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Blood Pressure and It's Association with Heavy Metal Exposure and Adiposity Indices Among Overweight and Obese Adults in Kaélé, Cameroon: A Cross-Sectional Study

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ABSTRACT

Introduction: Hypertension is a major public health challenge worldwide. In low- and middle-income countries, hypertension is rapidly increasing and contributes substantially to premature mortality. It is commonly associated with overweight and obesity. Growing evidence also indicates that environmental pollutants, particularly heavy metals, play a significant role in the development of cardiometabolic disorders, including hypertension.

Objective: To assess the relationship between adiposity indices and dietary intake of heavy metals (lead (Pb), Cadmium (Cd), and Manganese (Mn)) from commonly consumed foods (baobab leaves, cowpea, and corète), and the associated risk of elevated blood pressure (BP) in the Kaélé village in the Far North Region of Cameroon.

Methods: This three-month cross-sectional descriptive study was conducted among overweight and obese adults (≥18 years) residing in Kaélé, Far North Cameroon. Anthropometric measurements (height, weight, waist and hip circumferences) and BP were recorded. Cooked food samples were subsequently analyzed for heavy metal (Pb, Cd and Mn), using atomic absorption spectrophotometry.

Results: Based on body mass index (BMI), 57.32% were overweight and 42.68% obese. According to the Body Adiposity Index (BAI), 68.29% were overweight and 31.71% obese. The prevalence of hypertension was 46.34% of the study population. BMI was the only adiposity index that was able to predict the increase in blood pressure (BP) [for a one-unit increase in BMI, an increase of 1.61 mmHg in systolic blood pressure (SBP) and 1.45 mmHg in diastolic blood pressure (DBP) was observed; with a beta coefficient of B = 1.609; p = 0.002; 95% CI: 0.618 – 2.600 for SBP and B = 1.445; $p < 0.001$; 95% CI: 0.739 – 2.152 for DBP]. Total Cadmium (Cd) was the only predictor of hypertension in a polynomial regression model, where nonlinear relationships (quadratic and cubic) were observed. In the first regression, the quadratic and cubic models were found to be predictors of SBP with respective beta coefficients ($B = 7.04 \times 10^{-6}$; p = 0.003; 95% CI: 0.016 – 0.840) and ($B = 5.64 \times 10^{-9}$; p = 0.040; 95% CI: 0.000 – 0.000). Only the quadratic model was statistically significant with DBP ($B = 5.42 \times 10^{-6}$; p = 0.010; 95% CI: 0.000 – 0.000). A multiplicative interaction term between Cd and BMI (BMI × Cd_total) was used to evaluate the effect on BP, but the result was not statistically significant ($p > 0.05$).

Conclusion: The BMI was the only adiposity index found to be associated with the prevalence of hypertension. Regarding the different dietary heavy metal intakes, total Cd was the only predictor of BP in our study population.

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Introduction

Nowadays, High Blood Pressure (HBP) is one of the major public health problems due to its increasing prevalence worldwide [1]. From 1990 to 2019, the number of people reported to be hypertensive increased from 650 million to 1.3 billion; and it is projected that 1.59 billion people will be affected by 2030 [2-4]. Despite poor detection rates, recent global and regional reports consistently confirm the high and increasing prevalence of HBP in middle- and low-income countries, particularly in sub-Saharan Africa [5]. In Cameroon, with an estimated population of approximately 30 million, the prevalence of HBP is estimated at 30%. Epidemiological projections suggest a significant increase in this prevalence, possibly reaching 40% by 2030 if current trends continue [6]. This cardiometabolic disorder is a major cause of death worldwide and is thought to be linked to dietary factors, a sedentary lifestyle, aging, and a high Body Mass Index (BMI) [7]. Adiposity is a major risk factor in the development of many diseases, including hypertension [8]. A study using magnetic resonance imaging (MRI) conducted on an overweight and obese population showed that a high BMI, and more particularly a high body fat index, is associated with an increased risk of developing hypertension [9]. Another cyclical epidemiological study (between 2003 and 2018) demonstrated a non-linear positive association between the adiposity index and the risk of HBP occurrence among American adults [10]. Beyond these traditional risk factors, new studies are trying to highlight the existence of a link between environmental factors (Heavy Metals) and increased Blood Pressure (BP).

In 2022, a systematic review on the role of environmental toxicants in the development of hypertensive and cardiovascular diseases highlighted the existence of a causal link between heavy metals (Arsenic, Mercury, Cadmium, and Lead) and hypertension [7]. A prospective cohort study conducted in China in the local area of the Yangtze River was able, using a Bayesian kernel regression analysis, to establish a link between certain heavy metals (Cadmium, Cd; Copper, Cu; Lithium, Li; Magnesium, Mg; Molybdenum, Mo; and Zinc, Zn) and hypertension [11]. Another study on air pollution was able to highlight the involvement of Cadmium (Cd) and Lead (Pb) in the risk of increased BP, with a higher risk in men compared to women [12]. The biochemical mechanisms by which this risk factors modulate BP remain poorly understood. However, some hypotheses suggest that they promote the production of peroxynitrite, while inflammatory mediators intensify oxidative stress, increase the synthesis of vasoconstrictor prostaglandins, and reduce vasodilator prostaglandins [13-15].

