaths associated with chronic non-communicable diseases by 25%^{2,10}. Consequently, CVD death rates have decreased over the past few decades due to the improved prevention and treatment in high-income countries, but in low- and middle-income countries, it has increased between 2007 and 2017¹¹.

In Ecuador, for instance, Ischemic Heart Disease (IHD) occupied first place among the principal causes of death for several years. So by 2016, IHDs were the first cause of mortality in men and women^{12,13}. Similarly, DM caused 5064 deaths in 2015, ranking as the second cause of general mortality, the first cause of death in women, and the

third in men¹³. Besides, cardiovascular deaths account for 44% of death in those with type 1 DM and 52% of deaths in type 2 DM⁴.

Moreover, related to diets, dietary protein is integral to human health. However, there are controversies around the cardiovascular health effects of consuming animal-based and plant-based protein-rich foods¹⁴. Besides, increasing dietary protein may benefit cardiovascular health by aiding in weight loss/maintenance, improving the lipid/lipoprotein profile, and reducing blood pressure. In addition, the health benefits of dietary protein should interpret with caution since increasing the consumption of protein/protein-rich food typically results in other changes in diet, such as energy, nutrients, or food intake, depending on the source of the protein. Therefore, the specific protein food source determines the effect of increased protein consumption^{14,15}.

Plant-based intake pattern does not exclude all animal products; instead, the primary source of protein relies on plant foods like fruit and vegetables, plant proteins, oils, nuts and seeds, and wholegrain carbohydrates^{16,17}. Plant-based diets can improve blood lipid profiles, blood pressure, and weight management^{16,18}, which reduces the risk of developing CVD and diabetes^{7,11}. However, on the intake outcomes comparison, studies do not specify the type of diet or food given to subjects, whether animal-based or plant-based protein. And the plant protein sources (grains, legumes, soy, nuts, or whether they are low or high quality) or meats (red or white meat) are not specified.

This study analyses different food supplies across the population from 1990 to 2017 with data published by United Nations Food and Agricultural Organization (FAO)¹⁹. In addition, provided by Amnesty International, the annual number of death by cause in Ecuador during that period is also

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analyzed as a variable through the years. To determine a relationship between the food supply of Ecuadorians and the mortality rate of NCDs such as DM and CVD, HJ-Biplot and hierarchical Cluster Analysis is used to analyze the years when the animal-protein or meat supply plant-based proteins affected the number of death by NCDs.

Materials and methods

Data Collection

For this study, the variables are described in Table 1. The average supply of protein from animal products (g/ capita/ day), the average supply of plant-based protein products (g/ capita/ day), and the average supply of meat (kg/ capita/ year) are from data published by the United Nations Food and Agricultural Organization (FAO)¹⁹ where food supply defines as food available for human consumption. In addition, at the country level, in this case, Ecuador, it is calculated as the food remaining for human use after deduction of all non-food utilization. However, such values do not include consumption-level waste and therefore overestimate the average amount of food consumed¹⁹.

The annual number of deaths by cause is from data published by Amnesty International²⁰ that consists of executions, death sentences, and commutations and exonerations, where there is reasonable confirmation²⁰.

RStudio Software

The multivariate statistical analysis used RStudio, an Integrated Development Environment (IDE) for the R programming language. RStudio combines various components of R into one seamless and productive workbench²¹. In addition, the MultBiplot²² and the SparseBiplot R-packages²³ performed the HJ-Biplot and Hierarchical Cluster analysis.

The 'MultBiplot' package offers Several Multivariate Techniques from a biplot perspective²². While the 'SparseBiplot' Package implements three new techniques and constructs in each case an 'HJ-Biplot'. Based on the regularization theories, it adapts restrictions to reduce weights and/or produce zero weight in the dimensions. In addition, it implements three methods of regularization: Ridge, LAS-SO, and Elastic Net²³.

HJ-Biplot analysis

The HJ-Biplot originally proposed by Galindo-Villardón²⁴ presents the

advantages of Correspondence Analysis and applies to any data matrix, not just frequencies. It is a technique for inspecting multivariate data matrices with fewer restrictions than Correspondence or Factor Analysis. It has been applied to many fields of science. For instance, Cárdenas & Galindo²⁵ cite applications in medicine, economics, biology, or environmental technology.

