Research Square

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Multivariate study of renal function in hypertensive patients treated at the Amissa Bongo University Hospital Center

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Abstract

Background

Arterial hypertension remains a major public health challenge in sub-Saharan Africa, with inadequate blood pressure control despite available treatments.

Objective

To describe the epidemiological, clinical, and biological profile of hypertensive patients and assess associations between antihypertensive treatment, blood pressure control, and renal function.

Methods

A cross-sectional descriptive and analytical study was conducted from October to December 2025 at the Amissa Bongo University Hospital Center, Franceville, Gabon, including 73 hypertensive patients. Sociodemographic, clinical, therapeutic, and biological data were collected using a standardized questionnaire and analyzed with R software (v4.3.1).

Results

Mean age was 60.9 ± 15.2 years, with a balanced sex distribution (50.7% male). Mean systolic and diastolic blood pressures were 169.1 ± 31.9 and 101.0 ± 24.9 mmHg, respectively; Grade 3 hypertension predominated (35.6%). Major comorbidities included type 2 diabetes (28.8%), stroke history (19.2%), and chronic kidney disease (16.4%). Perindopril/amlodipine (Coveram®) was the most prescribed treatment (61.6%). Only 23.3% achieved blood pressure control (< 140/90 mmHg). Coveram® use was associated with lower serum creatinine (142 ± 89 vs. 218 ± 341 µmol/L; p = 0.042). Age correlated with systolic pressure (r = 0.38; p = 0.001). Multivariate analyses identified distinct renal, blood pressure-glycemic, and hepatic profiles, with age particularly associated with renal parameters.

Conclusion

Blood pressure control remains suboptimal despite frequent combination therapy. Perindopril/amlodipine use was associated with better renal parameters. Therapeutic education and closer follow-up are warranted.

1. Introduction

Arterial hypertension represents one of the major modifiable risk factors for cardiovascular morbidity and mortality worldwide. It is associated with a significant increase in the risk of stroke, myocardial infarction, heart failure, and chronic kidney disease [1]. In sub-Saharan Africa, the prevalence of hypertension has increased considerably over the past two decades due to urbanization, dietary changes, sedentary lifestyle, and population aging. A recent meta-analysis estimated the average prevalence of hypertension at approximately 28.5%, with values exceeding 30% in several urban areas [2]. In Gabon, hypertension also constitutes a major public health problem. Available studies report a high prevalence in the adult population as well as a low blood pressure control rate despite treatment. Recent hospital data indicate that only about 35% of followed patients have adequate blood pressure control [3, 4].

The Amissa Bongo University Hospital Center in Franceville, located in the Haut-Ogooué Province in southeastern Gabon, is a reference center for the management of cardiovascular diseases. However, data concerning the epidemiological, clinical, and biological characteristics of hypertensive patients followed in this facility remain limited. Similarly, the impact of different therapeutic regimens on blood pressure control and associated complications remains insufficiently documented in this hospital setting.

Furthermore, the relationships between hypertension, antihypertensive treatments, and renal function constitute a major clinical challenge. Indeed, hypertension represents both a cause and a consequence of chronic kidney disease, while certain therapeutic classes can influence the evolution of renal function depending on the clinical context [5].

The main objective of this study was to describe the epidemiological, clinical, and biological profile of hypertensive patients followed at the Amissa Bongo University Hospital Center in Franceville. The secondary objectives were: (i) to analyze the associations between prescribed therapeutic regimens and the level of blood pressure control; (ii) to evaluate the relationships between antihypertensive treatments and biological parameters of renal function; (iii) to identify factors associated with poor blood pressure control.

2. Materials and Methods

2.1. Study Setting and Design

This was a cross-sectional descriptive and analytical study conducted at the Internal Medicine and Cardiology Department of the Amissa Bongo University Hospital Center in Franceville, between October 6 and December 18, 2025.

2.2. Study Population

Inclusion and non-inclusion criteria

The present study included any patient aged at least 18 years, with a diagnosis of arterial hypertension (HTN) consistent with the European Society of Cardiology recommendations (blood pressure ≥ 140/90 mmHg and/or ongoing antihypertensive treatment) [6], and who had previously signed informed consent. Conversely, subjects who refused to participate, as well as those whose clinical or biological records contained more than 30% missing values, were excluded, in order to preserve the robustness and validity of the statistical analyses.

2.3. Data Collection

Data collection was conducted using a standardized questionnaire, previously subjected to a pre-test phase to ensure its clarity and reliability. First, this questionnaire collected the sociodemographic characteristics of the participants (age, sex, occupation, and education level), closely coupled with clinical information. The latter included medical and family history, duration of hypertensive disease, reported symptomatology, and classification of the hypertension grade according to the 2023 European Society of Cardiology recommendations [6].

In parallel with this clinical evaluation, the therapeutic aspect and lifestyle habits were recorded. Thus, current antihypertensive treatments were precisely listed, specifying the prescribed molecules, dosages, and self-reported degree of adherence. Additionally, the main behavioral risk factors were investigated, whether smoking, alcohol consumption, physical activity level, or dietary practices (notably salt and sugar intake).

Finally, routine biochemical analysis was performed on blood samples collected according to the protocol described by Ngoua et al [7]. Fasting blood glucose, creatinine, urea, uric acid, and hepatic transaminases were measured using the methods described by Ngoua et al., utilizing the Cobas c 111, a compact benchtop clinical chemistry analyzer manufactured by Roche Diagnostics [7, 8]. Serum electrolyte levels were determined using a BIOBASE BKE-C series electrolyte analyzer. Regarding blood pressure measurement, a standardized protocol was strictly followed: readings were taken using a validated electronic blood pressure monitor (M7 Intelli IT AFib) after the patient had rested in a seated position for five minutes. Two consecutive measurements, spaced two minutes apart, were performed for each patient, with the final value recorded being the arithmetic mean of these two measurements.

2.4. Operational Definitions

Optimal blood pressure control: BP < 140/90 mmHg in non-diabetic adults, < 130/80 mmHg in case of diabetes or kidney disease [9];

Kidney disease: serum creatinine > 110 µmol/L in men, > 90 µmol/L in women, or estimated GFR < 60 mL/min/1.73 m²;

Polytherapy: simultaneous prescription of at least two classes of antihypertensives.