In our daily lives, we coexist with various metals in almost all environments (soil, drinking water, air, food, and medicines) [16]. It is in this perspective that a cross-sectional study was conducted in 2021 in Bihar, India, to evaluate the effect of exposure to Arsenic (As) from certain foods (rice, wheat, drinking water, and potatoes) on the risk of developing hypertension. Except for a slightly significant positive relationship between Asernic (As) intake from rice and changes in low-density lipoprotein (LDL) levels, no significant association was identified between as intake and the risk of hypertension [17]. To date, few studies have examined exposure to heavy metals from food and the risk of developing hypertension [18]. This study examined the relationship between hypertension and both adiposity indices (Body Adiposity Index [BAI], Body Mass Index [BMI], and Waist-to-Hip Ratio [WHR]) and the daily intake of heavy metals (Cadmium [Cd], Lead [Pb], and Manganese [Mn]) from three commonly consumed cooked leafy vegetables (baobab, cowpea, and koreta leaves), and further assessed their combined effect on hypertension in the Kaélé village in the Far North Region of Cameroon.

Materials and Methods

Study Area and Target Population

This prospective descriptive cross-sectional study was carried out in the Kaélé village in the Far North Region of Cameroon for 3 months (from December 2023 to February 2024). Kaélé is located in the Mayo kani division, in the Far North region of Cameroon, very close to the border with Chad. It is a hot and dry desert climate, with an average annual temperature of around 30°C.

The target population was the local indigents of the Kaélé village, whose main source of income is mainly based on agropastoral activities, including the cultivation of cotton, onions, rice, millet, and sorghum. Livestock farming and seasonal fishing, especially during river flooding in the rainy season, complete these activities. The selection of participants was conducted through simple random sampling, considering the socio-economic diversity of the community's inhabitants. To ensure balanced representation, the survey was conducted in three localities within the community, selected randomly with an informal stratification based on residents' socio-economic levels.

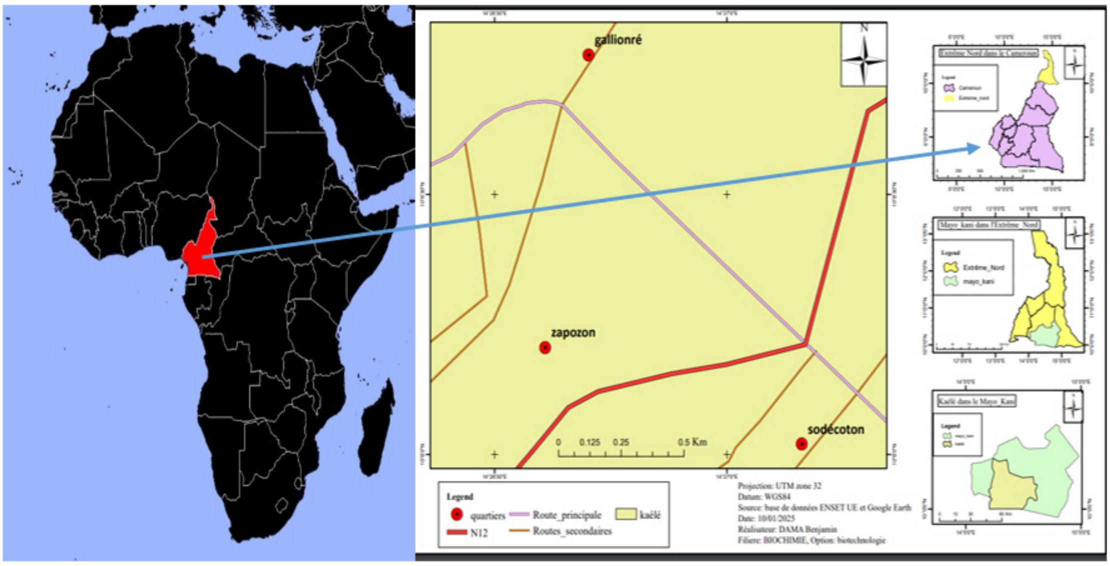

Figure1: Sampling locations are indicated by red dots on this map of *Kaélé*, Cameroon.

Inclusion and Exclusion Criteria

Eighty-two adults of both sexes, aged 18 years and over, were included in this study. Each represents a separate household. The target population included overweight or obese adults of Cameroonian nationality living in Kaélé and not a priori exposed to environmental heavy metals.

