Atherosclerosis 342 (2022) 36–43

Contents lists available at ScienceDirect

Atherosclerosis

journal homepage: www.elsevier.com/locate/atherosclerosis

Serum potassium concentration and its association with hypertension among Ghanaian migrants and non-migrants: The RODAM study

Amie K. Ndong [a,1], Eva L. van der Linden [a,b,*,1], Erik J.A.J. Beune [a], Karlijn A.C. Meeks [a,c], Ina Danquah [d,e], Silver Bahendeka [f], Kerstin Klipstein-Grobusch [g,h], Matthias B. Schulze [e], Juliet Addo [i], Bert-Jan H. van den Born [a,b], Charles Agyemang [a]

[a] Department of Public & Occupational Health, Amsterdam UMC, University of Amsterdam, Amsterdam Public Health Research Institute, Amsterdam, the Netherlands
[b] Department of Internal Medicine, Amsterdam UMC, University of Amsterdam, Amsterdam Cardiovascular Sciences, Amsterdam, the Netherlands
[c] Center for Research on Genomics and Global Health, National Human Genome Research Institute, National Institutes of Health, Bethesda, MD, USA
[d] Institute for Social Medicine, Epidemiology and Health Economics, Charité Universitätsmedizin Berlin, Corporate Member of Freie Universität Berlin, Humboldt Universitaet zu Berlin, and Berlin Institute of Health, Berlin, Germany
[e] Department of Molecular Epidemiology, German Institute of Human Nutrition Potsdam-Rehbrücke, Nuthetal, Germany
[f] MKPGMS-Uganda Martyrs University, Kampala, Uganda
[g] Julius Global Health, Julius Center for Health Sciences and Primary Care, University Medical Center Utrecht, Utrecht University, the Netherlands
[h] Division of Epidemiology and Biostatistics, School of Public Health, Faculty of Health Sciences, University of the Witwatersrand, Johannesburg, South Africa
[i] Department of Non-communicable Disease Epidemiology, London School of Hygiene and Tropical Medicine, London, United Kingdom

ARTICLE INFO

Keywords:
Serum potassium
Hypertension
Blood pressure
Sub-Sahara Africa
Europe
Ghana
Migration
Research on Obesity and diabetes among African migrants study

ABSTRACT

Background and aims: Low serum potassium concentration is associated with hypertension, but whether the same association can be found in African origin populations, is unknown. We assessed serum potassium concentration, and its association with hypertension among Ghanaians living in different geographical locations.

Methods: Baseline data of 962 rural, 1420 urban, and 2947 migrant Ghanaians from the Research on Obesity and Diabetes among African Migrants study were analysed. Mean serum potassium concentration was compared between the groups, and the association between serum potassium and hypertension was assessed using multivariate regression analyses.

Results: Mean serum potassium concentration was higher in rural Ghana (4.28, 95% confidence interval 4.25–4.32 mmol/L) than in Ghanaians living in Amsterdam (3.90, 3.88–3.92 mmol/L) and London (4.11, 4.07–4.14 mmol/L), but lower than in Ghanaians living in urban Ghana (4.38, 4.34–4.42 mmol/L) and Berlin (4.57, 4.51–4.62 mmol/L) in both sexes. In the age-adjusted analyses, serum potassium was associated with hypertension in urban- (odds ratio 0.44, 0.23–0.82), London- (0.34, 0.17–0.64) and Amsterdam-Ghanaian males (0.41, 0.20–0.86), and in rural- (0.49, 0.28–0.84), London- (0.29, 0.17–0.49) and Amsterdam-Ghanaian females (0.33, 0.17–0.64). However, after adjustment for demographic, lifestyle, and health factors, serum potassium was associated with hypertension in Amsterdam-Ghanaian males only (0.12, 0.02–0.59).

Conclusions: This study shows differences in mean serum potassium among Ghanaian populations living in different locations in Europe and Ghana, and different associations with hypertension between sites. Further research should focus on elucidating the mechanism underlying potassium handling and blood pressure regulation in African populations, in order to mitigate the burden of hypertension among these populations.