2.5. Statistical Analysis

Statistical analyses were conducted using R software, version 4.3.1 (R Foundation for Statistical Computing, Vienna, Austria). Quantitative variables are expressed as mean ± standard deviation or median (with interquartile range), depending on their distribution, whereas categorical variables are presented as frequencies and percentages. Data distributions were visualized using appropriate graphical representations.

The normality of data distributions was assessed using the Shapiro-Wilk test. Group comparisons were performed using the independent Student's t-test or the Mann-Whitney U test, as appropriate. Associations between categorical variables were evaluated using the chi-square (χ^2) test or Fisher's exact test. Linear correlations were examined using Pearson's correlation coefficient. A p-value of < 0.05 was considered statistically significant.

To explore multidimensional relationships and identify predominant profiles, Principal Component Analysis (PCA) was performed on quantitative variables following centering and scaling, while Multiple Correspondence Analysis (MCA) was applied to categorical variables. These multivariate analyses and subsequent data visualizations were executed using the FactoMineR, factoextra, and ggplot2 packages in R.

3. Results

3.1. Sociodemographic and Clinical Characteristics

Table 1 presents the general characteristics of the patients included in the study. Among the 73 included patients (mean age: 60.9 ± 15.2 years; balanced sex ratio), grade 3 hypertension predominated (35.6%) with high mean pressures (169/101 mmHg). The disease had been evolving for more than 5 years in 56.2% of subjects. Type 2 diabetes (28.8%), stroke (19.2%), and kidney disease (16.4%) constituted the main comorbidities, characterizing a population at high cardiovascular risk.

Table 1
Sociodemographic and clinical characteristics of the study population (n = 73)

Variables	Frequency (%) or Mean ± SD
Age (years	60.9 ± 15.2
Male sex	37 (50.7%)
Female sex	36 (49.3%)
Age groups	
20–40 years	8 (11.0%)
40–60 years	24 (32.9%)
60–80 years	33 (45.2%)
≥ 80 years	8 (11.0%)
Systolic blood pressure (mmHg)	169.1 ± 31.9
Diastolic blood pressure (mmHg)	101.0 ± 24.9
HTN grade	
Grade 1 (140–159/90–99)	16 (21.9%)
Grade 2 (160–179/100–109)	20 (27.4%)
Grade 3 (≥ 180/≥110)	26 (35.6%)
High normal / Normal	9 (12.3%)
Not classified	2 (2.7%)
Duration of HTN	
< 1 year	8 (11.0%)
1–5 years	12 (16.4%)
> 5 years / "Very long time"	41 (56.2%)
Not reported	12 (16.4%)
Main comorbidities	
Type 2 diabetes	21 (28.8%)
History of stroke	14 (19.2%)
Chronic kidney disease	12 (16.4%)
Ischemic heart disease / heart	9 (12.3%)

Variables	Frequency (%) or Mean ± SD
HIV / HCV / HBV infection	5 (6.8%)

3.2. Therapeutic Profile

Table 2 presents the distribution of antihypertensive treatments among the 73 patients followed at the Amissa Bongo UHC. The perindopril/amlodipine combination (Coveram®) is the most prescribed (61.6%, n = 45), followed by extended-release nifedipine (Loxen®, 34.2%, n = 25). Other regimens remain marginal (≤ 5.5%), while 11.0% of patients (n = 8) reported no treatment, suggesting non-adherence or recent follow-up. The sum of percentages exceeds 100% due to polytherapies.

Table 2
Distribution of prescribed antihypertensive treatments in hypertensive patients followed at the Amissa Bongo University Hospital Center in Franceville (n = 73)

Treatment	Frequency (%)	Pharmacological class
Coveram® (perindopril/amlodipine)	45 (61.6%)	ACE inhibitor + calcium channel blocker
Loxen® (extended-release nifedipine)	25 (34.2%)	Calcium channel blocker
Exforge® (valsartan/amlodipine)	4 (5.5%)	ARB + calcium channel blocker
Triplixam® (perindopril/indapamide/amlodipine)	4 (5.5%)	Fixed triple therapy
Bipterax® (perindopril/indapamide)	4 (5.5%)	ACE inhibitor + diuretic
Methyldopa	3 (4.1%)	Central antihypertensive
Others (Amlor®, Natrixam®, etc.)	7 (9.6%)	Various
No declared treatment	8 (11.0%)	—

ACE: Angiotensin-Converting Enzyme inhibitors; ARB: Angiotensin II Receptor Blockers.

Note

some patients received multiple treatments; percentages do not sum to 100%.

Monotherapy was prescribed in 28 patients (38.4%), while 37 patients (50.7%) received dual or triple therapy. Eight patients (11.0%) reported no antihypertensive treatment at the time of inclusion.

3.3. Blood Pressure Control and Associated Factors

Only 17 patients (23.3%) had optimal blood pressure control (< 140/90 mmHg). Control was significantly more frequent in patients on Coveram® (28.9% vs. 14.3%; p = 0.18, Fisher's exact test), although this difference did not reach statistical significance, probably due to the limited sample size (Fig. 1).

Legend: Bar chart showing the proportion of patients with BP < 140/90 mmHg according to treatment: Coveram® 28.9%, Loxen® 20.0%, Others 18.2%, No treatment 0%. Y-axis: Percentage of control (0–40%); X-axis: Type of treatment. Colored bars with 95% confidence intervals.

3.4. Factors Associated with Poor Blood Pressure Control

The results of the univariate analysis of factors associated with blood pressure control are presented in Table 3. Univariate logistic regression analysis identified three factors significantly associated with inadequate blood pressure control. First, a duration of hypertension exceeding five years multiplied the risk of poor control by 3.2 (OR = 3.2; 95% CI: 1.1–9.4; p = 0.035). In parallel, the presence of at least two associated comorbidities increased this risk by 2.8 times (OR = 2.8; 95% CI: 1.0–7.9; p = 0.048). Finally, self-reported irregular therapeutic adherence appeared as the most strongly predictive factor, multiplying by 4.1 the probability of treatment failure (OR = 4.1; 95% CI: 1.4–12.3; p = 0.012). Overall, these results demonstrate that the chronicity of the disease, polymorbidity, and above all, treatment adherence constitute major determinants of the effectiveness of antihypertensive management in our cohort.