Participants with severe or chronic comorbidities other than hypertension (severe heart disease, cancer, kidney failure) that could significantly influence the results, e.g., pregnant or breastfeeding women, were excluded from this study. Participants who were unable to provide reliable information due to cognitive impairment or severe psychiatric disorders were excluded from the study. Participants with missing data were excluded from the analysis.

Ethical Aspects

The study was conducted as part of a large-scale project for which ethical clearance (reference No. 1905 CEI-Udo/05/2019/T) was secured from the Ethics Committee of the University of Douala, thus guaranteeing compliance with the ethical and regulatory principles in force for the conduct of this study.

Survey - Questionnaires

The questionnaire, inspired by the WHO Stepwise Approach to Surveillance (STEPS) instrument on metabolic diseases, was developed and translated into French. The questionnaire was pre-tested (to assess understanding of different questions). Primary data collection was conducted through face-to-face interviews. The adjusted nutritional survey questionnaire was administered to each participant. The field survey was carried out in two phases, conducted concurrently. The awareness-raising phase, during which the purpose of the study and the issues involved were presented to the participants; the data collection phase was carried out directly after the awareness-raising phase by administering the questionnaire to collect data on the sociodemographic characteristic (Age, gender, education level, income, occupation, family, situation, ethnic, religion and housing type), dietary habits (24-hours dietary recall, number of meal per day, drinking water source, 7-days food frequency, dietary counseling), and lifestyle of the participants (diet and nutrition, physical activity, substance use etc…) and then taking anthropometric parameters (weight, height, BMI, arm circumference) from participants who had given their agreement to take part in the study.

Sampling

Samples of respective dishes of baobab leaf mixed with cooked corn couscous (N = 27), cowpea leaves mixed with cooked corn couscous (N = 21) and coretes leaves mixed with cooked corn couscous (N = 24) were collected from selected households using polypropylene jars previously cleaned following the protocol described by Mondal et al and transported to the University of Maroua, where they were dried and sterilized in an oven [18]. The dried foods were transported to the Food, Food Security and Nutrition Research Center (CRASAN) of IMPM, where heavy metal concentrations were determined using atomic absorption spectrophotometry [23].

Determination of Levels of Heavy Metals in Dishes

The total daily intake of heavy metals (Cadmium [Cd], lead [Pb], and manganese [Mm]) from the different food items was estimated and expressed in µg/day. For each metal, the total intake was calculated as the sum of its concentrations across all consumed food items [16].

$$Cd\_total = \Sigma\, Cd_{xi}$$
$$Mn\_total = \Sigma\, Mn_{xi}$$
$$Pb\_total = \Sigma\, Pb_{xi}$$

Where Cd_{xi} Mn_{xi} and Pb_{xi} represent the concentrations of cadmium, manganese and lead respectively in each food item i. The intake of heavy metals (HM) from each individual food component was calculated using the following equation:

$$HMx = \left(\frac{IR}{100}\right) \times T - HM_x$$

Where *HMx* is the estimated intake of heavy metal from food item x (µg/day), *IR* is the daily intake rate of the food item (g/day), and $T\text{-}HM_X$ is the total concentration of the heavy metal in the food item (µg/kg). [18].

The daily intake of cadmium, lead, and manganese from food was previously determined according to the method described by Xu and colleagues [16]. The daily consumption amounts of baobab, cowpea, and corete leaves were estimated using 24-hour recorded data collected via the questionnaire administered by a qualified nurse [18].

Measurement of Blood Pressure

Blood pressure was measured using an OMRON radial electronic blood pressure monitor. The participant sat on a chair with their left arm positioned parallel to their heart. The monitor was placed on the wrist of their left arm and then slid down to the muscle approximately 3 cm from the elbow. After 1 minute of counting, the values of Systolic Blood Pressure (SBP), Diastolic Blood Pressure (DBP) expressed in mmHg, and resting heart rate expressed in beats per minute were displayed on the dial of the device and recorded. BP was measured twice at 10-minute intervals, and the lowest value of the systolic and diastolic measurements was retained to ensure an accurate assessment.

Hypertension was defined as either a self-reported diagnosis confirmed by a physician (verified by medical records from district or higher-level hospitals), or a systolic blood pressure (SBP) ≥ 140 mmHg and/or a diastolic blood pressure (DBP) ≥ 90 mmHg. In addition, the use of antihypertensive medication was considered a diagnostic criterion for hypertension. To adjust for treatment-related changes in blood pressure (BP), an increment of 10 mmHg was added for patients receiving antihypertensive medication [20].

Weight Measurement

This measurement was performed using a Tanburo CF470BT electronic scale. The lightly dressed participant steps onto the scale barefoot and places the soles of their feet on the metal parts of the scale. The subject's weight in kilograms (kg) is displayed directly on the screen with an accuracy of 0.1 kg.

Size Measurement

The height measuring instrument was a SECA vertical measuring rod. For height measurement, participants stood barefoot and together, with their backs, buttocks, calves, and heels against the anthropometry column. This device allows direct reading of the subject's height on the device's graduation with an accuracy of 0.1 cm.