In this study, HJ-Biplot analysis was done using the 'SparseBiplot' Package, with the years as labels for the rows shown in Figure 1. The HJ-Biplot command returns values such as an eigenvalues vector, a vector containing the proportion of variance explained by the first principal components obtained, a matrix with the coordinates of individuals, matrix with the coordinates of variables. While the HJ-Biplot command of MultBiplot returns more values such as inertia and column contributions.

Furthermore, the Biplot method, developed by Gabriel²⁶, allows the representation of the data matrix ($X(I*J)$) in low dimensional space, facilitating interpretation. It uses vectors as markers i_1, i_2, \dots, i_i for each row, and j_1, j_2, \dots, j_j for each column, which are obtained from the usual singular value decomposition (SVD) of the data matrix²⁷.

For this paper, the goal of the HJ-Biplot is to describe the relations between the row markers (years 1990-2017)

Variable	Description
AnimalPS	Average supply of protein from animal products (grams per person per day)
VegetalPS	Average supply of plant-based protein products (grams per person per day)
MeatFS	Average supply of meat across the population (kilograms per person per year)
DeathsDM	Annual number of death by Diabetes Mellitus
DeathsCD	Annual number of death by Cardiovascular Disease

Table 1. Variable Description.

and column markers (NCDs and food supplies, variables). The analysis of the HJ-Biplot is explained as follows: two variables separated by a minimal angle are strongly correlated; in addition, a group of years next to a variable indicates that the years have taken preponderant values for this variable^{27,28}.

Cluster Analysis

The Hierarchical cluster analysis of *n* objects is a stepwise algorithm that merges two things with a high similarity at each step^{29,30}. In this study, these differences between clusters of objects are defined by average linkage. The cluster analysis results are a binary tree, or dendrogram, with *n*-1 nodes³¹.

In this study, cluster analysis was performed using a hierarchical cluster using the HJ-Biplot (principal components) scores, Euclidean distances, and Ward's method. The linkage process used the MultBiplot Package as shown, for instance, in Figure 2.

Results and discussion

Figure 1, the total absorption of information by the axes is 96.82%, and the vectors have similar vector lengths showing the same variability. Besides, the columns that contribute the most to dimension 1 (73.18%) are the average supply of protein from animal products, meat supply, and DM's deaths (see Table 2). Similarly, the years when the animal products have higher contributions to dimension 1 than the plant-based products. While the years (2003-2015,2017) dominated by plant-based products, contribute the most to dimension 2 (23.6%).

In figure 2, there are 3 groups, where the labels are from I1 to I28, which correspond to 1990 to 2017, respectively. In blue, the years 2014-2017 have similarities in the number of plant-based and animal protein products but hi-

gher deaths by DM. During these years, there were patterns of obesity and overweight because of the rapid economic and demographic changes that Ecuador, as a developing country, was facing¹³. These years are marked by an easy replacement of predominantly plant-based low-calorie diets with predominantly animal-based high-calorie diets high in fat, sugar, and refined grains³².

While in red (1900 – 2005), the supply of plant-based protein started to decrease as animal products and meat started to increase, and it was reported that between 1990 and 2000, DM's deaths rose from 8% to 18% for men; and for women rose from 11% to 22%³².

Similarly, for the CVDs, the HJ-Biplot showed a total absorption of information by the axes of 94.7% (see Figure 3 and Figure 4). The animal products and meat supply contribute the most to dimension 1 (see Table 3). There are three clusters (figure 4), where the green cluster confirms a study done in 2018 about ischemic heart diseases (IHDs)¹³, which states that mortality from ischemic heart diseases increased in Ecuador from 2001 to 2016 (Figure 3). Researchers have found that a diet with high contents of red meat, mainly processed red meat, is primarily to heart disease and stroke³³⁻³⁵. Moreover, a diet with high contents of plant-based protein could have benefits like lower risk of cardiovascular disease because these are mostly unsaturated, which lowers LDL cholesterol—an established risk factor for heart disease^{16,36,37}.

Moreover, countries and international agencies for the UN High-Level Meeting on NCDs have recommended aligning national policies on agriculture, trade, industry, and transport to promote improved diets and increase physical activity to reduce obesity, unhealthy diet, and physical inactivity as an intervention to tackle the NCDs crisis⁸. Also, mass-media campaigns, food taxes, subsidies, labeling, and marketing restrictions could raise awareness to maintain a good lifestyle³⁸.

