

Assessment of the Interaction between Ethnical Groups and Chronic Metabolism Diseases Occurrence in Côte d'Ivoire: Cases of Diabetes and Hypertension

Yéboué Kouadio Auguste^{1,2}, Gnanoui Sara Laetitia Elphège¹, Dagnogo Olefongo³,
Dagnogo Dramane¹, Dago Dougba Noel^{1,4*}

¹Department of Genetic and Biochemistry, Biological Sciences Teaching and Research Unit, Peleforo GON COULIBALY University, Korhogo, Côte d'Ivoire

²National Institute for the Training of Health Workers, Abidjan, Côte d'Ivoire

³Biosciences Training and Research Unit (UFR), Felix Houphouët-Boigny University, Abidjan, Côte d'Ivoire

⁴African Center for Shea Research and Application (CRAK), Korhogo, Ivory Coast

Email: *dgnoel7@gmail.com, *noel.dago@upgc.edu.ci

How to cite this paper: Auguste, Y.K., Elphège, G.S.L., Olefongo, D., Dramane, D. and Noel, D.D. (2026) Assessment of the Interaction between Ethnical Groups and Chronic Metabolism Diseases Occurrence in Côte d'Ivoire: Cases of Diabetes and Hypertension. *Journal of Biosciences and Medicines*, 14, 399-424.

<https://doi.org/10.4236/jbm.2026.1410027>

Received: August 18, 2026

Accepted: October 24, 2026

Published: October 27, 2026

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Abstract

Background: Hypertension and diabetes are two common metabolic disorders that often coexist in the same individual. Previous study exhibited hypertension as the second reason why people visit Korhogo hospital, Northern of Côte d'Ivoire, while molecular diabetes predisposition risks result to be higher in that area of the country as opposite to Abidjan Southern. Therefore, understanding how cultural, genetic and environmental factors interact with the occurrence of these two diseases may contribute to more effective prevention and patient management. This study aimed to evaluate the association between regional ethnic background and the occurrence of diabetes and hypertension in Côte d'Ivoire. **Methods:** Study sample includes 200 patients with type 2 diabetes, 200 patients with both diabetes and hypertension, 200 patients with hypertension, and 150 healthy controls from several diabetology and cardiology departments as well as Regional and University Hospitals across Côte d'Ivoire. We collected anthropomorphic, ethnical and clinical data of all participant as well as venous blood and measured fasting blood glucose, glycated hemoglobin; triglycerides, total cholesterol, high-density lipoprotein cholesterol, and low-density lipoprotein cholesterol features. Anthropomorphic, clinical and biochemical data were submitted to a multivariate statistical analysis. **Results:** Findings showed a high prevalence of overweight and obesity of studied population and as well high dyslipidemia prevalent, predominantly associated with hypercholesterolemia. Multivariate and clustering analysis by

showing heterogeneous variability of anthropomorphic (age), clinical and biochemical parameters, suggested three distinct groups in the studied population with a statistical difference at $p = 0.11$, with substantial intra-group variability. Clustering survey revealed two major profiles among these clusters: one predominantly composed of Mandé ethnic group and characterized by hypertension, and another mainly composed of Akan ethnic group and characterized by diabetes. Statistical analyses revealed a significant association between the Mandé ethnic group and hypertension (odds ratio = 0.57; $p = 0.027$), as well as between the Akan ethnic group and diabetes (odds ratio = 75.51; $p < 0.001$). **Conclusions:** The study revealed a susceptibility between metabolic disorder (*i.e.* diabetes and hypertension) occurrence and regional ethnical features in Côte d'Ivoire.

Keywords

Type 2 Diabetes, Hypertension, Ethnical Groups, Dyslipidemia, Anthropomorphic, Biochemical and Clinical Parameters, Côte d'Ivoire

1. Introduction

Type 2 diabetes mellitus is a chronic metabolic disease that, if inadequately managed, places affected individuals at high risk of developing serious complications. These complications, particularly vascular complications, are a major cause of morbidity and may reduce the life expectancy of patients with diabetes. Hypertension is a critical aggravating factor for these complications. The two conditions are so closely linked that they often form a vicious cycle: diabetes promotes the development of hypertension, while hypertension increases the risk of developing diabetes [1]. The coexistence of these two disorders characterizes the metabolic syndrome, whose common underlying pathophysiological mechanism is insulin resistance [2]. This association has been extensively documented in both African and Western populations [2] [3].

In Côte d'Ivoire, diabetes and hypertension represent major public health challenges, with prevalence rates estimated at 27.6% [4] and 6.2% in 2017 [5]. Despite their public health importance, these conditions remain insufficiently documented because of the lack of comprehensive epidemiological data. Indeed, the available information is derived mainly from hospital-based populations [6], thereby limiting its representativeness at the national level.

However, Dago *et al.* (2022) [7] showed a high frequency of hypertension cases in Korhogo locality, Northern of Côte d'Ivoire. Of note, studies concerning polymorphism of the rs12255372 allele of the TCF7L2 gene associated with predisposition to type 2 diabetes in i) diabetic, ii) hypertensive, iii) diabetic-hypertensive and healthy population in Côte d'Ivoire suggested high susceptibility of Northern population to develop diabetes as opposite to Southern population [8] [9]. Therefore, the characterization of the cultural and environmental profiles of patients with both diabetes and hypertension is essential for improving our understanding

of the epidemiology of these metabolic disorders and for developing appropriate prevention and management strategies. Reducing diabetes- and hypertension-related mortality largely depends on improving access to curative, preventive, and health promotion services, thereby contributing to a better quality of life for affected individuals. Within this context, the present study aimed to characterize patients with both diabetes and hypertension in Côte d'Ivoire using clinical, biochemical, and anthropometric parameters in order to generate relevant epidemiological evidence that may help guide national strategies for the prevention and management of these chronic diseases.

2. Material and Methods

2.1. Study Sites

The study was conducted from May 5 to September 30, 2025, in five healthcare facilities located in the southern, northern, central, eastern, and western regions of Côte d'Ivoire: the National Institute of Public Health (INSP), Abidjan (South); the Bouaké University Teaching Hospital (CHU), Bouaké (Central); the Regional Public Hospital (EPHR), Korhogo (North); the Regional Hospital (CHR), Man (West); and the Regional Hospital (CHR), Abengourou (East). These healthcare facilities were selected from different geographical regions because of their high patient attendance and the availability of specialized services providing care for patients with diabetes and hypertension.

2.2. Study Population

A cross-sectional analytical study was conducted among patients with type 2 diabetes mellitus, patients with both type 2 diabetes and hypertension, and non-diabetic patients with hypertension, all of whom were receiving regular follow-up care at the participating healthcare facilities. A control group consisting of individuals with neither diabetes nor hypertension was also included. Participants were recruited using a non-probability convenience sampling approach after providing written informed consent. For this study, 750 participants were enrolled, including 200 patients with type 2 diabetes, 200 patients with both diabetes and hypertension, 200 patients with hypertension only, and 150 healthy controls. Control participants were considered healthy because they had neither diabetes nor hypertension, as confirmed by blood pressure measurements and fasting blood glucose assessment. Of note, ethically, we structured the studied population in *Mandé, Akan, Gour, Krou* and foreign groups.

2.3. Biomedical Critters of Study Population

Based on their clinical status, recruited participants were divided into four groups: i) diabetic patients, ii) hypertensive patients, iii) patients with both diabetes and hypertension, and iv) control subjects. Classification of the patient groups was based on medical diagnoses previously established and documented in their medical records. Control subjects were considered free of diabetes and hypertension

based on examinations performed at the time of enrollment. Diabetic patients were recruited from individuals regularly followed in diabetes clinics for the management of their condition. Similarly, hypertensive patients were recruited from those followed in cardiology departments for their hypertension. Patients with both diabetes and hypertension were identified based on the presence of both diagnoses in their medical records and ongoing medical management for both conditions. At the time of recruitment, diabetic patients were receiving antidiabetic treatment, and hypertensive patients were receiving antihypertensive medication. As part of routine medical follow-up, blood pressure was measured and glycated hemoglobin (HbA1c) levels were assessed during the scheduled check-up. A blood sample was also collected from each patient to determine blood glucose and lipid parameters as part of the biological follow-up assessment. For control subjects, the absence of hypertension was verified by blood pressure measurement, while the absence of diabetes was assessed via a blood sample for glucose level determination.

2.4. Structuration of Study Population Ethnicity

The ethnicity of participants under medical care was determined based on information recorded in their medical files. For control group participants, ethnicity was ascertained through direct questioning. The various ethnic groups identified were then categorized according to the four main sociolinguistic and cultural groups recognized in Côte d'Ivoire: Akan, Mandé, Gour, and Krou. Participants whose declared or recorded ethnicity did not fall into any of these four groups were classified as "Foreign." A review of the information from medical files and control group interviews revealed no instances of mixed ethnic background; consequently, each participant was assigned to a single ethnic group. Regarding the distribution of participants across healthcare facilities and pathology categories, a cohort comprising 40 diabetic participants, 40 hypertensive participants, and 40 participants with both diabetes and hypertension was recruited at each healthcare facility within each of the five study zones.