Table 3
Factors associated with poor blood pressure control: univariate logistic regression analysis (n = 73)

Studied factor	Odds Ratio (OR)	95% Confidence Interval	p-value
Duration of HTN > 5 years	3.2	1.1–9.4	0.035
Presence of at least two comorbidities	2.8	1.0–7.9	0.048
Self-reported irregular therapeutic adherence	4.1	1.4–12.3	0.012

Dependent variable: inadequate blood pressure control (BP ≥ 140/90 mmHg). Model: univariate binary logistic regression. Significance threshold: p < 0.05.

3.5. Renal Function and Therapeutic Correlations

As indicated in Table 4, the analysis of biological parameters according to treatment revealed significant differences. Patients on Coveram® had a globally more stable metabolic profile (median creatinine: 92 µmol/L) compared to the untreated or non-adherent group (median creatinine: 185 µmol/L, p = 0.032). Due to the asymmetric distribution of renal markers and the presence of extreme values (advanced kidney disease), analyses were conducted using median and interquartile range, thus ensuring the robustness of statistical comparisons.

Table 4
Biological parameters (renal, hepatic, and ionic) according to main antihypertensive treatment (n = 73)

Biological parameter	Coveram® (Perindopril/Amlodipine) = 42	Calcium Channel Blockers * (Loxen, Amlor, Nicardipine) n = 12	Other ACEi/ARB + Diuretics (Triplixam, Bipreterax, etc.) n = 10	No treatment / Non-adherence n = 9	p-value (Kruskal-Wallis / ANOVA)
Renal function					
Creatinine (µmol/L)	92 [71–145]	104 [78–158]	115 [85–190]	185 [110–520]	0.032
Urea (mmol/L)	6.4 [4,8–8.9]	7.1 [5.2–9.5]	8.2 [6.1–12.5]	13.5 [9.2–24.1]	0.018
eGFR (CKD-EPI), mL/min/1,73 m²	74 ± 26	71 ± 29	66 ± 32	48 ± 38	0.045
CKD stage ≥ eGFR < 60), n (%)	11 (26.2%)	3 (25,0%)	4 (40,0%)	5 (55,6%)	0.142
Purine metabolism					
Uric acid (µmol/L)	335 ± 95	358 ± 110	380 ± 125	445 ± 160	0.041
Hepatic profile					
AST (UI/L)	21 [16–28]	24 [18–32]	26 [20–35]	38 [25–62]	0.089
ALT (UI/L)	24 [18–31]	27 [20–36]	30 [22–41]	42 [28–75]	0.076
Ionic profile					
Sodium (Na^+, mmol/L)	138.2 ± 4.1	139.1 ± 3.5	137.5 ± 5.2	135.8 ± 6,8	0.185
Potassium (K^+, mmol/L)	4.1 ± 0.6	4.0 ± 0.5	4.3 ± 0.7	4.6 ± 0.9	0.092
Chlorure (Cl-, mmol/L)	105.5 ± 5.2	106.2 ± 4.8	104.8 ± 6.1	102.1 ± 8,5	0.112
Calcium (Ca^{2+}, mmol/L)	2.21 ± 0.18	2.25 ± 0.21	2.18 ± 0.25	2.05 ± 0.32	0.154

Legend and methodological notes: Values are expressed as Mean ± Standard Deviation (SD) for variables with normal distribution (eGFR, ions), and as Median [Interquartile Range: Q1 – Q3] for variables with asymmetric distribution (Creatinine, Urea, AST, ALT, Uric acid), in order to neutralize the impact of extreme values (e.g., patient #44 with creatinine at 1838 µmol/L).

Calcium Channel Blockers

Loxen, Amlor, Nicardipine.

* Other ACEi/ARB + Diuretics: Triplixam, Bipterax, Amaday, Natrixam, Cotareg.

Statistical test

Kruskal-Wallis test for non-parametric variables, one-way ANOVA for parametric variables, and Fisher's exact test for proportions. Significance threshold set at $p < 0.05$.

CKD

Chronic Kidney Disease.

3.6. Correlations Between Clinical and Biological Parameters

As shown in Fig. 2, several statistically significant correlations were identified between the studied clinical, biological, and therapeutic parameters. Linear correlation analysis revealed several significant associations within the cohort. First, a moderate positive correlation was observed between age and systolic blood pressure ($r = 0.38$; $p = 0.001$), reflecting a progressive increase in blood pressure with aging. In parallel, a strong and highly significant correlation linked serum creatinine to blood urea ($r = 0.82$; $p < 0.001$), reflecting the close physiological dependence between these two markers of renal function. Finally, an inverse correlation, although of low intensity, was found between potassium levels and diuretic use ($r = -0.24$; $p = 0.041$), a result consistent with the known hypokalemic effect of this therapeutic class.

Legend: X-axis: Age (years, 20–100); Y-axis: SBP (mmHg, 120–260). Pearson coefficient displayed in legend ($r = 0.38$; $p = 0.001$). Points colored according to HTN grade: green = grade 1, orange = grade 2, red = grade 3.

Coded interpretation in the figure

The positive slope of the regression line confirms the moderate positive correlation ($r = 0.38$) between age and SBP. The increasing density of orange points (severity grade 2) and red points (severity grade 3) with age illustrates the progression towards severe HTN grades. The 95% CI widens at the extremes (20

years and > 80 years), reflecting the increased variability of SBP in underrepresented age groups and the lower local precision of the regression model.

3.7. Multivariate Analyses: PCA and MCA of Clinical-Biological Profiles

To explore the multidimensional association structures between quantitative and qualitative variables, a Principal Component Analysis (PCA) was applied to biological parameters (renal, hepatic, and ionogram), and two Multiple Correspondence Analyses (MCA) were conducted, one on clinical symptoms and blood pressure grade, the other on lifestyle factors and blood pressure severity.