Body Mass Index

The determination of body mass index was determined automatically by the Tanburo CF470BT electric scale by applying the following formula:

$$BMI\left(\frac{Kg}{m^2}\right) = \frac{Weight\ (Kg)}{Height^2}$$

BMI was divided into four categories according to WHO standards for adults: underweight (< 18.5 kg/m²), normal weight (≥ 18.5 kg/m² and < 24.9 kg/m²), overweight (≥ 25.0 kg/m² and 29.9 kg/m²), and obese (≥ 30.0 kg/m²). Central obesity was defined as a waist circumference ≥ 102 cm for men and ≥ 88 cm for women.

Measurement of Waist Circumference and Hip Circumference
Waist circumference (WC) and hip circumference (HC) were measured using a tailor's tape measure, respectively. The WC was measured midway between the enterosuperior iliac spine and was expressed in centimeters with an accuracy of 0.1 cm. For the HC, the subjects were always measured in a standing position with their feet together, and the tape was placed at the largest diameter of the hips.

Definition and Determination of the Body Adiposity Index
Body adiposity index was determined by relating hip circumference (cm) to height (cm) according to the following formula:

$$BAI = \frac{\text{Hip circumference (cm)}}{\text{Height (cm)}^{1.5}} - 18$$

Generally, Body Adiposity Index Classification for women is as follows: thinness: BAI < 21%, normal: 21 < BAI < 32%, overweight: 32 < BAI < 38%, obesity: BAI > 38%. On the other hand, in men, the BAI classification is thinness: BAI < 8%, normal: 8 < BAI <21%, overweight: 21 < BAI <25%, obesity: BAI > 25% (21, 22).

Ethics Statement
The study was a prospective, descriptive, cross-sectional survey. The survey protocol for this study was approved by the Ethics Committee of the University of Douala, Littoral region of Cameroon. All subjects gave their written informed consent to participate in the study. Furthermore, the study was conducted in full compliance with the Declaration of Helsinki.

Statistical Analysis
The data collected were entered into Excel software, and statistics were performed using the Statistical Package for the Social Sciences (SPSS) version 25 for Windows. A descriptive analysis was performed to differentiate between socio-demographic factors, lifestyle, and certain established or suspected risk factors for hypertension. These results were presented according to the data distribution as mean ± standard deviation for quantitative variables, median (interquartile range) for continuous variables, and percentage for categorical variables. The difference in means was assessed by Chi2 tests and Wilcoxon ranks according to the data distribution.

The relationship between the different indices (IAC, BMI, and WHR) and BP values (SBP and DBP) was analyzed using a multiple linear regression model. A comprehensive approach was adopted, based on a hierarchical forced entry method of variables. To limit the risk of committing a type II error and to optimize the detection of statistically significant associations, we favored a backward elimination strategy while maintaining the variables of interest in the final model.

Subsequently, we used a series of polynomial regressions of degrees 1, 2 and 3; and the most optimal model was chosen using a curve estimator, then we centered the means of all independent variables to reduce the effects of multi-collinearities, this to evaluate the association between dietary intake of heavy metals (Cd, Pb and Mn) and BP (SBP/DBP).

Finally, a multiplicative variable was created to assess the combined effect of adiposity and heavy metals on BP. Throughout these analyses, we considered as confounding variables such as age, sex, tribal origin, education level, smoking status, alcohol consumption, family history, as well as the use of antihypertensive drugs (24). For all these tests, a two-sided value of $p < 0.05$ was considered statistically significant.

Results

Basic Characteristics of the Population
The general study population was predominantly women (61%). Forty-six (46%) of the women were hypertensive, and 54% were normotensive. The average age of the overall population was 48.26 years for hypertensive patients and 39.61 years for non-hypertensive patients, with a minimum age of 19 years and a maximum age of 77 years. Most of the participants were married and had trading as their main occupation. The entire population lived in Kaélé, not all of them from the same tribe. Among the six ethnic groups comprising the study population, the Moundang were the largest group (42%), while the remaining ethnic groups accounted for 58%. Regarding the level of education, 42% of the population had a secondary education level.