2.5. Data Collection

Data were recorded using a standardized survey questionnaire. Clinical and anthropometric variables included age, sex, and ethnic group, family history of diabetes and/or hypertension, body mass index (BMI), systolic blood pressure (SBP), and diastolic blood pressure (DBP). Body mass index (BMI) was calculated using the following formula:

$$\text{BMI} = \frac{\text{Weight (in Kg)}}{(\text{Height})^2}.$$

Body weight was measured using a Seca Clara 803 electronic scale (Germany), whereas height was measured using a stadiometer. BMI categories were defined according to the World Health Organization (WHO) classification [10]. Participants were classified as overweight when BMI ranged from 25.0 to 29.99 kg/m²,

Class I obesity for BMI between 30.0 and 34.99 kg/m², Class II obesity for BMI between 35.0 and 39.99 kg/m², and Class III obesity for BMI $\geq$ 40 kg/m². Systolic and diastolic blood pressure measurements were obtained after a resting period using an OMRON Healthcare electronic sphygmomanometer (Japan). Information on family history of diabetes and hypertension, smoking status, and physical activity was also collected. For biochemical analyses, 5 mL of fasting venous blood was collected from each participant. Blood was drawn into sodium fluoride tubes for fasting blood glucose determination, EDTA tubes for glycated hemoglobin (HbA1c) measurement, and plain tubes without anticoagulant for the determination of triglycerides, total cholesterol, high-density lipoprotein cholesterol (HDL-C), and low-density lipoprotein cholesterol (LDL-C). Serum lipid parameters (triglycerides, total cholesterol, HDL-C, and LDL-C) and fasting glucose were measured using enzymatic methods [11] [12] on a Mindray BS-240 automated chemistry analyzer. Glycated hemoglobin (HbA1c) was determined using an *On Cal* analyzer based on an immune-chromatographic method [13]. Dyslipidemia was defined as the presence of at least one lipid or lipoprotein abnormality exceeding the thresholds recommended by the American Diabetes Association (ADA) [13]. Hypertriglyceridemia was defined as triglyceride concentrations $>$ 1.5 g/L (1.7 mmol/L). Hypercholesterolemia was defined as total cholesterol $>$ 2.0 g/L (5.2 mmol/L), whereas elevated LDL cholesterol was defined as LDL-C $>$ 1.6 g/L (4.10 mmol/L). Low HDL cholesterol (hypo-HDL cholesterol) was defined as HDL-C $<$ 0.4 g/L (1.03 mmol/L) in men and $<$ 0.5 g/L (1.29 mmol/L) in women. Poor glycemic control was defined as HbA1c $\geq$ 7% [14].

2.6. Statistical Analysis

The clinical, anthropometric, and biochemical characteristics of the population were analyzed using R software (version 4.5.2; 2025-10-31 UCRT). A multivariate statistical framework integrating descriptive and analytical methods was implemented. Measures of central tendency (mean and median) and dispersion (standard deviation, range, and variance) were calculated for quantitative variables, whereas categorical variables were summarized as frequencies and percentages. In our analysis, we used Z-score normalization (standardization) hierarchical clustering in data preprocessing step because of the different scales of measured variable *i.e.* clinical, biochemical and anthropomorphic data. We performed a p-value (version 2.2-0) hierarchical clustering analysis in R by using the *pvclust* package that force data into clusters even if the data (clinical, biochemical and anthropomorphic data) is completely random. The *pvclust* package solves this by using multiscale bootstrap resampling to calculate p-values for every branch, helping you identify which clusters are statistically significant. We performed exact Fisher test and as well, ANOVA test to check for the variance difference as well as for interaction assessment between metabolic chronic disease occurrence and participant ethnical group. Statistical significance was established at $\alpha = 0.05$. To identify homogeneous participant subgroups according to their clinical, anthropometric, and biochemical characteristics, K-means clustering analysis was performed.

K-means is an unsupervised clustering algorithm that partitions a dataset into K predefined, mutually exclusive clusters, assigning each observation to the cluster with the nearest centroid [15]. This approach was used to classify the study population according to similarities in their clinical, anthropometric, and biochemical profiles. Data submitted to K-mean clustering analysis were standardized using z score approach by using StandardScaler script in python by applying the following formula: $(x_i - \text{mean}(X))/SD$, where x_i is observable variable, $\text{mean}(x)$ refers to average value of x statistical series while SD refers to standard deviation. Indeed, Dago *et al.* (2021) [16] showed the aptitude of z score standardization method adjusting data variance homogeneity. We performed K-mean clustering analysis by processing clinical, biochemical, and as well anthropomorphic data of all participants as described above. Our data collection and analysis encountered no issues related to missing data. Clustering and interaction analysis between ethnic groups and diseases in K-mean generated cluster groups were performed basing on participants ethnic and disease frequencies in each cluster group. Of note, the K-means analysis was performed using Python. The Pandas and NumPy libraries were used for data preparation and manipulation, while the K-means algorithm was implemented using the scikit-learn library. Matplotlib and Seaborn were used to generate graphical visualizations. A preliminary data quality check was conducted to identify missing data and outliers. The data were then standardized using the StandardScaler function. This transformation places the data on a comparable scale, preventing variables with large magnitudes from dominating the Euclidean distance calculations used by the K-means algorithm. The optimal number of clusters was sought for k-values ranging from 2 to 6. Individual silhouette coefficients (silhouette samples) and the average silhouette coefficient (silhouette score) were calculated to evaluate within-cluster cohesion and between-cluster separation for each value of k. The optimal number of clusters was determined based on the best average silhouette score. To ensure result reproducibility despite the algorithm's stochastic nature, the K-means model was fitted using the k-means++ initialization method and a random state of 42. Principal Component Analysis (PCA) was performed to visualize the cluster structure. The coordinates of the data points on the first two principal components were used to create a scatter plot, with points differentiated by their assigned cluster.

3. Results

3.1. Descriptive Characteristics of the Diabetic, Hypertensive, and Diabetic-Hypertensive Populations Based on Anthropometric and Qualitative Variables

Diabetic population: The diabetic population includes 126 women (63.0%) and 74 men (37.0%). Ethnically, the diabetic population was predominantly composed of individuals from the Mandé ethnic group (33.0%), followed by the Akan (30.0%) and Gour (25.0%) ethnic groups. Participants belonging to the foreign and Krou ethnic groups were less represented, accounting for 7.5% and 4.5% respectively. Within the diabetic population, 32 patients (16.0%) reported engaging

in regular physical activity, whereas 168 patients (84.0%) were physically inactive. Regarding smoking status, 198 patients (99.0%) were non-smokers, while 2 patients (1.0%) were smokers. Above-mentioned results were summarized in **Figure S1**. Of note, 108 diabetic patients (54.0%) reported a family history of chronic disease. Among them, 52 patients (26.0%) had a family history of diabetes, 42 (21.0%) reported a family history of both diabetes and hypertension, and 14 (7.0%) had a family history of hypertension (**Table 1**).

Diabetic-hypertensive population: In diabetic-hypertensive population, women predominated, accounting for 71.5% of the population (**Figure S1**). Overall, 106 patients (53.0%) reported a family history of chronic disease, including 47 (23.5%) with a family history of both diabetes and hypertension, 30 (15.0%) with a family history of hypertension, and 29 (14.5%) with a family history of diabetes (**Table 1**). The diabetic-hypertensive population was predominantly composed of individuals from the Mandé ethnic group (33.0%), followed by the Gour (30.0%) and Akan (28.0%) ethnic groups. Participants belonging to the foreign and Krou ethnic groups each represented 4.5% of the population. Most participants of this category (90.5%) were physically inactive, while 1.0% were smokers (**Figure S1**).

Hypertensive population: The hypertensive population includes 130 women (65.0%) and 70 men (35.0%) (**Figure S1**). This population was dominated by the Akan ethnic group (39.5%), followed by the Mandé (28.0%) and Gour (23.0%) groups. The Krou and foreign ethnic groups were less represented, accounting for 7.5% and 2.0% of the population, respectively (**Figure S1**). Most participants (92.0%) were physically inactive and only one patient was a smoker, whereas 199 patients (99.5%) were non-smokers (**Figure S1**). Of note, 95 patients (47.5%) of this group reported a family history of chronic disease, including 66 (33.0%) with a family history of hypertension, 20 (10.0%) with a family history of both diabetes and hypertension, and 9 (4.5%) with a family history of diabetes (**Table 1**).

Table 1. Frequency of family prevalence history of i) diabetes, ii) hypertension and iii) diabetic-hypertensive in the study population.

Pathologies	Terms	Staff numbers (n = 200)	Percentage (%)	Total
Diabetic-hypertensive	Diabetes	29	14.5	106 (53%)
	HTA	30	15	
	D + HTA	47	23,5	
Hypertensive	Diabetes	9	4,5	95 (47.5%)
	HTA	66	33	
	D + HTA	20	10	
Diabetic	Diabetes	52	26	108 (54%)
	HTA	14	7	
	D + HTA	42	21	

HTA: arterial hypertension, D + THA: diabetic-hypertensive patients.

3.2. Association between Ethnic Groups and Disease Status (Hypertension, Diabetes and Diabetic-Hypertensive)

The descriptive analyses showed that the diabetic and diabetic-hypertensive populations were predominantly composed of individuals belonging to the Mandé ethnic group, whereas Akan ethnic group mainly represented the hypertensive population. In addition, the Gour ethnic group was more frequently represented than the Akan ethnic group among patients with both diabetes and hypertension. Conversely, this trend was reversed for patients with diabetes alone and/or those with hypertension alone. The Krou and foreign ethnic groups appeared to be less represented among patients with diabetes and hypertension (**Figure S1**). The association between ethnic groups and disease status (diabetes, hypertension, and combined diabetic-hypertensive) was assessed using the Chi-square (χ^2) test based on the expected frequencies presented in **Table 2**. The calculated Chi-square statistic was $\chi^2 = 17.037$ with 8 degrees of freedom (DF). The corresponding critical value at a significance level of $\alpha = 0.05$ was 15.507, which was lower than the calculated value (17.037). Therefore, the null hypothesis was rejected in favor of the alternative hypothesis stipulating an association between metabolic diseases occurrence and ethnical group in Côte d'Ivoire. The Chi-square test demonstrated a statistically significant association between ethnic groups (Akan, Mandé, Gour, Krou, and Foreign) and disease status (diabetes and/or hypertension) ($\chi^2 = 17.037$, DF = 8, $p < 0.05$) (**Table 2**).

Table 2. Frequency of theoretical observations among the Akan, Mandé, Gour, Krou and foreign ethnic groups, based on the recorded conditions, namely diabetes, arterial hypertension and diabetes combined with arterial hypertension.

Variables	Akan (n = 196)	Mandé (n = 187)	Gour (n = 156)	Krou (n = 33)	Foreigners (n = 28)
HTA	80	55	46	15	4
D + HTA	56	66	60	9	9
Diabetes	60	66	50	9	15

HTA: arterial hypertension; D + HTA: diabetic-hypertensive patients; $\chi^2 = 17.037$; DF = 8; $p = 0.03 < 0.05$; Cramer coefficient = 0.119; IC at 95% = 0.091- 0.194.