4. Discussion

4.1. General Discussion of Results

This cross-sectional study, conducted among 73 hypertensive patients followed at the Amissa Bongo University Hospital Center in Franceville, presents a worrying but realistic picture of hypertension management in the Central African context. The most striking result was the rate of inadequate blood pressure control, observed in 76.7% of the cohort, a figure well above the therapeutic target. This finding aligns perfectly with recent epidemiological data in sub-Saharan Africa, where control rates generally range between 15% and 30%, far from the standards of high-income countries [10, 11]. The predominance of grade 3 hypertension (35.6%) and the chronicity of the disease (evolving for more than 5 years in 56.2% of patients) testified to often late management or silent progression of the disease. The high prevalence of comorbidities, notably type 2 diabetes (28.8%), history of stroke (19.2%), and chronic kidney disease (16.4%), confirmed that our population belonged to a category at very high cardiovascular and renal risk, in accordance with the ESC/ESH 2023 risk stratifications [12].

Regarding therapeutics, the clear predominance of the perindopril/amlodipine combination (Coveram®, 61.6%) reflected adherence to international recommendations that favor renin-angiotensin system (RAS) inhibitors combined with a calcium channel blocker for their synergistic efficacy and favorable tolerability profile [13, 14]. However, the persistence of poor control despite this first-line prescription highlighted the limitations of pharmacological orientation alone in the absence of dosage adjustments or concomitant lifestyle measures.

Univariate analysis identified three major determinants of poor control, which deserve in-depth analysis. First, self-reported non-adherence emerged as the most powerful predictive factor (OR = 4.1; p = 0.012). This result corroborates studies conducted in sub-Saharan Africa, which identified treatment adherence as the main bottleneck in hypertension management [15]. In Gabon, this non-adherence is multifactorial. First, it is often dictated by economic constraints (cost of medications), then by the relative asymptomaticity of the disease, cultural beliefs, or stock-outs in peripheral pharmacies. The fact that 11.0% of patients reported no treatment at the time of inclusion illustrates this therapeutic dropout phenomenon strikingly.

Second, the chronicity of the disease (> 5 years) multiplied the risk of poor control by 3.2 (p = 0.035). This association probably reflected a combination of natural aggravation of arterial stiffness linked to aging (confirmed by the positive correlation between age and SBP, r = 0.38; p = 0.001) and "therapeutic inertia" on the part of prescribers, who hesitate to intensify treatment in elderly polymedicated patients [16].

Finally, the presence of at least two comorbidities significantly increased the risk of failure (OR = 2.8; p = 0.048). The coexistence of diabetes and kidney disease complicates management, imposing stricter blood pressure targets (< 130/80 mmHg according to KDIGO 2021 [17]) and sometimes limiting the available therapeutic arsenal due to contraindications or adverse effects.

The comparative analysis of biological parameters according to treatment provided valuable clinical insight. Contrary to a theoretical fear that ACE inhibitors could deteriorate renal function in case of poor hemodynamic tolerance, the present study showed that patients on Coveram® had a significantly more stable renal profile (median creatinine: 92 µmol/L) than the untreated or non-adherent group (median: 185 µmol/L; p = 0.032). This observation is explained by the fact that the absence of treatment exposes patients to progressive and unchecked hypertensive nephroangiosclerosis. The perindopril/amlodipine combination, by ensuring vasodilatory control and a reduction in intraglomerular pressure, plays a clear nephroprotective role here, consistent with literature data [18, 19].

In parallel, the uric acid level was significantly higher in the untreated group (445 ± 160 µmol/L, p = 0.041), which may reflect both an alteration of renal excretion secondary to uncontrolled hypertension and an absence of the uricosuric effect that some diuretics can offer (although marginally represented in our cohort) [20]. The inverse correlation between diuretic use and potassium level (r = -0.24; p = 0.041) further validated the biological coherence of our database, by reflecting the expected hypokalemic effect of this class, which justified the recommended systematic ionic monitoring [21].

The PCA of biological parameters (Fig. 3) confirmed the structure of univariate correlations: the first axis opposes renal function (creatinine, urea) to hepatic profile (AST/ALT), while blood pressure (SBP/DBP) projects independently of age, suggesting partially distinct determinants, consistent with recent multivariate approaches applied to renal and metabolic markers [22]. The analysis of electrolytic profiles (Fig. 4) showed a wider dispersion of chloride and potassium in untreated patients, compatible with the known role of diuretics and renin-angiotensin system inhibitors in ionic homeostasis [23]. The MCA of symptoms (Fig. 5) highlighted a grouping of functional complaints (headaches, dizziness, chest pain) with high blood pressure grades, while the MCA of lifestyle (Fig. 6) associated sedentary behavior and salty diet with female sex and grades 2–3, a pattern consistent with West African data on behavioral determinants of poor blood pressure control [12, 15]. These factorial representations, although exploratory due to sample size, provide a visual reading complementary to classical statistical tests and corroborate the interest of factorial methods for clinical research [24].

4.2. Methodological Strengths and Limitations of the Study

Strengths: This study has the advantage of being one of the first to systematically document the correlations between therapeutic profile, blood pressure control, and renal function in the southeastern Gabonese region, thanks to standardized collection reinforcing the internal validity of the results. The use of medians and interquartile ranges for asymmetric variables (creatinine, urea) allowed neutralizing the impact of extreme values, ensuring the robustness of statistical analyses.

Limitations: The main bias lies in the cross-sectional design, which does not allow establishing a temporal causal link between non-adherence and poor control. Moreover, the evaluation of adherence relies on patient self-reporting, a potential source of social desirability bias (under-reporting of non-adherence). The modest sample size (n = 73) limited the statistical power of multivariate analysis, making certain trends (such as the superiority of Coveram® on control, p = 0.18) non-significant despite a notable clinical difference. Finally, the absence of microalbuminuria measurement did not allow refining the staging of renal involvement according to KDIGO criteria.