Table 1: Socio-Demographic and Anthropometric Characteristics of the Population

Parameter	Hypertensive (n = 38)	Non-hypertensive (n = 44)	p-value
Age (year)	48.26 ± 12.026	39.61 ± 12.068	
Sex (%)			0.938
Man	15(46.9)	17(53.1)	
Women	23(46.0)	27(54.0)	
Ethnicity (%)			0.780
Bamileke	3(27.3)	8(72.7)	
Kirdi	6(54.5)	5(45.5)	
Moundang	20(47.6)	22(52.4)	
Fulani	3(50.0)	3(50.0)	
Tikar	4(44.4)	5(55.6)	
Toupouri	2(66.7)	1(33.3)	
Education level (%)			0.617
Not in school	3(30.0)	7(70.0)	

Primary	13(52.0)	12(48.0)	
Secondary	19(45.2)	23(54.8)	
Superior	3(60.0)	2(40.0)	
Marital status (%)			0.626
Bachelor	7(35.0)	13(65.0)	
Married	24(52.2)	22(47.8)	
Divorce	5(45.5)	6(54.5)	
Widower	2(40.0)	3(60.0)	
Family background (%)			0.158
Yes	16(57.1)	12(42.9)	
No	22(40.7)	32(59.3)	
Under antihypertensive (%)			0.010*
Yes	27(100)	0(0.0)	
No	11(25)	33(75)	
Smoking status (%)			0.355
Smoking	6(60.0)	4(40.0)	
Non-smoker	32(44.4)	40(55.6)	
Alcohol consumption (%)			0.019*
Yes	18(36.0)	32(64.0)	
No	20(62.5)	12(37.5)	
SBP [mean (range)] (mmHg)	150.95 (112-211)	119.23 (81-138)	< 0.001*
DBP [mean (range)] (mmHg)	97.85 (72-129)	77.59 (59-88)	< 0.001*
BMI [mean (range)] (Kg/m2)	32.21 (25-46)	27.65 (25-38)	< 0.001*
BAI [mean (range)]	31.07 (21.19-41.31)	32.65 (21.19-41.31)	0.040*
WHR [mean (range)]	0.85 (0.58-1.46)	0.91 (0.71-1.14)	0.225

SBP: Systolic Blood Pressure; **DBP:** Diastolic Blood Pressure; **BMI:** Body Mass Index; **BAI:** Body Adiposity Index; **WHR:** Waist-to-Height Ratio. *: $p < 0.05$

Heavy Metal (Cd, Pb, and Mn) Contents in Different Food Matrices

Cadmium (Cd) and manganese (Mn) were detected in all sampled vegetable matrices, whereas lead (Pb) concentrations were consistently below the analytical detection limit in all food sources. Cd was present in 100% of samples across the three leafy vegetables, including cowpea leave (21/21), baobab leaves (27/27) and corete leaves (24/24). The concentration means of Cd were relatively consistent across matrices, ranging from 1332.85 µg/kg/day in cowpea leaves (median: 1305; range: 90-2520 µg/kg/day) to 1340 µg/kg/day in baobab leaves (mean: 1409 µg/kg/day; median: 1260; range: 90-3690 µg/kg/day). The overall mean dietary Cd intake across all sources was 1362.69 µg/kg/day (median: 1305; range: 90-3690 µg/kg/day).

Similarly, manganese was detected in all samples. Cowpea leaves exhibited the highest Mn concentrations (mean: 1787.14 µg/kg/day; median: 1710; range: 990-3150 µg/kg/day), followed by baobab leaves (mean: 1548.33 µg/kg/day; median: 1440; range: 315-2970 µg/kg/day) and coretes leaves (mean: 1449.37 µg/kg/day; median: 1215; range: 270-2790 µg/kg/day). The pooled Mn intake from all dietary sources reached a mean of 1593.49 µg/kg/day (median: 1593; range: 270-3150 µg/kg/day).

Table 2: Concentrations of Cadmium, Manganese, and Lead in the Different Food Matrices Sampled in Certain Households (n= 27)

Heavy metal	Vegetables	Frequency (%)	Mean (range)	Median
Pb (µg/kg/day)	Cowpea leaves	0/21 (0)	Nd	nd
	Baobab leaves	0/27 (0)	nd	nd
	Coretes leaves	0/24 (0)	nd	nd
Cd (µg/kg/day)	Cowpea leaves	21/21 (100)	1332.85 (90–2520)	1305
	Baobab leaves	27/27 (100)	1340 (90–2790)	1350
	Coretes leaves	24/24 (100)	1409 (90–3690)	1260
Mn (µg/kg/day)	Cowpea leaves	21/21 (100)	1787.14 (990–3150)	1710
	Baobab leaves	27/27 (100)	1548.33 (315–2970)	1440

	Coretes leaves	24/24 (100)	1449.37 (270–2790)	1215
Cd total (µg/kg/day)		72/72 (100)	1362.69 (90–3690)	1305
Mn total (µg/kg/day)		72/72 (100)	1593.49 (270–3150)	1593

Pb: Lead intake from each food source, µg/kg/day: microgram per kilogram per day; Cd: cadmium intake from each food source; Mn: Manganese intake from each food source; Cd total: intake of Cadmium from all dietary sources; Mn total: intake of manganese from all dietary sources; nd: not detectable.