3.3. Comparative Analysis of Clinical, Biochemical, and Anthropometric Parameters in the Study Population

The clinical, biochemical, and anthropometric parameters of patients with diabetes, diabetes and hypertension, and hypertension were compared with those of the control group (healthy individuals). This analysis revealed statistically significant differences ($p < 0.05$) for all parameters except body mass index (BMI) (**Table 3**). To further investigate differences among the study groups, a one-way analysis of variance (ANOVA) was performed to compare the diabetic, hypertensive, diabetic-hypertensive, and control populations (**Table 4**). When diabetes status was considered, the ANOVA revealed a significant difference between patients with diabetes and those with both diabetes and hypertension ($p = 0.02$), as well as be-

tween patients with hypertension and those with both diabetes and hypertension ($p = 0.001$) (**Table 4**). By contrast, considering participant hypertension status, no significant difference was observed between the diabetic and hypertensive populations ($p = 0.14$) (**Table 4**). Of note, the same analysis supported significant statistically difference between diabetic-hypertensive patients and diabetic ($p = 0.02$) and hypertensive ($p = 0.001$) participants (**Table 4**).

Table 3. Comparative analysis of the mean values of clinical and biochemical parameters within the study population (the “diabetic”, “hypertensive”, “hypertensive-diabetic”, and “control” groups).

Settings	Diabetic (n = 200)	Hypertensive-diabetic (n = 200)	Hypertensive (n = 200)	Control (n = 150)	p-value
Mean age $\pm$ SD (years)	55.3 $\pm$ 10	61.8 $\pm$ 8.6	56.5 $\pm$ 10.6	48 $\pm$ 7.94	0.00***
Mean SBP $\pm$ SD (mmHg)	135 $\pm$ 20.3	152 $\pm$ 23.3	147 $\pm$ 19.8	127 $\pm$ 16.9	0.00***
Mean DBP $\pm$ SD (mmHg)	84.6 $\pm$ 11.4	88.2 $\pm$ 13.9	89.0 $\pm$ 15.9	81.4 $\pm$ 11.5	0.00***
Mean BMI $\pm$ SD (Kg/m ²)	26.3 $\pm$ 5.17	27.3 $\pm$ 5.3	27.5 $\pm$ 5.72	27.5 $\pm$ 5.05	0.09 ^{NS}
Mean Glycaemia $\pm$ SD (g/l)	1.89 $\pm$ 1.11	1.57 $\pm$ 0.81	0.94 $\pm$ 0.13	0.92 $\pm$ 0.11	0.00***
Mean Triglycerides $\pm$ SD (g/l)	1.32 $\pm$ 0.83	1.29 $\pm$ 0.63	1.33 $\pm$ 0.73	0.96 $\pm$ 0.64	0.00***
Mean total Cholesterol $\pm$ SD (g/l)	1.92 $\pm$ 0.56	2.04 $\pm$ 0.57	2.15 $\pm$ 0.55	1.98 $\pm$ 0.42	0.00***
Mean HDL-C $\pm$ SD (g/l)	0.47 $\pm$ 0.18	0.53 $\pm$ 0.23	0.53 $\pm$ 0.19	0.57 $\pm$ 0.20	0.00***
Mean LDL-C $\pm$ SD (g/l)	1.05 $\pm$ 0.50	1.14 $\pm$ 0.56	1.18 $\pm$ 0.52	1.01 $\pm$ 0.39	0.00***
Mean HbA1C $\pm$ SD (%)	8.69 $\pm$ 2.71	7.73 $\pm$ 2.28	5.20 $\pm$ 1.00	4.94 $\pm$ 0.73	0.00***

SBP: Systolic Blood Pressure; DBP: Diastolic Blood Pressure; BMI: Body Mass Index; HDL-C: high-density lipoprotein cholesterol; LDL-C: low-density lipoprotein cholesterol; HbA1C: glycated hemoglobin; SD: Standard Deviation; ^{NS}: Non-significant; ***: Statistically significant.

Table 4. Table of the analysis of variance of the parameters Diabetes, Hypertension (HTA) and Diabetes-Hypertension (Diabetes-HTA).

Disease statute	Explanatory Variable	Sum of Squares	Degree of freedom	F-Coefficient Value	p
HTA	Control	15.77	1	35.51	0.00***
	Diabetes	1.23	1	2.77	0.14 ^{NS}
	Diabetes-THA	15.44	1	34.75	0.001***
	Residual	2.67	6	--	--
Diabetes	Control	11.53	1	8.71	0.03***
	THA	3.66	1	2.77	0.14 ^{NS}
	Diabetes-THA	12.98	1	9.81	0.02***
	Residual	7.94	6	--	--
Hypertensive-diabetic	Control	22.83	1	27.3	0.002***
	Diabetes	8.2	1	9.81	0.02***
	THA	29.06	1	43.76	0.001***
	Residual	5.02	6	--	--

SBP: Systolic Blood Pressure; DBP: Diastolic Blood Pressure; BMI: Body Mass Index; HDL-C: High-Density Lipoprotein Cholesterol; LDL-C: Low-Density Lipoprotein Cholesterol; HbA1C: Glycated Hemoglobin; SD: Standard Deviation; ^{NS}: Non-significant; ***: Statistically significant.

Table 5. Frequency and proportion of diabetic, diabetic-hypertensive and hypertensive populations based on biochemical parameters and BMI.

	Biochemical parameters					
	Triglycerides (g/l) > 1.5	Total Cholesterol (g/l) > 2	HDL cholesterol (g/l) < 0.4	LDL cholesterol (g/l) > 1.6	Dyslipidemia	HbA1C ≥ 7%
Diabetes Frequency (%)	58 (29%)	83 (41.5%)	74% (37%)	27 (13.5%)	140 (70%)	138 (69%)
Hypertensive Frequency (%)	57 (28.5%)	121 (60.5%)	50 (25%)	41 (20.5%)	122 (61%)	
Diabetic-hypertensive Frequency (%)	61 (30.5%)	101 (50.5%)	56 (28%)	36 (18%)	137 (68.5%)	122 (61%)
	WHO BMI Classification, 2025					
	BMI	(25 - 29.9) Kg/m ² Overweight	(30 - 34.9) Kg/m ² Class 1 obesity	(35 - 39.9) Kg/m ² Class 2 obesity	≥40 Kg/m ² Class 3 obesity	
Diabetes Frequency (%)		66 (33%)	28 (14%)	9 (4.5%)	5 (2.5)	
Hypertensive Frequency (%)		80 (40%)	35 (17.5%)	10 (5%)	7 (3.5%)	
Diabetic-hypertensive Frequency (%)		63 (31.5%)	47 (23.5%)	9 (4.5%)	5 (2.5%)	

3.4. Assessment of Clinical Biochemical and Anthropometric Profile of the Study Population

The mean age of the diabetic, diabetic-hypertensive, and hypertensive populations was 55.3 ± 10.5 years, 61.8 ± 8.6 years, and 56.5 ± 10.6 years, respectively (**Table S1**). Among patients with diabetes, the mean fasting blood glucose and glycated hemoglobin (HbA1c) levels, which are the principal biomarkers used to characterize diabetes, were 1.89 ± 1.11 g/L and $8.69\% \pm 2.71\%$, respectively (**Table S1**). The mean body mass index (BMI) of the diabetic and hypertensive populations was 26.3 ± 5.17 kg/m² and 27.5 ± 5.72 kg/m², respectively (**Table S1**). Descriptive analysis further showed that 33.0% of diabetic patients were overweight (**Table 5**). Dyslipidemia was identified in 70% of diabetic patients and was mainly attributable to hypercholesterolemia, which accounted for 41.5% of cases (**Table 5**). Among patients with both diabetes and hypertension, the mean fasting blood glucose level was 1.57 ± 0.81 g/L, with individual values ranging from 0.58 to 5.16 g/L (**Table S1**). The mean HbA1c level was $7.73\% \pm 2.68\%$ (**Table S1**). Their lipid profile was characterized by mean values of 2.04 ± 0.57 g/L for total cholesterol, 1.14 ± 0.55 g/L for LDL cholesterol (LDL-C), 0.53 ± 0.23 g/L for HDL cholesterol (HDL-C), and 1.29 ± 0.63 g/L for triglycerides (**Table S1**). In addition, the mean systolic blood pressure (SBP) and diastolic blood pressure (DBP) were 152 ± 23.3

mmHg and 88.2 ± 13.9 mmHg, respectively (**Table S1**). This population also exhibited excess body weight, with a mean BMI of 27.3 ± 5.34 kg/m². Overall, 31.5% of patients were overweight, whereas 30.5% presented with combined obesity (**Table 5**). Among hypertensive patients, the mean SBP and DBP were 147 ± 19.8 mmHg and 89.0 ± 15.9 mmHg, respectively (**Table S1**). Overall, 40.0% of participants were overweight, while 26.0% had combined obesity (**Table 5**).

3.5. Multivariate Analysis for Evaluating the Variability between Biochemical Clinical and Anthropometric Parameters

We evaluated the relationships between biochemical, clinical and anthropometric parameters in the study population. Clustering analysis of the probability values revealed strong positive associations between i) total cholesterol and LDL cholesterol, ii) diastolic blood pressure (DBP) and systolic blood pressure (SBP), and iii) fasting blood glucose and glycated hemoglobin (HbA1c) (**Figure 1(A)**). Multivariate analysis identified three distinct patterns in the variability of the clinical, biochemical, and anthropometric parameters (**Figure 1(B)**). The first pattern was characterized by age, SBP, and DBP, which exhibited the highest variance values. The second parameter pattern comprised body mass index (BMI) and HbA1c, which showed intermediate levels of variability (**Table 6; Figure 1(B)**). The third feature pattern included fasting blood glucose, triglycerides, total cholesterol, HDL cholesterol (HDL-C), and LDL cholesterol (LDL-C), with variance values ranging from 0.04 to 0.68 (**Table 6**). Furthermore, Z-score analysis by combining the variability of clinical, biochemical, and anthropometric parameters with the study population status (*i.e.* healthy and/or controls participants, diabetic, diabetic-hypertension and hypertensive patients), confirmed the three variability patterns previously identified and as well suggested studied population partition in two major clusters (**Figure 2**). In addition, the Kruskal-Wallis non-parametric test supported a statistically significant difference in terms of the variability between clinical, biochemical, and anthropometric parameters ($p \leq 0.05$) (**Figure S2(A)**). Projection of study population in two-dimension analysis through principal component analysis (ACP) suggested 38.72% of the variability explained by the first two component (**Figure 3**). This analysis by exhibiting the 75 most contributive individual to the data variability, suggested three clustering groups, *i.e.* control, diabetic and hypertensive population by contrast to z-score clustering analysis (**Figure 2, Figure 3**). Interestingly PCA analysis by characterizing diabetic population to the biochemical parameters, *i.e.* blood glucose and glycated hemoglobin (HbA1c) and triglyceride, exhibited this patient category as the most contributive in term of variability in the study population (**Figure 3**). In addition, it is noteworthy to underline the correlative aptitude between IMC and cholesterol features and hypertensive patients (**Figure 3**). Of note, the PCA analysis do not supported any evidence in terms of correlation between metabolic diseases and ethnical groups.