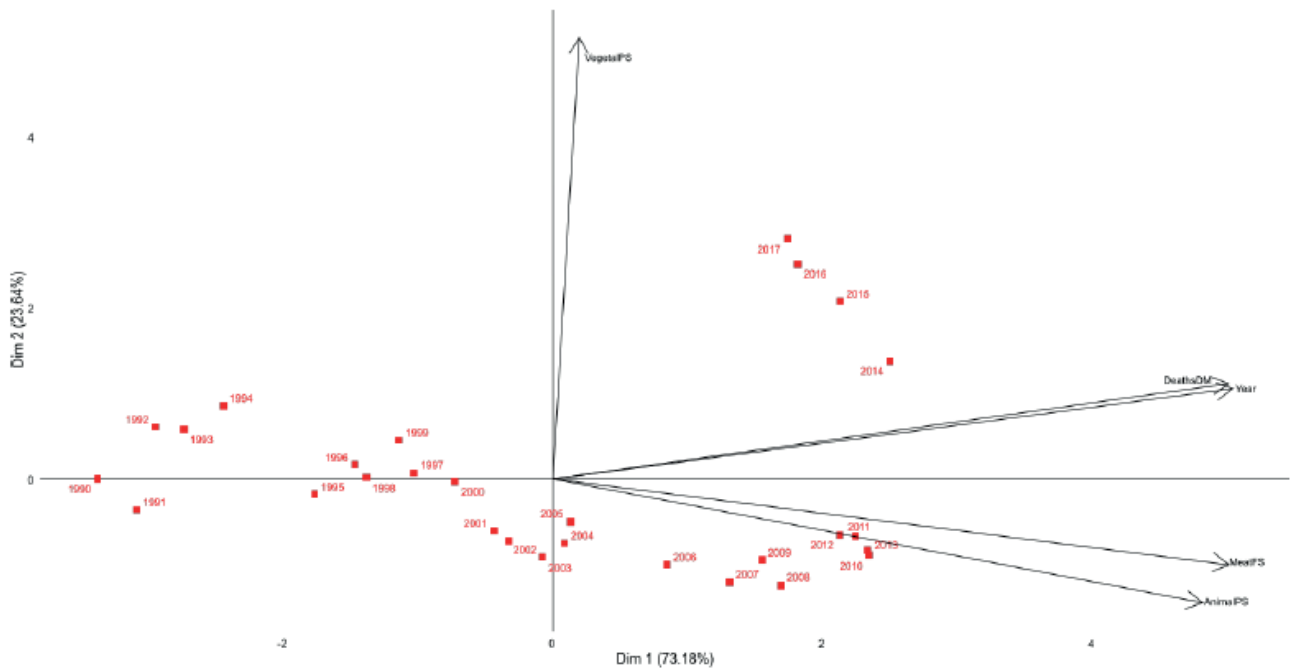


Figure 1. HJ-Biplot with SparseBiplot Package of Food supply and deaths by DM, 1990-2017.



HJ Biplot (Dim 1 (73.2 %)- 2(23.6 %))