5. Conclusion

Although fixed-dose combinations are commonly prescribed at the Amissa Bongo University Hospital Center in Franceville, blood pressure control remains insufficient. In parallel, the perindopril/amlodipine combination appears to better preserve renal function, which supports its priority use in at-risk patients. Therefore, optimization of management requires strengthening therapeutic education, closer follow-up with rapid adjustment of treatments, and systematic integration of renal screening. Finally, the conduct of prospective cohort studies and operational research remains essential to validate these findings and inform public policies for hypertension control in Gabon.

Declarations

Conflicts of Interest

The authors declare no conflicts of interest related to this manuscript.

Clinical Trial Number

Clinical trial number: not applicable.

Use of Artificial Intelligence

The authors declare that the use of artificial intelligence-assisted tools was solely to improve the English language and grammar of the manuscript. No artificial intelligence was used in the generation, analysis or interpretation of the scientific data or results. The authors have reviewed and approved the final manuscript and take responsibility for its contents.

Ethics declarations

Ethical approval and consent to participate

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional research ethics committee, as well as the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. The study was approved by the bioethics committee of the Amissa Bongo University Hospital (CHU) in Franceville, in conjunction with the scientific and educational board of the Chemistry Department (Biochemistry Section) at the University of Science and Technology of Masuku (USTM) (Nº. 738 MS/SG/DRSSE/DGCHUAB). Free and informed consent was obtained from participants (or their parents or legal guardians for children under 16 years of age).

Consent for publication

All study participants gave their consent for publication.

Calcium Channel Blockers

Loxen, Amlor, Nicardipine.

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Declaration

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Author Contribution

JPO designed the study, supervised data collection, interpretation of results, and wrote the manuscript. TNM drafted the manuscript and revised the English language. BNM and AREK collected and analyzed the data. CSO and EJMM performed the statistical analysis. RLNMM and LCOE supervised the study and translated the manuscript into English. All authors reviewed and approved the final version of the manuscript.

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Figures

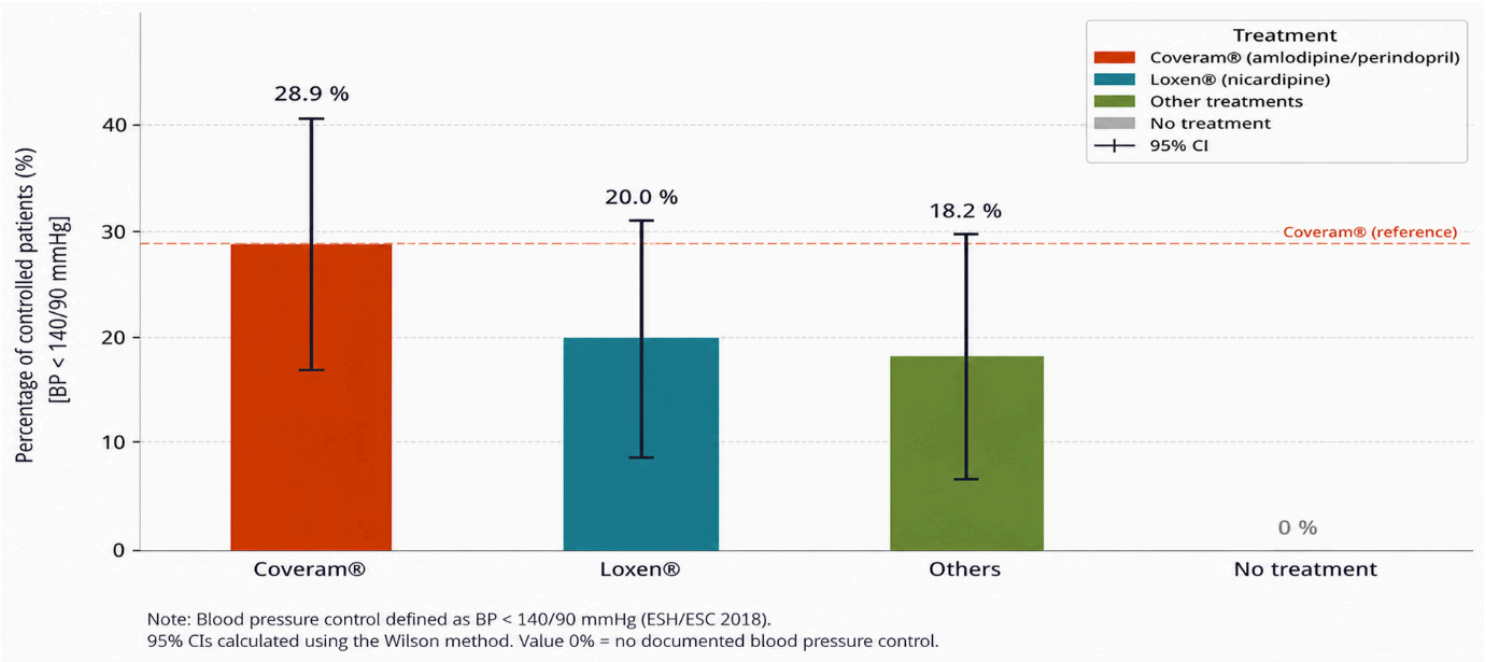


Figure 1

Distribution of blood pressure control according to main treatment type

Legend: Bar chart showing the proportion of patients with BP <140/90 mmHg according to treatment: Coveram® 28.9%, Loxen® 20.0%, Others 18.2%, No treatment 0%. Y-axis: Percentage of control (0-40%); X-axis: Type of treatment. Colored bars with 95% confidence intervals