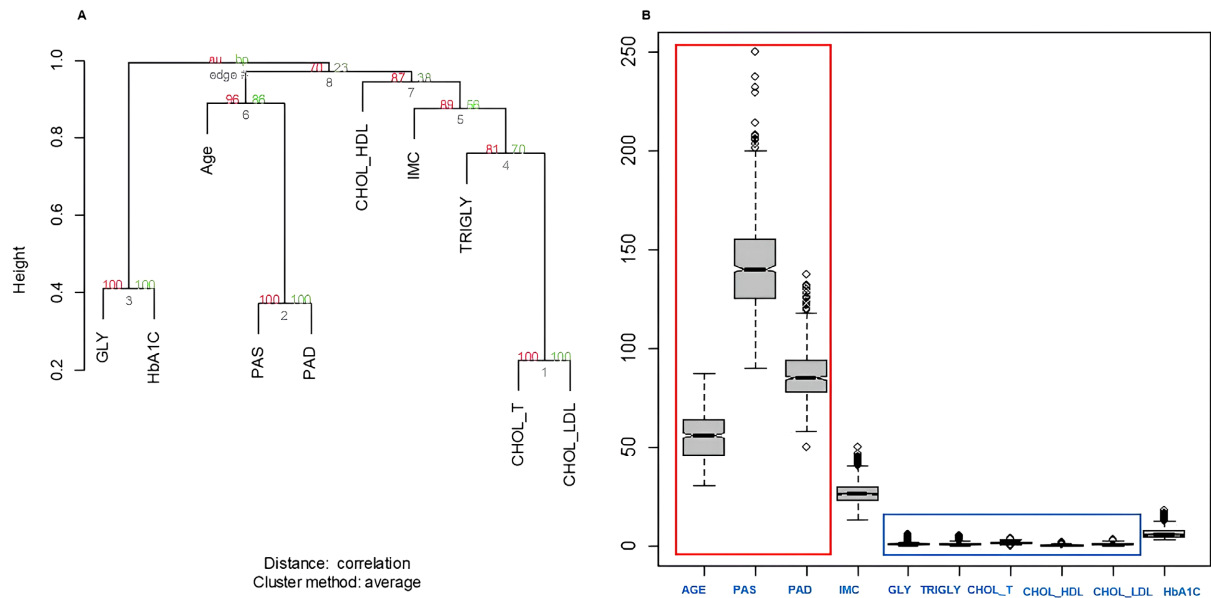


Figure 1. (A) Correlation among clinical, biochemical, and anthropometric parameters within the study population (controls, hypertensive patients, diabetic patients, and diabetic-hypertensive patients). (B) Multivariate analysis of the variability of clinical, biochemical, and anthropometric parameters within the study population. PAS: Systolic Blood Pressure; PAD: Diastolic Blood Pressure; IMC: Body Mass Index; GLY: Blood glucose; HbA1C: glycated hemoglobin; Trygly: triglycerides; CHOL_T: Total Cholesterol; CHOL_HDL: high-density lipoprotein cholesterol; CHOL_LDL: low-density lipoprotein cholesterol.

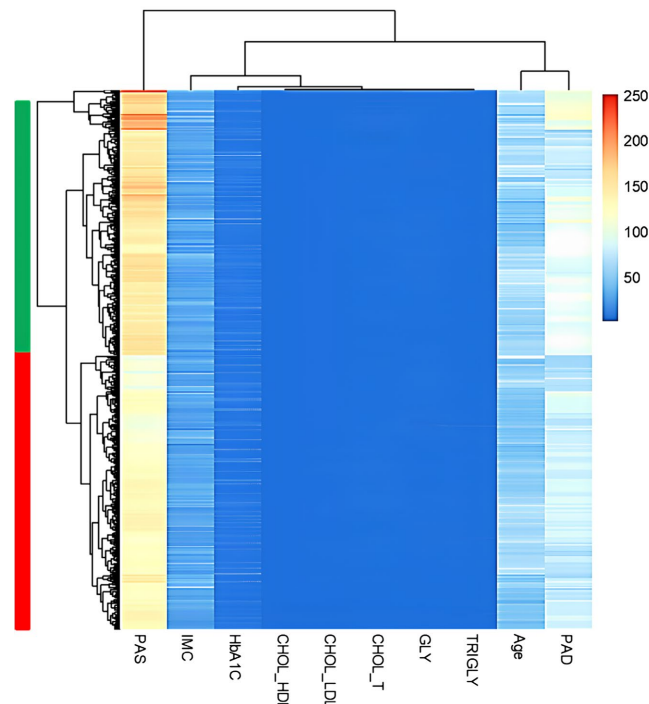


Figure 2. Heatmap of the interactive z-score analysis between clinical, biochemical, and anthropometric variables and the grouping of the study population (controls, hypertensive patients, diabetic patients, and diabetic-hypertensive patients). PAS: Systolic Blood Pressure; PAD: Diastolic Blood Pressure; GLY: blood glucose IMC: Body Mass Index; HbA1C: glycated hemoglobin; Trygly: triglycerides; ChOL_T: Total Cholesterol; ChOL_HDL: high-density lipoprotein cholesterol; CHOL_LDL: low-density lipoprotein cholesterol.

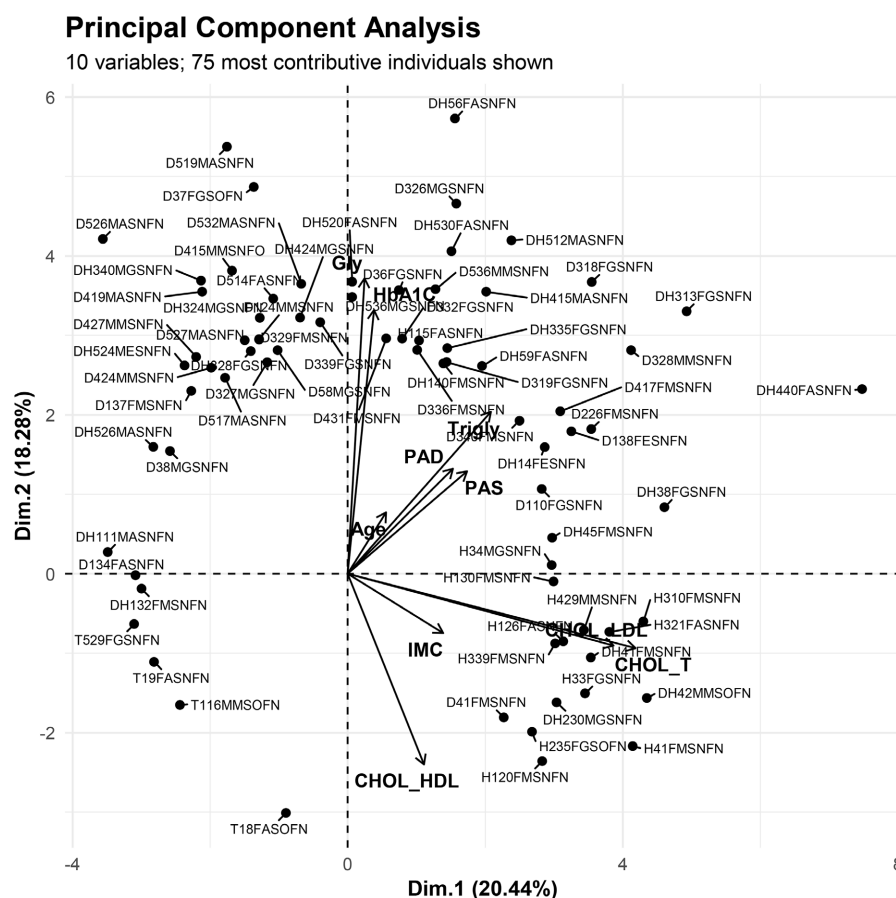


Figure 3. Principal component bi-plot analysis (PCA) illustrating the 75 most contributive individual in term of study population dispersion by assessing participants biochemical, clinical and anthropometric features (10 variables).

Table 6. Descriptive statistics of biochemical, clinical, and anthropometric parameters in the study population (controls, hypertensive patients, diabetic patients, and diabetic-hypertensive patients).

	Age	SBP	DBP	BMI	GLY	TRIGLY	T_C	HDL_C	LDL_C	HbA1C
Minimum	31	90	50	13.3	0.52	0.22	0.27	0.09	0.1	3.2
Maximum	87	250	137	50	5.79	5.28	4.27	1.9	3.22	18
Range	56	160	87	36.7	5.27	5.06	4	1.81	3.12	14.8
Médian	56	140	85	26.5	1.04	1.09	2	0.505	1.06	5.88
Mean	55.43	141.19	86.10	27.13	1.36	1.24	2.02	0.52	1.1	6.75
SE.mean	0.39	0.82	0.5	0.2	0.03	0.027	0.02	0.01	0.019	0.09
CI.mean.0.95	0.77	1.62	0.98	0.38	0.06	0.052	0.04	0.01	0.04	0.19
Variance	114.53	510.036	187.72	28.7	0.68	0.53	0.29	0.043	0.26	6.66
SD	10.7	22.58	13.7	5.36	0.82	0.72	0.54	0.21	0.51	2.58
CV	0.193	0.16	0.159	0.2	0.61	0.58	0.27	0.39	0.461	0.38

SBP: Systolic Blood Pressure; DBP: Diastolic Blood Pressure; BMI: Body Mass Index; HbA1C: glycated hemoglobin; GLY: Blood glucose; Trygly: triglycerides; T_C: Total Cholesterol; HDL-C: high-density lipoprotein cholesterol; LDL-C: low-density lipoprotein cholesterol. Standard Deviation: SD; Coefficient of Variation: CV.