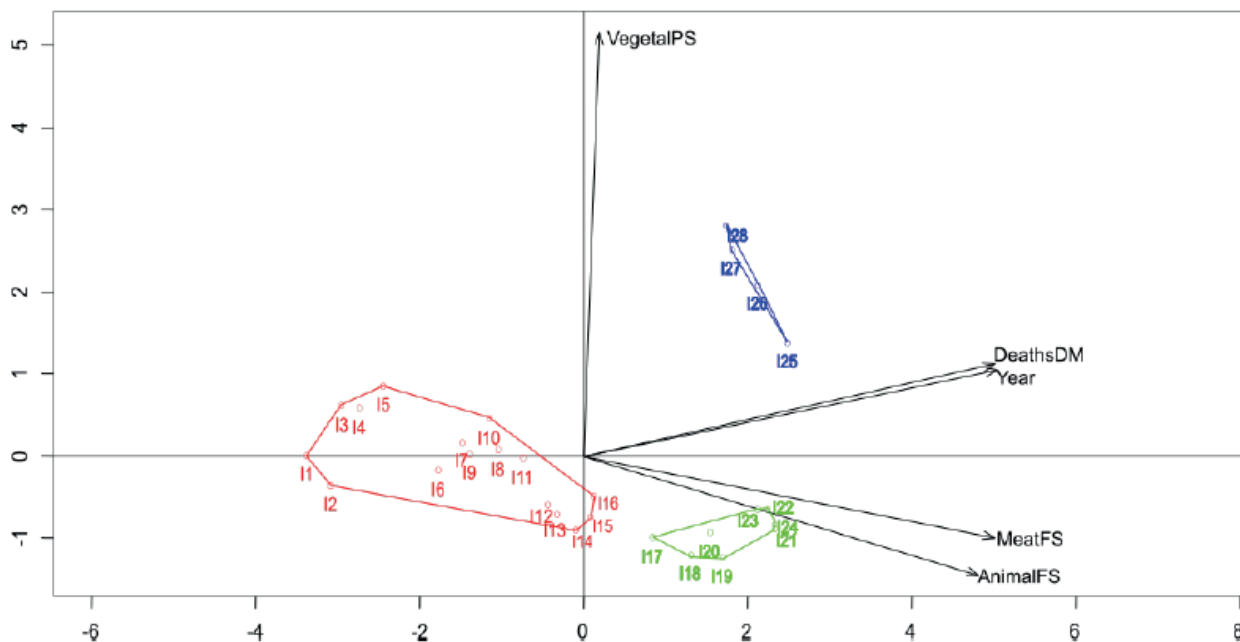


Figure 2. HJ-Biplot and Clusters formation with MultBiplot Package of Food supply and deaths by DM, 1990-2017.

	Dimension 1	Dimension 2
Year	94.03	4.11
Supply of protein from animal product	85.85	7.69
Supply of meat	93.04	3.65
Supply of protein from plant-based product	0.14	98.14
Deaths by Diabetes Mellitus	92.83	4.61

Table 2. Column Contributions for HJ-Biplot analysis of food supply and deaths by DM.

	Dimension 1	Dimension 2
Year	75.69	20.74
Supply of protein from animal product	92.10	0.03
Supply of meat	95.83	0.91
Supply of protein from plant-based product	5.34	92.56
Deaths by cardiovascular diseases	79.88	10.04

Table 3. Column Contributions for HJ-Biplot analysis of food supply and deaths by CVDs.

Conclusions

According to the HJ-Biplots analysis, the average amount of proteins from animal products and meat supply in the diet of Ecuadorians is highly and positively correlated with mortality by CVDs and Diabetes Mellitus.

From the Cluster Analysis, the years when the diet of Ecuadorians included more proteins from animal products and meat align with the years when the deaths by CVD and DM were high in numbers.

Since 2015, when the 2030 Agenda for Sustainable development² started, the awareness of the death risk by NCDs rose. Nevertheless, Diabetes Mellitus has not decreased as CVDs have because DM cases and deaths keep rising at dangerous levels globally (including in Ecuador); it is crucial to raise awareness in public health about this disease using the recommended guidelines by the UN⁸.