Relationship Between Adiposity Indices and the Risk of Elevated Blood Pressure (SBP/DBP)

Considering the unstandadized linear regression model that integrated the following indices (BMI, BAI, and WHR), regarding SBP, only BMI was positively and significantly associated with an increase in SBP [B=1.609; p=0.002, 95% CI (0.618-2.60)]. This indicates that an increase of 1 kg/m^2 in BMI is associated with an average increase of 1.61 mmHg in SBP. BAI and WHR had a contribution in the expected direction but did not present a significant association with SBP ($p>0.05$). Along the same lines, we performed the same procedure with DBP, and the same trend was observed. Indeed, the data collected showed that, for a one-unit increase in BMI, an average increase of 1.445 mmHg in DBP was observed [B=1.445; $p < 0.001$, 95% CI (0.739-2.152)].

Table 3: Beta Coefficient (95% CI) of Multiple Linear Regression Between Systolic Blood Pressure and Indices (BMI, WHR, and BAI)

Variables	Beta coefficient (B)	95% CI	P value
Unstandardized B			
BMI	1,609	0.618 – 2.600	0.002
WHR	15,017	-22,580 – 52,77	0.427
BAI	0.405	-0.917 – 1.728	0.543
Standardized B			
BMI	1,445	0.739 – 2.152	< 0.001
WHR	7,710	-18.22 – 33.64	0.555
BAI	0.417	-0.488 – 1.320	0.361

BMI: Body mass index; WHR: Waist-to-height ratio; BAI: Body adiposity index; B: Beta coefficient, degree of change in the dependent variable for each unit change in the independent variable; CI: 95% confidence interval; p value: Cutoff point of the p value below which the null hypothesis will be rejected.

Relationship Between Metal (Cd and Mn) Intake from Food Sources (Baobab, Cowpea, and Corete) and the Risk of Increased Blood Pressure (SBP and DBP)

Having observed no significant linear relationship between the variables studied (Tables 3 and 5), we introduced centered polynomial terms (quadratic and cubic) to examine possible nonlinear relationships (Tables 3 and 4). No significant nonlinear association was found between individual cadmium (Cd) and manganese (Mn) intakes from the consumption of baobab, cowpea, and corete leaves. The only statistically significant association was observed with total Cd intake, which was found to be associated with both SBP and DBP. Regarding SBP, the quadratic term of total Cd had a significant coefficient [B=7.04×10-6; p=0.003; 95% CI (0.016-0.840)], as was the cubic term [B=5.64×10-9; p=0.044; 95% CI (0.000–0.000)], suggesting a non-linear relationship. For DBP, only the quadratic trend was significant [B=4.42×10-6; p=0.010: 95% CI (0.000-0.000)].

Table 4: Summary of Polynomial Regression between Heavy Metal (Cd and Mn) Intake and Systolic Blood Pressure (SBP)

Polynomials	Unstandardized Beta Coefficient	p-value	95% CI
Cd_baobab_centered	0.022	0.178	-0.011 – 0.056
Cd_ baobab_quadratic	1.09×10^{-5}	0.192	0.000 – 0.000
Cd_baobab_cubic	-2.15×10^{-8}	0.090	0.000 – 0.000
Cd_niebé_centered	0.003	0.875	-0.033 – 0.038
Cd_cowpea_quadratic	-3.09×10^{-6}	0.796	0.000 – 0.000
Cd_cowpea_cubic	1.85×10^{-9}	0.912	0.000 – 0.000
	0.417	-0.488 – 1.320	0.361
Cd_total_centered	0.013	0.044	-0.025 – 0.000
Cd_total_quadratic	7.04×10^{-6}	0.003	0.016 – 0.084
Cd_total_cubic	5.64×10^{-9}	0.0036	0.000 – 0.000
Mn_baobab_centered	0.006	0.718	-0.028 – 0.028

Mn_ baobab_quadratic	-1.10×10^{-5}	0.314	0.000 – 0.000
Mn_baobab_cubic	-9.14×10^{-9}	0.472	0.000 – 0.000
Mn_niebé_centered	-0.007	0.609	-0.034 – 0.021
Mn_ quadratic cowpea	-7.95×10^{-6}	0.545	0.000 – 0.000
Mn_cowpea_cubic	3.55×10^{-8}	0.059	0.000 – 0.000
Mn_corete_centered	-0.016	0.311	-0.048 – 0.017
Mn_ baobab_quadratic	-3.86×10^{-6}	0.680	0.000 – 0.000
Mn_baobab_cubic	-1.09×10^{-8}	0.416	0.000 – 0.000
Mn_total_centered	0.08	0.320	-0.008 – 0.023
Mn_total_quadratic	4.48×10^{-7}	0.932	0.000 – 0.000
Mn_total_cubic	-9.48×10^{-9}	0.135	0.000 – 0.000

Cd: Cadmium; Mn: Manganese

Table 5. Summary of Polynomial Regression between Heavy Metal Intakes (CD and Mn) and Diastolic Blood Pressure