3.6. K-Mean Clustering Analysis of Diabetic Diabetic-Hypertensive and Hypertensive Populations

With the purpose to further investigate the structure of the study population, a K-means clustering analysis was performed to identify homogeneous subgroups within the overall population. The analysis yielded mean silhouette scores of 0.13 and 0.14 for solutions with 2 and 3 clusters, respectively, compared with 0.10 and 0.12 for solutions with 4 and 5 clusters (**Figure 4(A)**). These findings partially confirmed the results of the Z-score and as well PCA bi-plot analysis, which suggested respectively the study population partition in two and three major, clustering, groups (**Figure 2** and **Figure 3**). Evaluation of the optimal number of clusters using the silhouette index showed high score (0.14) for $k = 3$ as opposite to (0.13) for $k = 2$ (**Figure 4(A)**). Based on this criterion, the K-means analysis indicated that the study population was optimally partitioned into three distinct clusters (**Figure 4(B)**). Projection of the participants onto the first two principal components showed a clear, although partial, separation among the three clusters (**Figure 4(B)**). The cluster centroids represented the mean position of each cluster in the principal component space (**Figure 4(B)**). Multiple comparisons of the three clusters generated by the K-means analysis were performed using Tukey's Honestly Significant Difference (HSD) test. The analysis revealed non-significant difference between the three generated groups ($p = 0.11$) (**Figure S2(B)**) with substantial intra-clustering variability, confirming the relative heterogeneity of the clinical, biochemical, and anthropometric characteristics within the identified clusters (**Figure S2(B)**).

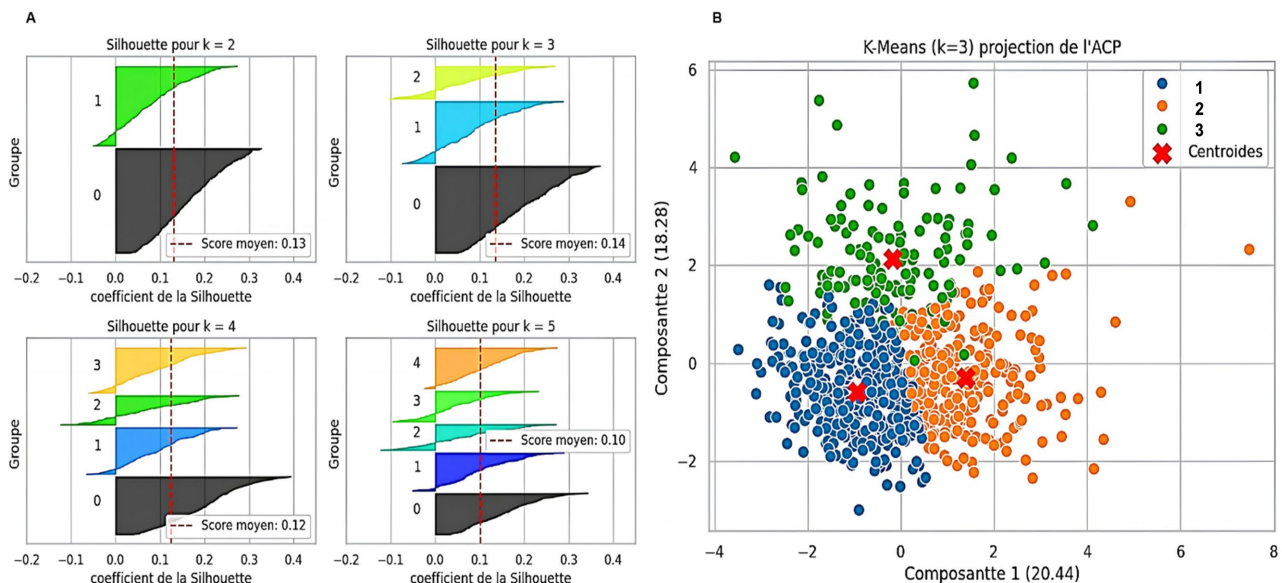


Figure 4. (A) Illustration of the hierarchical structure of the study population based on the average score calculated using the k-means method. (B) Clustering of the study population using an average score of 0.14 for $k = 3$. Coefficient de la silhouette: silhouette coefficient; Groupe: Group; Composante: Component; Score moyen: Average score; Silhouette pour k: silhouette for k; Projection de l'ACP: PCA projection; Centroides: Centroid.

3.7. Characterization of Study Population Subgroups by the Clinical Biochemical and Anthropomorphic Parameters

Clustering groups obtained through the K-means survey were characterized basing on the clinical, biochemical, and anthropometric features. The clusters groups designated as cluster 1, cluster 2 and cluster 3 comprising 359, 256, and 135 participants, respectively. Comparative analysis of the variability among the three clusters groups revealed a statistical differences at $p = 0.11$ (**Figure S2(B)**). However, substantial heterogeneity was observed within each cluster. Cluster 1 was predominantly composed of healthy controls and was characterized by biochemical and clinical parameters that were generally within the normal range (**Table S2**). Participants in this cluster had a mean age of 53.86 ± 11.26 years, which was lower than that of participants in clusters 2 and 3 (**Table 7**; **Figure 5**). Moreover, the mean values of systolic blood pressure (SBP), diastolic blood pressure (DBP), body mass index (BMI), fasting blood glucose, and lipid parameters were lower in cluster 1 than in clusters 2 and 3 (**Figure 5**). Cluster 2 was mainly composed of patients with hypertension (39.45%), followed by patients with both diabetes and hypertension (34.76%), patients with diabetes alone (16.02%), and healthy controls (9.77%) (**Table S2**). This cluster exhibited the highest mean values for hypertension-related parameters, including SBP (151.76 ± 22.73 mmHg), DBP (91.53 ± 14.71 mmHg), BMI (28.56 ± 5.31 kg/m²), total cholesterol (2.49 ± 0.43 g/L), HDL cholesterol (0.52 ± 0.20 g/L), and LDL cholesterol (1.51 ± 0.45 g/L) compared with clusters 1 and 3 (**Figure 5**; **Table S1**). In contrast, the mean HbA1c ($6.33\% \pm 2.03\%$), fasting blood glucose (1.17 ± 0.42 g/L), and triglyceride (1.49 ± 0.76 g/L) levels were slightly lower than those observed in cluster 3 (**Figure 5**; **Table S1**). Of note, cluster 2 was predominantly composed of individuals from the Mandé ethnic group (34.38%) and showed a marked predominance of women (73.44%). Cluster 3 comprised participants with the most pronounced disease profile, including a high proportion of patients with diabetes (64.44%), followed by patients with both diabetes and hypertension (34.81%) (**Table S2**). This cluster was characterized by markedly elevated glycemic parameters, with mean fasting blood glucose and HbA1c values of 2.67 ± 1.06 g/L and $10.41\% \pm 2.42\%$, respectively, compared with clusters 1 and 2 (**Table S1**; **Figure 5**). Ethnically, Cluster 3 was predominantly composed of individuals from the Akan ethnic group (32.59%), and 92.59% of participants were physically inactive (**Table S2**).

Table 7. Descriptive statistics of clinical, biochemical, and anthropometric parameters in subgroups 1, 2, and 3 from the K-mean analysis.

Variables	Group 1	Group 2	Group 3
Age (year)	53.86 ± 11.26	57.61 ± 9.93	55.44 ± 9.89
Systolic Blood Pressure (mmHg)	133.73 ± 17.99	151.76 ± 22.93	140.96 ± 25.31
Diastolic Blood Pressure (mmHg)	81.87 ± 11.96	91.53 ± 14.71	87.02 ± 12.28
Body Mass Index (Kg/m ²)	26.55 ± 5.2	28.56 ± 5.31	25.98 ± 5.34

Continued

Blood Sugar (g/l)	1.0 ± 0.26	1.17 ± 0.42	2.67 ± 1.06
Triglycerides (g/l)	0.95 ± 0.49	1.49 ± 0.76	1.57 ± 0.88
Total Cholesterol (g/l)	1.76 ± 0.39	2.49 ± 0.43	1.86 ± 0.51
HDL-cholesterol (g/l)	0.52 ± 0.2	0.59 ± 0.21	0.41 ± 0.16
LDL-cholesterol (g/l)	0.86 ± 0.36	1.51 ± 0.45	0.96 ± 0.46
Glycated hemoglobin (%)	5.68 ± 1.58	6.33 ± 2.06	10.41 ± 2.42

SBP: Systolic Blood Pressure; DBP: Diastolic Blood Pressure; BMI: Body Mass Index.