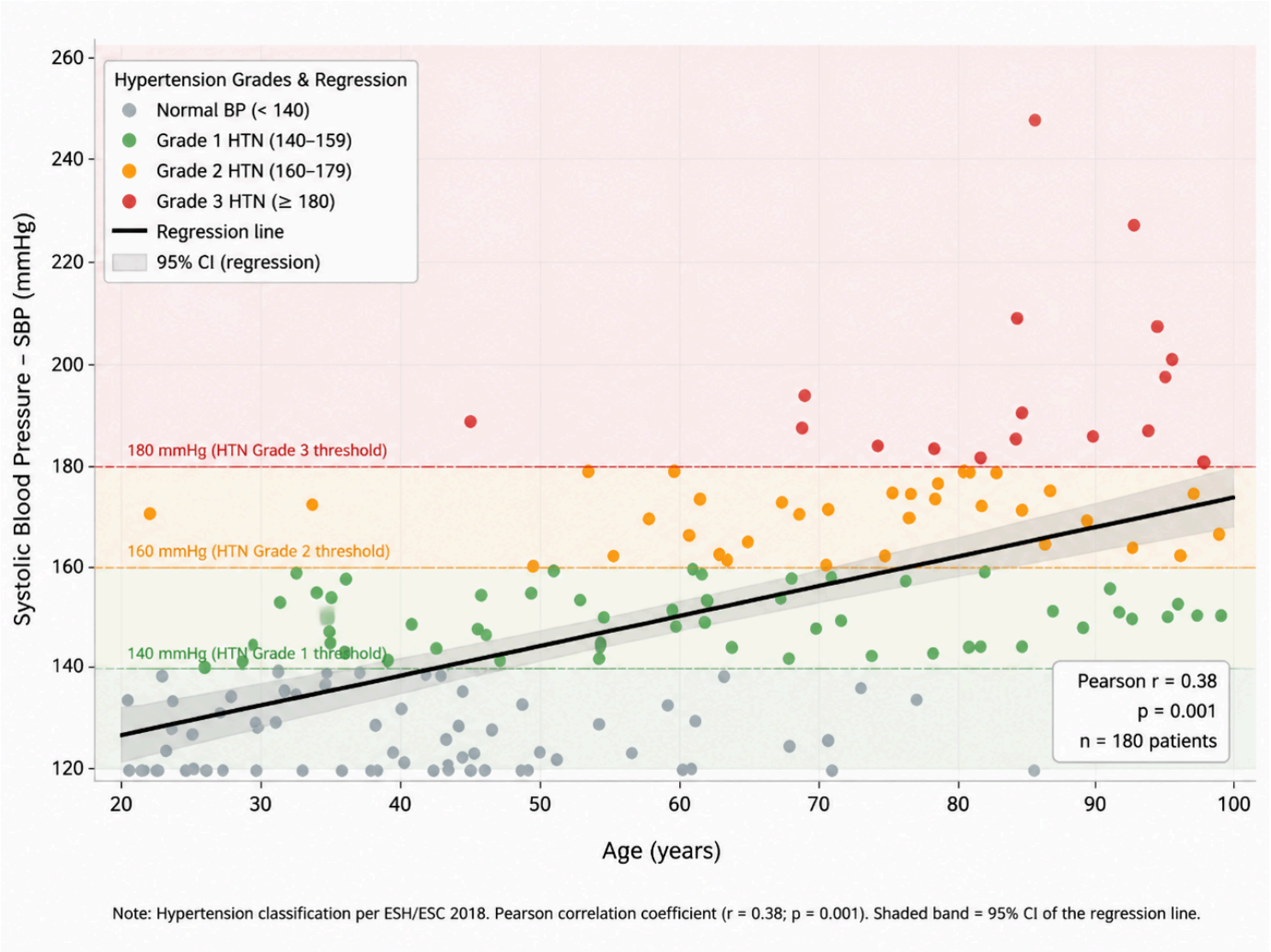


Figure 2

Correlation between age and systolic blood pressure: Scatter plot with linear regression line

Legend: X-axis: Age (years, 20-100); Y-axis: SBP (mmHg, 120-260). Pearson coefficient displayed in legend (r = 0.38; p = 0.001). Points colored according to HTN grade: green = grade 1, orange = grade 2, red = grade 3.

Coded interpretation in the figure

The positive slope of the regression line confirms the moderate positive correlation (r = 0.38) between age and SBP. The increasing density of orange points (severity grade 2) and red points (severity grade 3) with age illustrates the progression towards severe HTN grades. The 95% CI widens at the extremes (20 years and > 80 years), reflecting the increased variability of SBP in underrepresented age groups and the lower local precision of the regression model.