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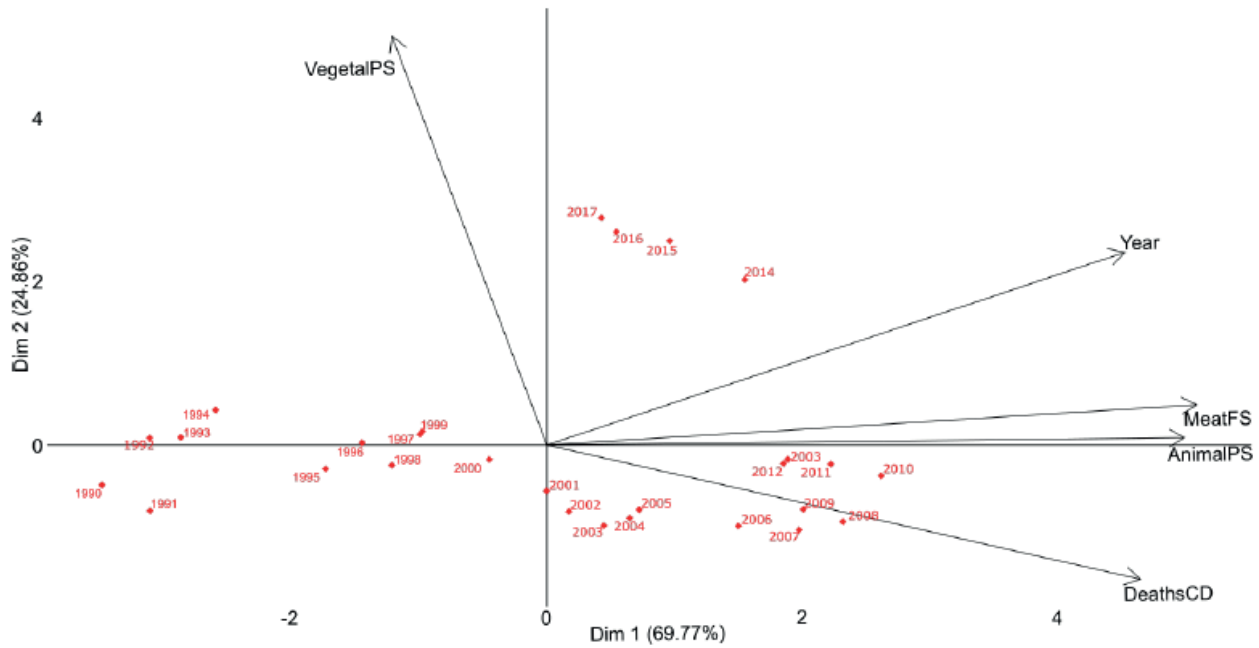


Figure 3. HJ-Biplot with SparseBiplot Package of Food supply and deaths by CVDs, 1990-2017.

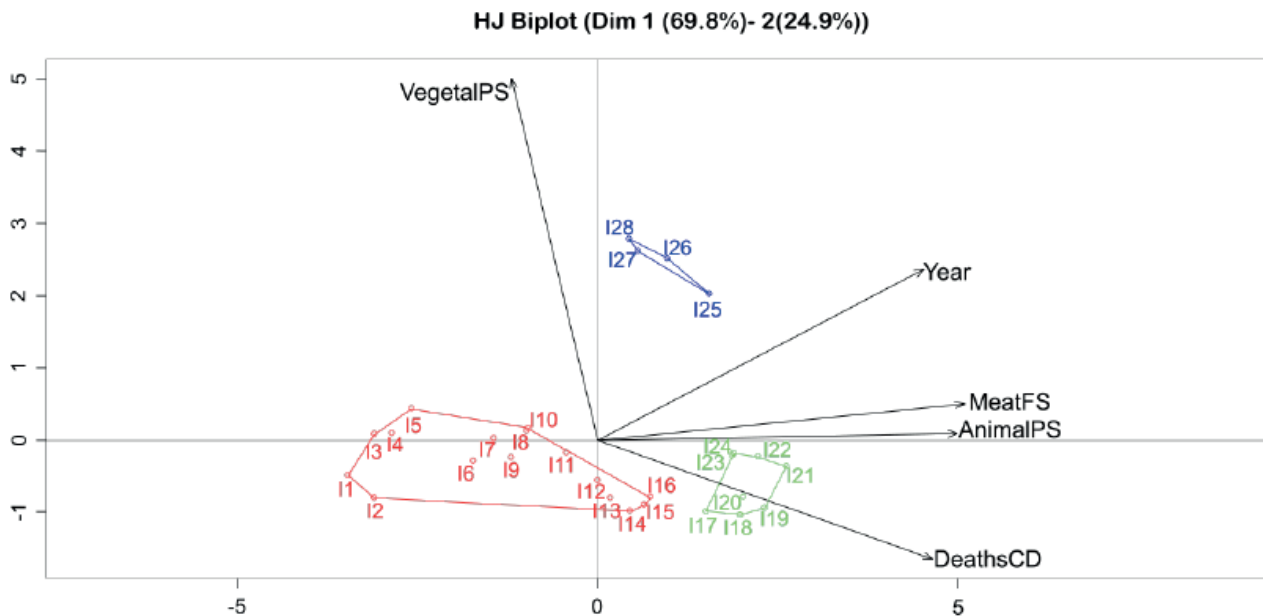


Figure 4. HJ-Biplot and Clusters formation with MultBiplot Package of Food supply and deaths by CVDs, 1990-2017.

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