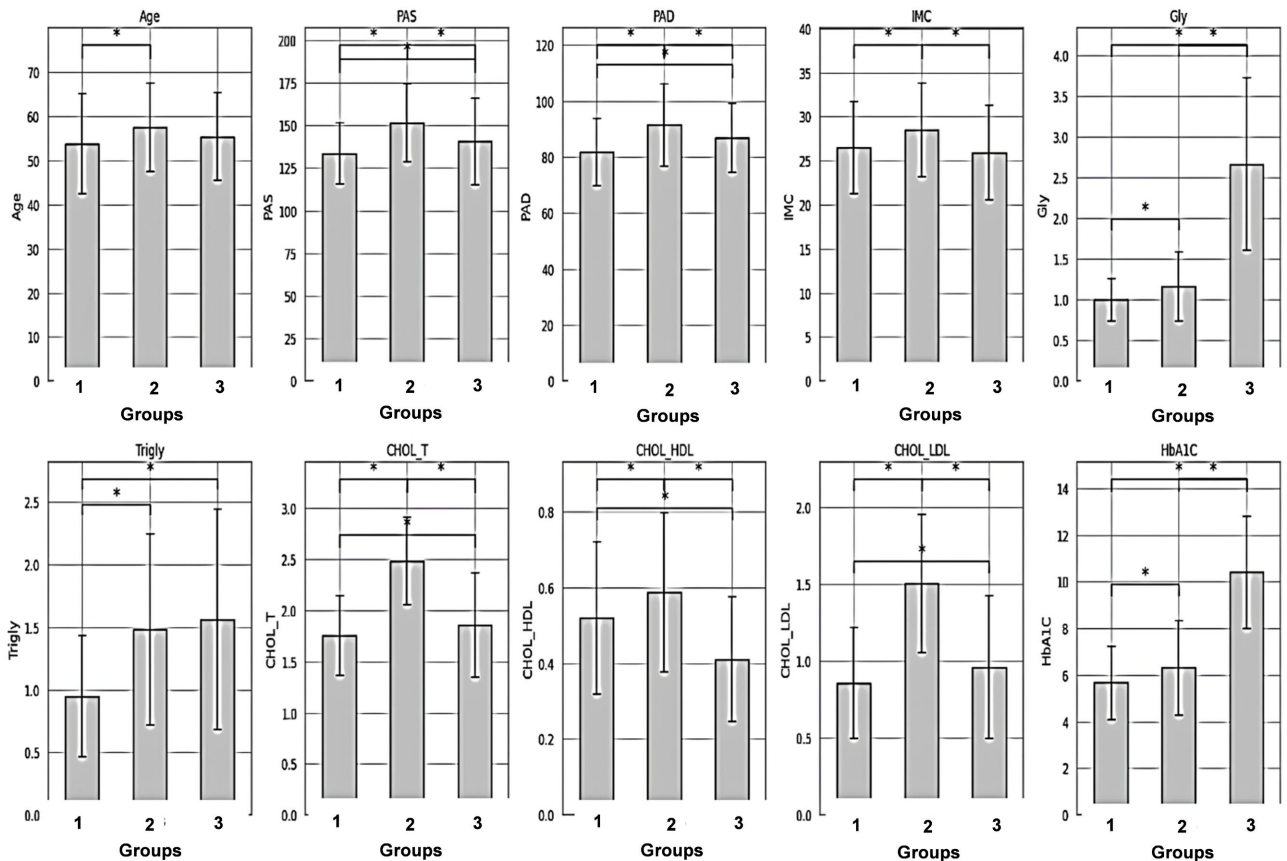


Figure 5. Analytical and Comparative Statistics of Clinical, Biochemical, and Anthropometric Parameters in Subgroups 1, 2, and 3 of the study population (diabetic, diabetic-hypertensive, and hypertensive). PAS: Systolic Blood Pressure; PAD: Diastolic Blood Pressure; GLY: blood glucose IMCI: Body Mass Index; HbA1C: glycated hemoglobin; GLY: Blood glucose; Trygly: triglycerides; CHOL_T: Total Cholesterol; ChOL_HDL: high-density lipoprotein cholesterol; CHOL_LDL: low-density lipoprotein cholesterol.

3.8. Assessment of the Interaction between the Occurrence of Metabolic Diseases Diabetes and Hypertension and Ethnic Groups

The previous analyses indicated cluster 2 as predominantly associated with the Mandé ethnic group and hypertension, while cluster 3 was mainly associated with the Akan ethnic group and diabetes. We checked for the association between the Mandé ethnic group and hypertension in cluster group 2 by performing Fisher's

exact test. The analysis yielded an odds ratio (OR) of 0.57 at $p \leq 0.05$ with an IC value ranging between 0.34 and 0.95 (**Figure 6(A)**), indicating a statistically significant association between the Mandé ethnic group and hypertension. Similarly, Fisher's exact test performed to investigate the association between the Akan ethnic group and diabetes disease occurrence in cluster 3, exhibited the following result; OR = 75.51 with a $p \leq 0.001$ with an IC value ranging between 11.95 and 3102.6, indicating statistically significant association between the Akan ethnic group and diabetes (**Figure 6(B)**). Finally, we evaluated the predictive ability of the Mandé and Akan ethnic groups for hypertension and diabetes by combining the data from clusters 2 and 3 and applying a single Fisher's exact test. The analysis indicated that individuals belonging to the Akan ethnic group were more likely to present with diabetes than hypertension, whereas individuals from the Mandé ethnic group were more likely to present with hypertension than diabetes. The corresponding odds ratio was 1.49, with a $p = 0.03$ with an IC value ranging between 1.02 and 2.18 (**Figure S3**).

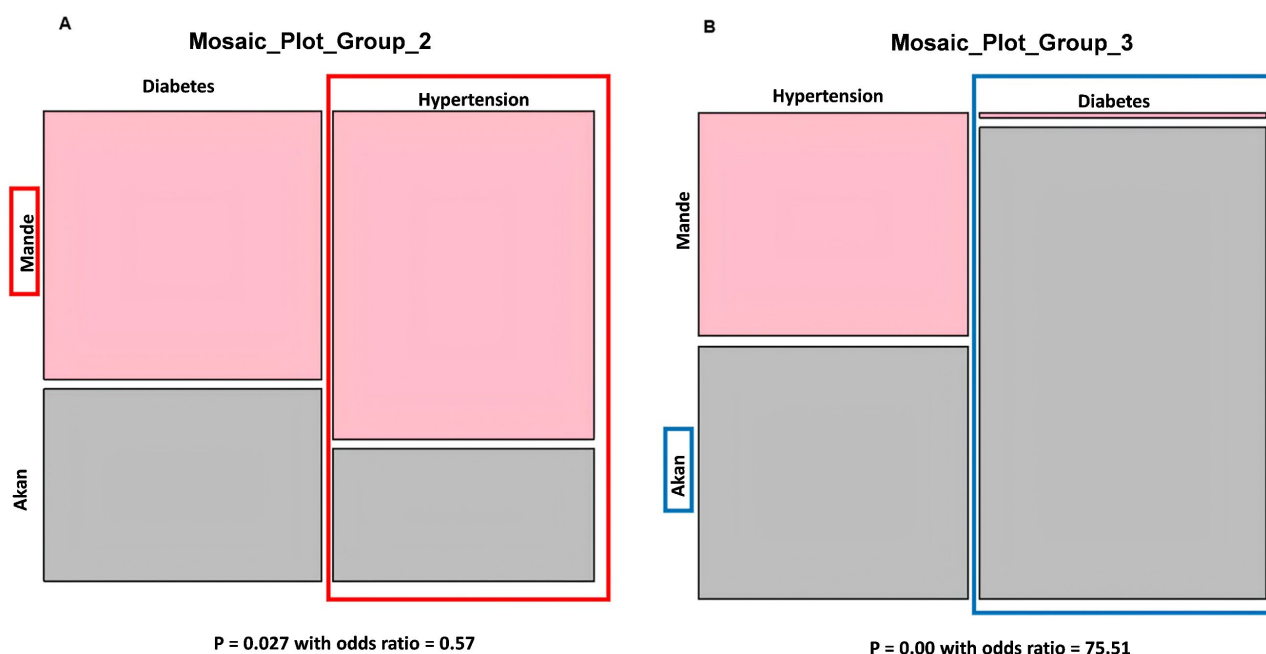


Figure 6. Mosaic plot of Fisher exact test in assessing relationship between ethnical group (Mandé and Akan ethnical groups) and (A) hypertension exhibiting odds ratio (OR) = 0.57 at $p = 0.027$ with an IC value ranging between 0.34 and 0.95 and (B) diabetes diseases displaying OR = 75.51 at $p = 0.00$ with an IC value ranging between 11.95 and 3102.6.

4. Discussion

Type 2 diabetes mellitus is a chronic metabolic disease that, if not adequately managed, is associated with a high risk of complications. Hypertension is a major aggravating factor contributing to the development of these complications. Reliable epidemiological data are essential for improving both the therapeutic management and prevention of these two chronic conditions. Conflicting results regarding diabetes predisposition features between northern and southern of Cote

d'Ivoire [8] [9] and as well as exponential growth in hypertension case [7], suggests the cultural, genetic and environmental components in monitoring chronic metabolism disease concerns in Côte d'Ivoire. Therefore, the present study aimed to investigate the association between ethnic groups and the occurrence of type 2 diabetes and hypertension in Côte d'Ivoire. To do that, we performed a multivariate statistical analysis of clinical, biochemical and anthropomorphic parameters of diabetic, hypertensive, diabetic-hypertensive and healthy participants in R programming environment (version 4.5.2; 2025-10-31 UCRT). Our study revealed a predominance of women among the diabetic, diabetic-hypertensive, and hypertensive populations, representing 63.0%, 71.5%, and 65.0% of participants, respectively. These findings are consistent with those reported by Dago *et al.* (2017) [17] and Oléfongo *et al.* (2025a) [8] who also observed a female predominance among individuals affected by metabolic and cardiovascular diseases, including hypertension, in Korhogo, northern Côte d'Ivoire. This predominance may be explained by the strong relationship between obesity and sex. Indeed, Koné *et al.* (2024) reported that women in Bouaké, Côte d'Ivoire, had obesity rates approximately three times higher than those of men, which may contribute to a higher incidence of diabetes among women [18]. Similarly, Acka *et al.* (2015) found that 47.1% of diabetic-hypertensive patients were women compared with 41.5% men in Bouaké, suggesting a substantial burden of diabetes-hypertension comorbidity among women in the Ivorian context [19]. Furthermore, menopause may contribute to the higher prevalence of hypertension in women through the loss of the vasoprotective effects of estrogens, which promote vasodilation and inhibit vascular smooth muscle cell proliferation. This hormonal change, together with the emergence of relative hyperandrogenism, has been associated with an increased risk of hypertension [20]. Our findings are also in agreement with those of Tougouma *et al.* (2018), who reported a female predominance (62.5%) among hypertensive patients in Bobo-Dioulasso, Burkina Faso [21]. Regarding ethnic distribution, the diabetic population was predominantly composed of individuals from the Mandé ethnic group (33.0%), followed by the Akan (30.0%) and Gour (25.0%) ethnic groups. Similarly, the diabetic-hypertensive population was mainly represented by the Mandé ethnic group, followed by the Gour (30.0%) and Akan (28.0%) ethnic groups. In contrast, the hypertensive population was dominated by the Akan ethnic group (39.5%), followed by the Mandé (28.0%) and Gour (23.0%) ethnic groups. The Krou and foreign ethnic groups were underrepresented across all study populations. These findings differ from those reported by Agbré-Yacé *et al.* (2015), who observed a predominance of the Akan ethnic group (37.5%), followed by foreign nationals (26.4%), Northern Mandé (10.1%), Southern Mandé (8.1%), Krou (7.4%), and Gour (6.73%) among diabetic patients [22]. These discrepancies may be explained by differences in healthcare-seeking behavior, recruitment strategies, and the demographic characteristics of the study populations. Of note, most participants reported a family history of either type 2 diabetes or hypertension, with proportions of 26.0%, 30.0%, and 33.0% in the dia-