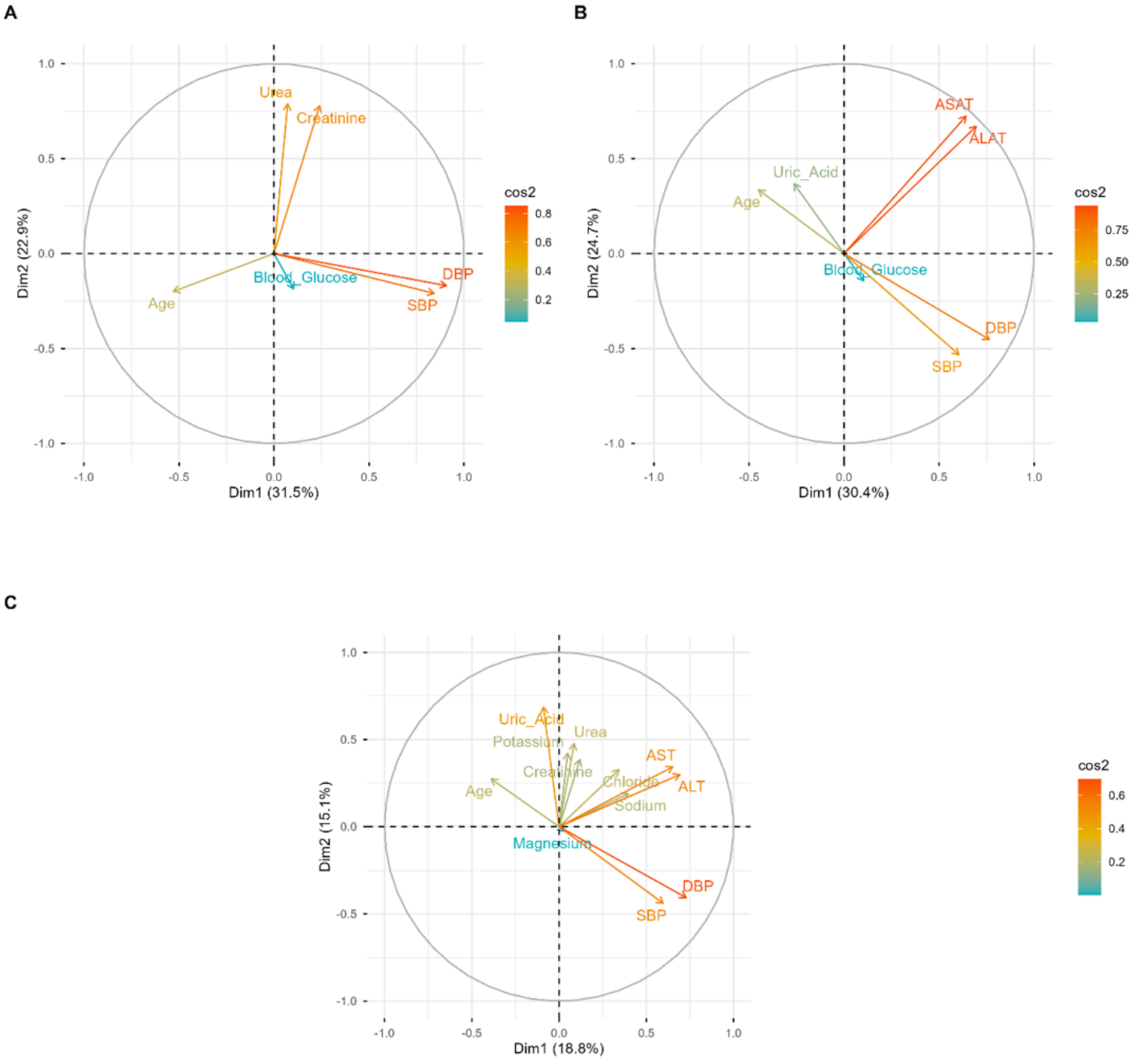


Figure 3

Correlation circles (PCA) of biological and blood pressure parameters in hypertensive patients

Legend: Correlation circle biplots representing the relationships between biological parameters and blood pressure values according to three distinct principal component analyses (PCA). (A) Cardio-renal PCA: correlations between creatinine, urea, glycemia, age, and systolic (SBP) and diastolic (DBP) blood pressures — Dim1: 31.8%; Dim2: 12.8%. (B) Hepato-metabolic PCA: correlations between AST, ALT, uric acid, glycemia, age, SBP, and DBP — Dim1: 31.4%; Dim2: 14.5%. (C) Global PCA (hepatic, renal, and

hydroelectrolytic): integration of all parameters (AST, ALT, creatinine, urea, uric acid, sodium, potassium, calcium, chloride, magnesium, SBP, DBP, age).

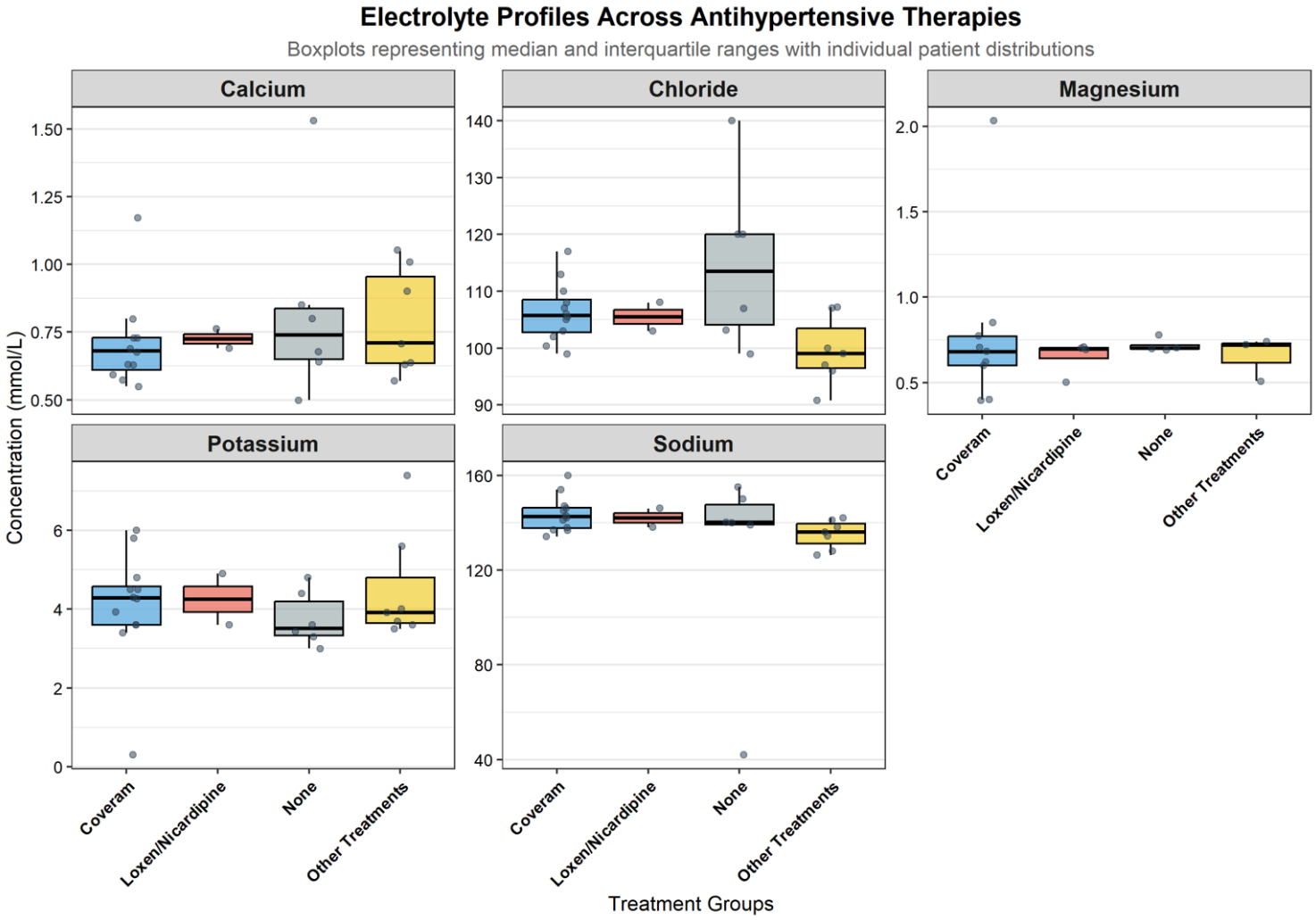


Figure 4

Electrolytic profiles (calcium, chloride, magnesium, potassium, sodium) according to main antihypertensive treatment