Polynomials	Unstandardized Beta Coefficient	p-value	95% CI
Cd_baobab_centered	0.002	0.867	0.022 – 0.026
Cd_ baobab_quadratic	6.15×10^{-6}	0.298	0.000 – 0.000
Cd_baobab_cubic	-4.57×10^{-9}	0.606	0.000 – 0.000
Cd_niebé_centered	-0.007	0.663	-0.042 – 0.028
Cd_cowpea_quadratic	-4.11×10^{-6}	0.723	0.000 – 0.000
Cd_cowpea_cubic	5.33×10^{-9}	0.736	0.000 – 0.000
Cd_total_centered	-0.001	0.905	-0.010 – 0.009
Cd_total_quadratic	4.21×10^{-6}	0.020	0.000 – 0.000
Cd_total_cubic	1.00×10^{-9}	0.628	0.000 – 0.000
Mn_baobab_centered	0.001	0.975	-0.025 – 0.026
Mn_ baobab_quadratic	1.51×10^{-6}	0.849	0.000 – 0.000
Mn_baobab_cubic	-1.54×10^{-9}	0.869	0.000 – 0.000
Mn_niebé_centered	-0.011	0.425	-0.041 – 0.019
Mn_ baobab_quadratic	-1.53×10^{-5}	0.290	0.000 – 0.000
Mn_baobab_cubic	3.77×10^{-8}	0.053	0.000 – 0.000
Mn_corete_centered	-0.003	0.796	-0.041 – 0.019
Mn_ baobab_quadratic	-1.4×10^{-6}	0.849	0.000 – 0.000
Mn_baobab_cubic	-2.74×10^{-9}	0.805	0.000 – 0.000
Mn_total_centered	0.006	0.286	-0.005 - 0.017
Mn_total_quadratic	0.84×10^{-6}	0.076	0.000 – 0.000
Mn_total_cubic	-7.45×10^{-9}	0.104	0.000 – 0.000

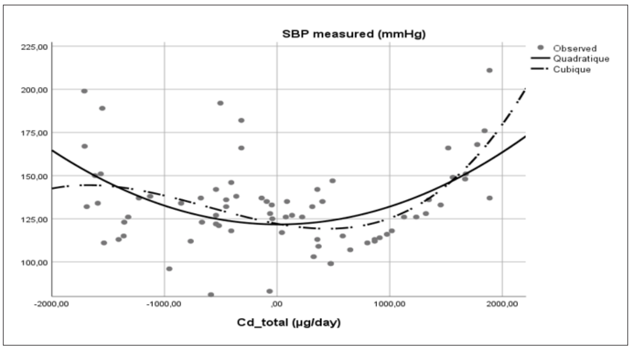

Figure 2: Curve for Estimating Total Cadmium Intake and Systolic Blood Pressure

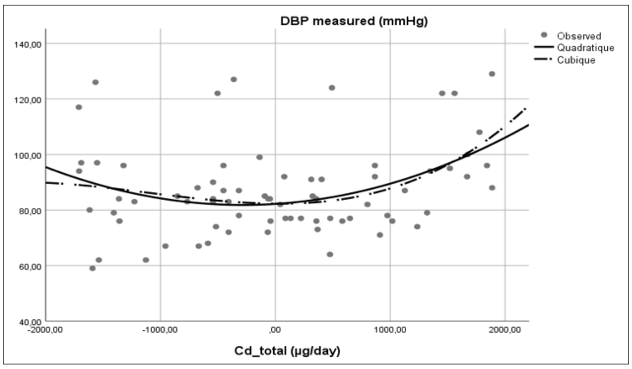

Figure 3: Curve for Estimating Total Cadmium Intake and Diastolic Blood Pressure

Discussion

Of the 72 participants (men 39.5% and women 60.5%) in this study, 38 (46.3%) were hypertensive. However, there were no statistical differences. It was found that women were only 1.036 times more likely to be hypertensive compared to men, with a 95% confidence interval [0.426; 2.521] and a p of 1.00. These results are contrary to those of Zangiabadian et al. [25]. This could be explained by the choice of our target population, which focuses specifically on overweight and obese people. Likewise, the prevalence of general hypertension measured was also slightly higher than that of Cameroon (estimated at 30%) among adults. This difference can be explained by both the specific characteristics of the study population and the sample size [26].

In our study population, the age ranged from 19 to 60 years with a mean age of 43.62 ± 12.73 years, and the most represented age group was 40 to 59 years, which is consistent with WHO statistics, which showed that hypertension, overweight, and obesity mainly affect adults in their most productive years. This observation may also be due to the participation of people in this age group in this study, as also found by Xu et al. [20]. However, all age groups are at risk of developing these chronic diseases [27].