betic, diabetic-hypertensive, and hypertensive groups, respectively. These findings confirmed the work of Diawara *et al.* (2023), who reported that individuals with a family history of diabetes had a 14.13 fold higher risk of developing type 2 diabetes than those without such a history [23]. Likewise, Li *et al.* (2021) demonstrated that a family history of diabetes and/or hypertension constitutes an important risk factor for hypertension, particularly a family history of diabetes [24]. Our results also demonstrated a statistically significant association between ethnic groups in Cote d'Ivoire and the occurrence of diabetes and hypertension. Similar findings were reported by Porhcsaliyan *et al.* (2021) in Singapore, where ethnicity (Indian versus Chinese) was significantly associated with type 2 diabetes among hypertensive patients [25]. Such associations may reflect environmental, socioeconomic, physiological, genetic, and behavioral differences among ethnic groups [26]. Furthermore, a statistically significant difference was observed between patients with diabetes and those with both diabetes and hypertension, as well as between hypertensive patients and diabetic-hypertensive patients. In contrast, no significant difference was found between the diabetic and hypertensive groups. These findings suggest that the coexistence of diabetes and hypertension defines a distinct clinical profile compared with either condition alone. According to Sun *et al.* (2019), type 2 diabetes and hypertension share several metabolic pathways and molecular mechanisms [27]. When both conditions coexist, these mechanisms may contribute to a more severely altered cardio metabolic profile, which could explain the differences observed in our study population. Conversely, when considered separately, diabetes and hypertension may exhibit overlapping clinical and metabolic characteristics because of their shared pathophysiological mechanisms [28]. This overlap may account for the absence of statistically significant differences between the diabetic and hypertensive groups observed in our study. Indeed, backing on the above mentioned statistically significant association between ethnic groups in Cote d'Ivoire and the occurrence of diabetes and hypertension, our study demonstrated a statistically significant association between the Mandé ethnic group and hypertension, as well as between the Akan ethnic group and diabetes. In addition, the combined analysis of the Mandé and Akan ethnic groups suggested that individuals from the Akan ethnic group were more likely to present with diabetes than hypertension, whereas individuals from the Mandé ethnic group were more likely to present with hypertension than diabetes. Similar associations between ethnicity and chronic cardio metabolic diseases have been reported in previous studies. In a multiethnic population in the United States, Kramer *et al.* (2004) reported that African American ethnicity (OR = 2.21; 95% CI: 1.91 - 2.56) and Chinese ethnicity (OR = 1.30; 95% CI: 1.07 - 1.56) were significantly associated with hypertension compared with White individuals [29]. Likewise, Rayas *et al.* (2024) showed that Black women had a higher risk of hypertensive disorders (OR = 1.36; 95% CI: 1.14 - 1.62; $p < 0.001$), whereas Hispanic women had a lower risk (OR = 0.71; 95% CI: 0.60 - 0.84; $p < 0.001$) [30]. Similarly, Porhcsaliyan *et al.* (2021) reported that individuals of Malay (OR = 1.59; 95% CI: 1.04 - 2.44; $p = 0.031$) and Indian (OR

= 3.65; 95% CI: 2.25 - 5.91; $p < 0.001$) ethnicity had a significantly higher probability of type 2 diabetes than those of Chinese ethnicity [25].

5. Conclusion

The study participant population was characterized by a high prevalence of overweight and obesity, with altered glycemic, lipid, and blood pressure parameters suggesting suboptimal control of diabetes and hypertension. Dyslipidemia was also highly prevalent among the participants. Furthermore, statistical clustering analysis by processing participant's clinical, biochemical and anthropomorphic features, supported a statistically significant associations between the Mandé and Akan ethnic groups and hypertension and type 2 diabetes occurrence respectively. These findings provide epidemiological evidence supporting the influence of ethnic background on the distribution of chronic cardio metabolic diseases in Côte d'Ivoire and may contribute to the development of targeted prevention and management strategies.

Ethical Considerations

The study was conducted in accordance with the Declaration of Helsinki, and approval was received from the National Ethics and Research Committee (CNER) of the Ministry of Health, Public Hygiene, and Universal Health Coverage of Côte d'Ivoire. After receiving appropriate information and explanations, adult participants, as well as the parents or legal guardians of all children wishing to participate in the study, provided their written consent prior to sampling.

Acknowledgements

The authors would like to thank i) the Headers of the diabetes, cardiology, and laboratory departments at the National Institute of Public Health in Abidjan; ii) Abengourou Regional Hospital, iii) University Hospital of Bouaké; iv) Man Regional Hospital, and Korhogo Regional Public Hospital for granting us access to their facilities for sample collection and the measurement of lipid and glucose levels. The authors also thank the staff at these institutions for their collaboration in patient recruitment, sample collection, and the provision of equipment, which made it possible to perform the biochemical analyses.

Author Contributions

Yéboué Kouadio Auguste: Conceptualization, Data curation and analysis, Formal Analysis, Resources, Validation, Writing original draft, Writing, Review and editing. **Dagnogo Oléfongo:** Methodology, Visualization, Writing, Review and editing. **Gnangui Sara Laetitia Elphège:** Methodology, Contribution in data analysis, Writing review & editing. **Dago Dougba Noel:** Conceptualization and Supervision; Formal Analysis, Orientation giving in data analysis as well as in original writing draft, Methodology, Resources, Software, Validation, Writing, review and editing.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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Appendix

Abbreviations

BMI	Body Mass Index
SBP	Systolic Blood Pressure
DBP	Diastolic Blood Pressure
HTA	Arterial Hypertension
D	Diabetes
EDTA	Ethylene Diamine Tetra-Acetic Acid

Table S1. Descriptive statistics of anthropometric, clinical, and biochemical parameters in the diabetic (D), diabetic-hypertensive (DH), and hypertensive (H) populations.

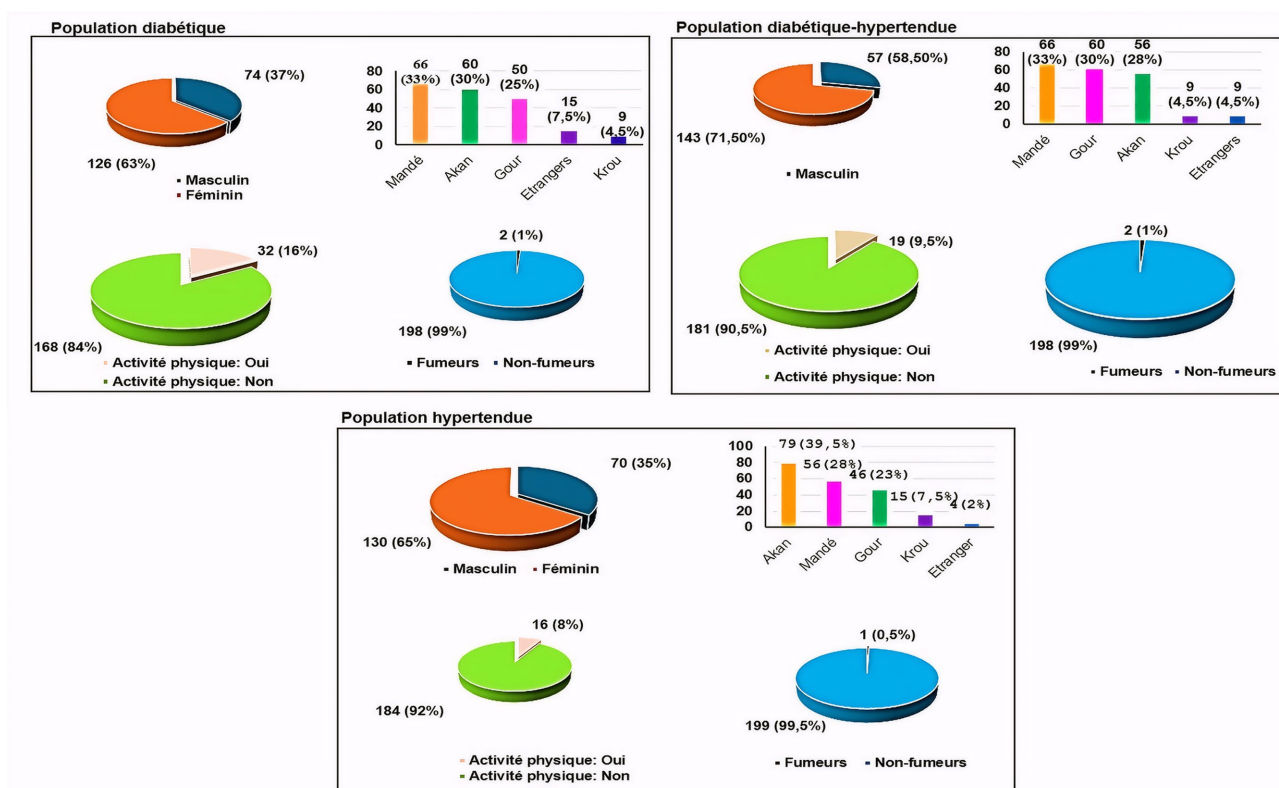
Parameters	Patients	Min	Max	Sum	Median	Mean	SEM	95% CI	Variance	SD
Age	D	31	82	10708	53	53.5	0.739	1.15	109	10.5
	DH	36	87	12361	62	61.8	0.606	0.19	73.5	8.57
	H	35	82	11300	56	56.5	0.753	1.47	113	10.6
SBP	D	90	190	26954	134	135	1.44	2.83	413	20.3
	DH	100	250	30470	150	152	1.65	3.23	541	23.3
	H	108	214	29400	147	147	1.4	2.74	391	19.8
DBP	D	60	125	16911	84	84.6	0.806	1.59	130	11.4
	DH	60	132	17645	88.5	88.2	0.981	1.92	193	13.9
	H	60	137	17800	86.5	89	1.12	2.19	252	15.9
BMI	D	13.3	45.2	5264	25.5	26.3	0.366	0.72	26.8	5.17
	DH	15.8	43.9	5468	26.9	27.3	0.377	0.74	28.5	5.34
	H	16.4	50	5500	26.9	27.5	0.405	0.79	32.8	5.72
Blood Sugar	D	0.52	5.79	377	1.5	1.89	0.078	0.15	1.23	1.11
	DH	0.58	5.16	314	1.3	1.57	0.057	0.11	0.65	0.81
	H	0.59	1.7	190	0.96	0.95	0.009	0.02	0.017	0.13
Triglycerides	D	0.25	5.28	264	1.13	1.32	0.058	0.11	0.68	0.83
	DH	0.32	4	258	1.15	1.29	0.044	0.09	0.396	0.63
	H	0.4	4.79	266	1.15	1.33	0.051	0.1	0.526	0.72
T_C	D	0.45	3.61	384	1.89	1.92	0.039	0.07	0.312	0.56
	DH	0.66	4.27	408	2.01	2.04	0.04	0.08	0.326	0.57
	H	0.27	3.82	430	2.12	2.15	0.038	0.07	0.3	0.54
HDL-C	D	0.09	0.97	94	0.47	0.47	0.012	0.02	0.033	0.18
	DH	0.13	1.9	106	0.51	0.53	0.016	0.03	0.053	0.02
	H	0.1	1.06	106	0.5	0.53	0.013	0.02	0.037	0.19
LDL-C	D	0.1	2.43	210	0.98	1.05	0.035	0.06	0.249	0.5
	DH	0.1	3.22	228	1.1	1.14	0.039	0.08	0.312	0.55
	H	0.27	2.75	236	1.17	1.18	0.037	0.07	0.274	0.52
HbA1C	D	4	15.3	1739	8.5	8.69	0.192	0.37	7.35	2.71
	DH	3.2	18	1547	7.44	7.73	0.183	0.35	6.68	2.68
	H	3.4	9.8	1040	5	5.2	0.07	1.14	1.01	1