Legend: Box plots representing the median and interquartile ranges of serum concentrations of calcium, chloride, magnesium, potassium, and sodium (mmol/L), according to four therapeutic groups: Coveram, Loxen/Nicardipine, absence of treatment (None), and other antihypertensive treatments. Points correspond to individual patient values. Asterisks indicate outlier values



Figure 5

Multiple Correspondence Analysis (MCA) between reported clinical symptoms and blood pressure grade

Legend: Multiple Correspondence Analysis (MCA) illustrating the associations between clinical symptoms (headaches, dizziness, epistaxis, visual disturbances, dyspnea, fatigue) and blood pressure grades (normal, high normal, grades 1, 2, and 3). The first two factorial axes explain 31.3% (Dim1) and 10.2% (Dim2) of total inertia, respectively. The "Unknown" modalities correspond to missing or unreported data. The color of modalities reflects their quality of representation on the factorial plane (cos^2), with the highest values represented by orange to red hues.

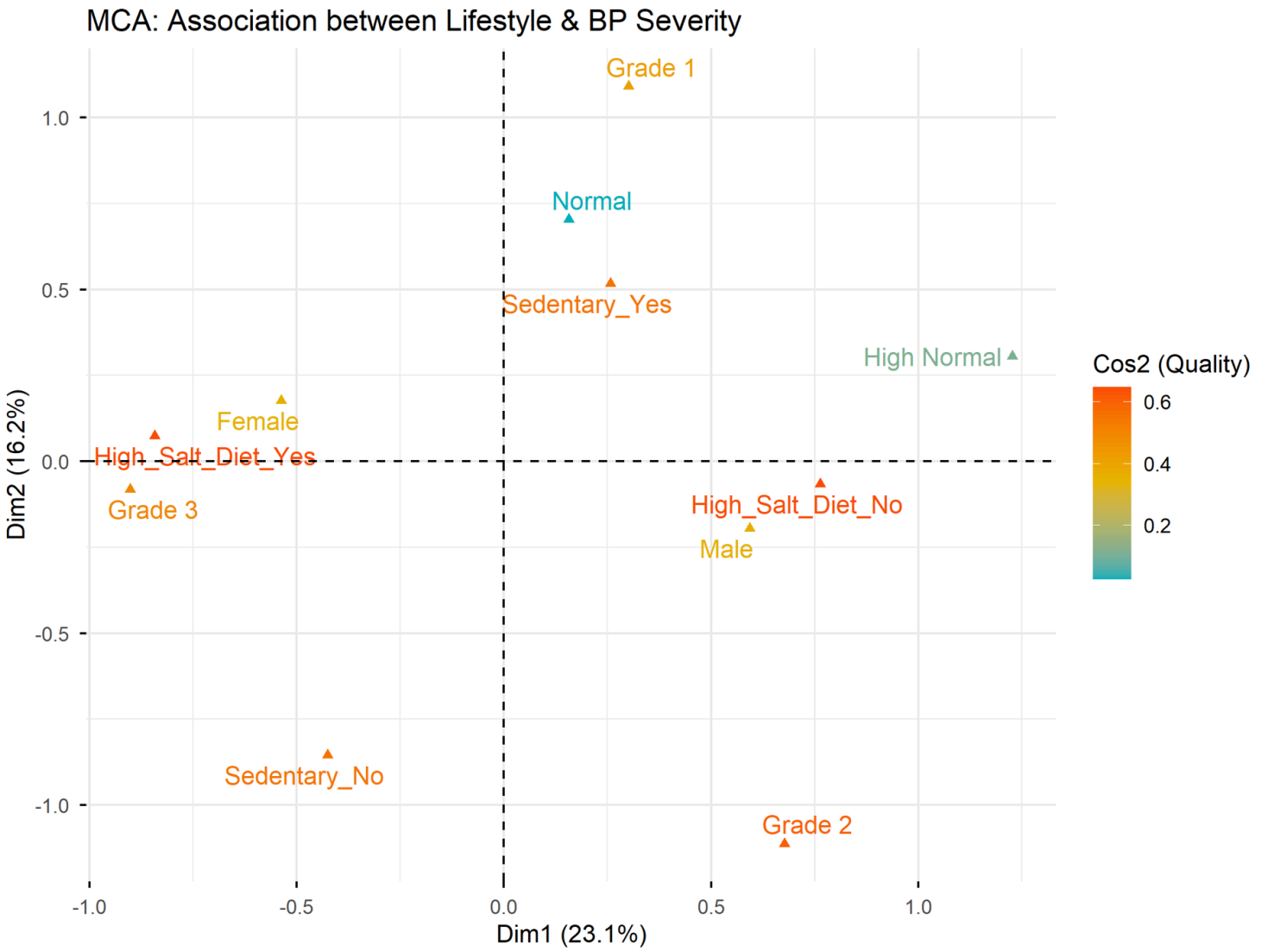


Figure 6

Multiple Correspondence Analysis (MCA) between lifestyle factors (sedentary behavior, salty diet), sex, and blood pressure severity

Legend: Graphical representation of factorial coordinates from a multiple component analysis (MCA), illustrating the associations between lifestyle modalities (sedentary behavior, high-sodium diet, sex) and blood pressure grades (Normal, High Normal, Grades 1, 2, and 3) according to the ESH/ESC classification. Dimension 1 (Dim1, 23.1%) and Dimension 2 (Dim2, 16.2%) represent the first two factorial axes. The quality of representation of variables is indicated by the color gradient (cos^2: from low in blue-green to high in orange-red).

Supplementary Files

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- TablemanuscriptOndoetal.2026.docx