The frequencies of the most relevant adiposity indices, and considering BMI, 57.32% of participants were overweight, 25.61% were moderately obese, 9.76% were severely obese, and 7.3% were morbidly obese. Overall, 42.68% were obese and 57.32% were overweight. According to the IAC, only 31.71% were obese, compared to 68.29% who were overweight. It was found that according to these results and according to the tool used to screen for obesity, a person in a condition of obesity according to the BMI can according to the BAI, be classified as overweight and this confirms the fact that because of the non-management of the distribution of body fat, the BMI is more general compared to the BAI which takes into account the distribution of body fat as well as the percentage of fat [28].

In a multiple linear regression model, adjusted for confounding variables (health and sociodemographic factors), only BMI showed a significant association ($p < 0.05$) with blood pressure (BP). The regression coefficient of BMI for SBP was B = 1.609 (95% CI: 0.618–2.600; p = 0.002), reflecting an increase of approximately 1.61 mmHg in SBP per unit of BMI. IAC and WHR were not significantly associated with SBP ($p < 0.05$). Regarding DBP, the same trend was observed with BMI (B = 1.445; 95% CI: 0.739–2.152; $p < 0.001$), i.e., 1.46 mmHg of DBP per BMI unit. BAI and WHR remained non-significant. These results are consistent with the literature; an excess weight of approximately 10 kg (approximately 3 BMI units), classically leads to an average increase of 3 mmHg in SBP and 2 mmHg in DBP [29, 30]. The predominance of BMI in our results highlights that it is the excess of overall fat rather than its distribution that determines BP in our study population. The IAC (based on hip circumference) and the WHR (abdominal obesity index) measure the distribution of fat mass, but were not predictors of BP. This is certainly due to the size of our sample and our target population. According to Ross et al., it is generally accepted that central obesity assessed by the TT is associated with an increased risk of cardiometabolic disorders, something which goes against our results obtained [31].

From an estimation curve, we set up a series of polynomial models to analyze the relationship between metal intakes (Cd and Mn) from food sources and BP, we were forced to note that the results obtained do not allow us to conclude a significant influence in the majority of cases. The results of polynomial regression analyses between dietary Cd intake, from cowpea, baobab leaves, and corete leaves, and SBP showed an absence of significant relationship in all polynomial models tested. The correlation coefficients (R) obtained indicate a moderate strength of relationship (with R varying from 0.658 to 0.774 for Cd intake from cowpea), but p-values greater than 0.05 show that these relationships are not statistically significant. These results are in line with the studies conducted by Yang et al. [32].

The adjusted models showed no substantial improvement. The adjusted R^2 values, oscillating around 0 0.1, confirm that these models explain little of the variance in BP. These results suggest that, although Cd is known for its adverse effects on cardiometabolic health, its dietary intake in this specific context does not appear to be a determining factor for the increase in BP in our population. In this case, our results are in contrast to those obtained by Dacunha et al., although their results were marginal [33]. However, analysis of total Cd intake from food reveals an interesting result.

Regarding PAS, the quadratic and cubic models were statistically significant with respective beta coefficients (B = 7.04 × 10-6, p = 0.003; 95% CI: 0.016 – 0.840), (B = 5.64 × 10-9; p = 0.040; 95% CI: 0.000 – 0.000). Regarding DBP, only the quadratic model was statistically significant with a beta coefficient of [B = 4.42 × 10-6; p = 0.010; 95% CI (0.000–0.000)]. Although the obtained beta coefficients were numerically reliable, their biological significance should not be underestimated. These low coefficients are most often due to the unit of measurement of Cd intake expressed in micrograms per kilogram (µg/kg) [17]. These results highlight that chronic exposure even to low concentrations can induce a cumulative adverse effect on BP regulation, especially in a vulnerable population such as overweight and obese people [18- 20]. The results of the analyses also showed generally non-significant relationships between dietary Mn intake and BP, whether for cowpea, baobab leaves, or coreta leaves. For example, for Mn from cowpea, the R values range from 0.66 to 0.71, but the p-values remain well above 0.05. These results suggest that dietary exposure to Mn through these specific sources has no measurable effect on BP. These results follow an opposite trend to that of Wu et al, who, in their study, found a statistically significant association of the effect of Mn on BP [29-35].

Conclusion

We aimed to assess the relationship between the adiposity index and heavy metals from foods (baobab, cortea, and cowpea leaves) on the increase in blood pressure in the town of Kaélé, Cameroon. Ultimately, in this present study, the prevalence of overweight and obesity among the participants was estimated at 57.32% and 42.68%, respectively, based on the body mass index (BMI). The measured general blood pressure revealed that 46.34% of the individuals presented a state of hypertension, while 53.66% were normotensive. BMI was found to be the only predictor of both systolic blood pressure (SBP) and diastolic blood pressure (DBP). In the same vein, exploration of polynomial models revealed that only total Cadmium presented a significant association with the elevation of blood pressure, despite the absence of non-linearity between the variables in question, suggesting a potentially toxic effect of this heavy metal. There was no link between the combined effect of heavy metals and adiposity indices on the risk of high blood pressure.

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