SBP: Systolic Blood Pressure; DBP: Diastolic Blood Pressure; BMI: Body Mass Index; T_C: Total Cholesterol; HDL-C: high-density lipoprotein cholesterol; LDL-C: low-density lipoprotein cholesterol; HbA1C: glycated hemoglobin.

Table S2. Qualitative descriptive analysis (frequency of qualitative variables) of the three subgroups of subjects identified by the k-means analysis.

Variables	Group 1 (n = 359)	Group 2 (n = 256)	Group 3 (n = 135)
Male	149 (41.50%)	68 (26.56%)	51 (37.78%)
Female	210 (58.50%)	188 (73.44%)	84 (62.22%)
Akan	153 (42.62%)	63 (24.61%)	44 (32.59%)
Mande	98 (27.30%)	88 (34.38%)	39 (28.89%)
Gour	77 (21.45%)	78 (30.47%)	36 (26.67%)
Krou	20 (5.57%)	17 (6.64%)	7 (5.19%)
Foreigner	11 (3.06%)	10 (3.90%)	9 (6.66%)
SO	58 (16.16%)	38 (14.84%)	10 (7.41%)
SN	301 (83.84%)	218 (85.16%)	125 (92.59%)
FO	3 (0.84%)	1 (0.39%)	2 (1.48%)
FN	356 (99.16%)	255 (99.61%)	133 (98.52%)
Hypertensive	98 (27.30%)	101 (39.45%)	1 (0.74%)
DH	64 (17.83%)	89 (34.76%)	47 (34.81%)
Diabetic	72 (20.05%)	41 (16.02%)	87 (64.44%)
Control	125 (34.82%)	25 (9.77%)	0 (0%)

SO: Physical activity: Yes; SN: Physical activity: No; FO: Participants who smoke; FN: Participants who do not smoke; DH: Participants with diabetes and hypertension.

**Figure S1.** Descriptive analysis of the qualitative characteristics of populations with diabetes, diabetes and hypertension, and hypertension. Population diabétique: People with diabetes; Population diabétique-hypertendue: population with diabetes and hypertension; Population hypertendue: population with hypertension; Masculin: male; Féminin: female; Activité physique (oui): Physical activity (Yes); Activité physique (non): Physical activity (No); Fumeurs: Smokers; Non-fumeurs: Non-smokers.

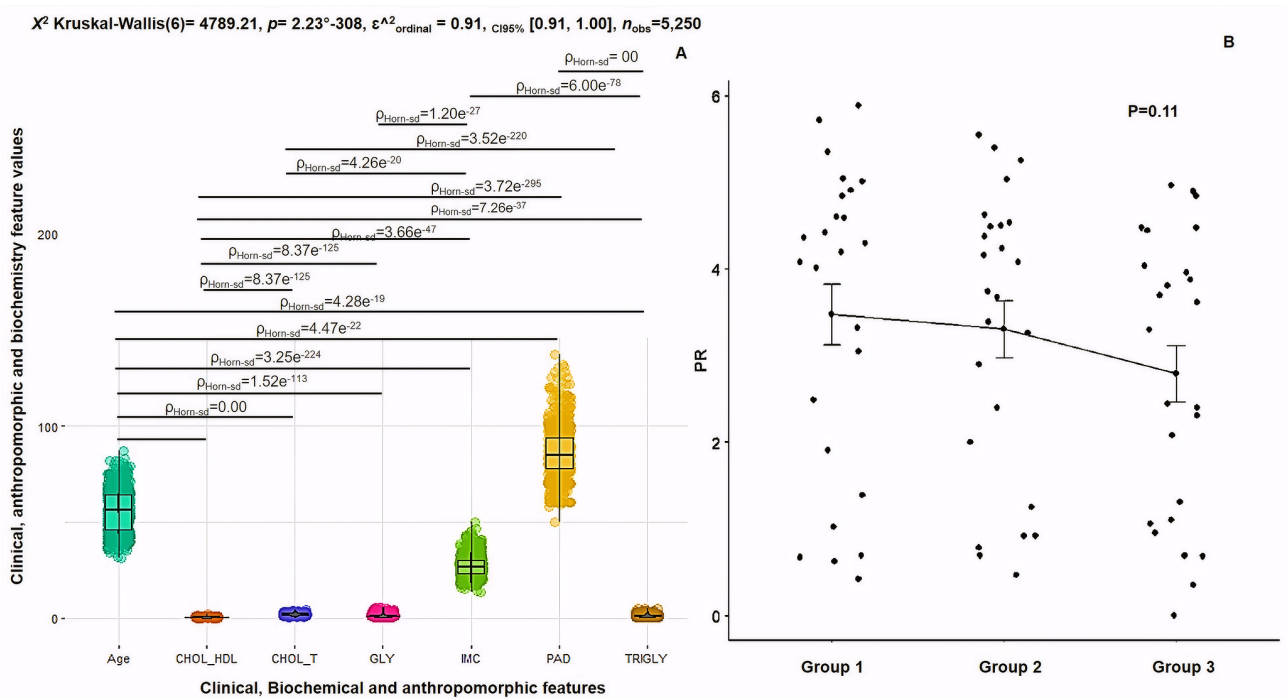


Figure S2. (A) Kruskal-Wallis test to analyze differences in the variability of clinical, biochemical, and anthropometric parameters among the control, diabetic, hypertensive, and hypertensive-diabetic groups. (B) Multivariate comparative analysis (Turkey's test) of differences in variance among the three groups generated by the k-means analysis. PAD: Diastolic Blood Pressure; IMC: Body Mass Index; CHOL_T: Total Cholesterol; CHOL_HDL: high-density lipoprotein cholesterol; TRIGLY: triglycerides.

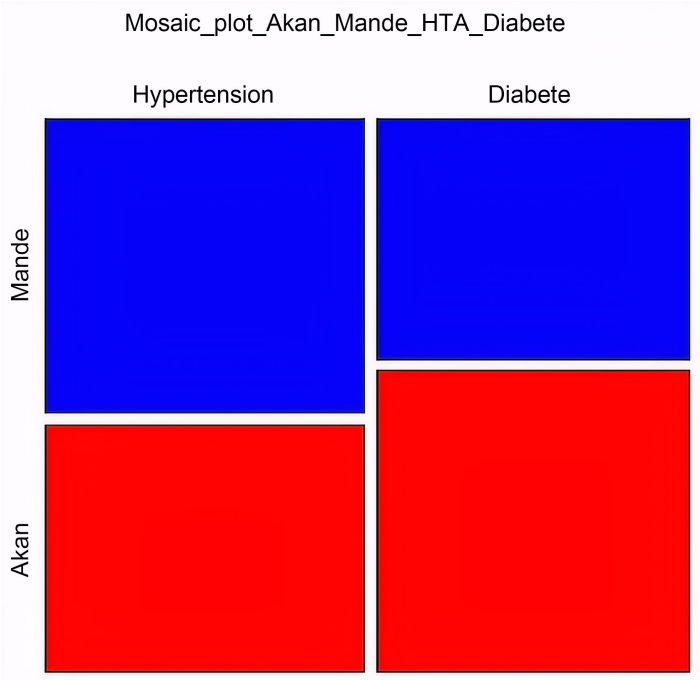


Figure S3. Analysis of the relationship between ethnic groups and diseases (diabetes and hypertension) for populations in Groups 2 and 3, characterized by the Mandé and Akan ethnic groups, respectively. P-value = 0.03 with an odds ratio of 1.49 with an IC value ranging between 1.02 and 2.18.