1. Introduction

Hypertension is the leading risk factor for cardiovascular diseases (CVDs) [1], and globally the highest blood pressure (BP) levels have shifted from high-income countries to low-income countries in South Asia and sub-Saharan Africa (SSA) [2]. In SSA, the prevalence of

* Corresponding author. Department of Public & Occupational Health, Amsterdam UMC, University of Amsterdam, Meibergdreef 9, 1105 AZ Amsterdam, the Netherlands.
E-mail address: e.l.vanderlinden@amsterdamumc.nl (E.L. van der Linden).
[1] These authors contributed equally to this work.

https://doi.org/10.1016/j.atherosclerosis.2021.12.006
Received 30 August 2021; Received in revised form 26 November 2021; Accepted 10 December 2021
Available online 12 December 2021

hypertension varies between countries, urban/rural locations, and sub-populations [3], with standardised prevalence rates of hypertension rising up to over thirty percent in countries such as Mali, Sierra Leone, and the Central African Republic [4]. These variations in hypertension prevalence among SSA populations are not only observed among those living in SSA but also outside SSA. The hypertension prevalence is higher in SSA migrants compared to their counterparts living in SSA [5,6] as well as compared to the European host populations [7–9]. Some studies have reported that hypertension occurs earlier, more severely, and is associated with more significant target-organ damage in African origin populations than in other populations [10–12]. However, explanations for the high prevalence of hypertension among African origin populations still need to be elucidated.

Low potassium intake may raise BP and increase the risk of CVD [13,14]. Low potassium intake would result in higher BP by serum potassium concentration mediated activation of sodium-chloride co-transporters in the kidney, hereby stimulating sodium and water retention and potassium excretion [15]. Moreover, low serum potassium concentration has been linked to salt-sensitivity and salt-sensitive hypertension by hyperaldosteronism [16,17]. However, regulatory mechanisms keep the serum potassium concentration within tight limits, and there is still little information about BP effects of differences within or near the normal serum potassium range [18,19]. Additionally, only a few studies have been published on the association between serum potassium and hypertension, and the results are inconsistent [20,21]. None of these studies were conducted in SSA populations, even though both salt-sensitivity and salt-sensitive hypertension are more prevalent among these populations [22]. This study, therefore, assessed serum potassium concentration and its independent association with BP and hypertension among Ghanaians living in rural and urban Ghana and their compatriots living in Germany, the United Kingdom, and the Netherlands. Additionally, the association between potassium intake and serum potassium, BP and hypertension was also studied.

2. Patients and methods

2.1. Study design and study population

Baseline data from the prospective, multi-centre Research on Obesity and Diabetes among African Migrants (RODAM) cohort study was used. Baseline data collection was conducted between 201 and 2015 in rural and urban Ghana and the European cities of Amsterdam, Berlin, and London. We only report a summary of the design and methodology of the RODAM study as it has been described elsewhere in detail [23]. In Ghana, the urban and rural recruitment sites were Kumasi and Obuasi, and 15 villages in the Ashanti region. Participants were randomly drawn from the 30 enumeration areas based on the 2010 census, and participants aged ≥25 years were included. In the European cities, the participants aged between 18 and 70 were randomly drawn from municipality registrations and member lists of Ghanaian organisations. The participation rates were 53% in Amsterdam, 68% in Berlin, 75% in London, 74% in urban Ghana, and 76% in rural Ghana. Almost all the participants in Europe were first-generation migrants (99%).

2.2. Measurements and definitions

In the RODAM study, standard operating procedures were applied across all study sites to ensure data collection standardisation. Questionnaires were used to obtain information on demographics, educational level, past medical history, health status, and lifestyle factors [23]. Smoking status was classified into current, former, and never smokers. Intake of potassium (mg/day), sodium (mg/day), total energy (kcal/day), and alcohol (grams/day) was estimated using standard portion sizes combined with intake frequencies based on a standardised Food Propensity Questionnaire (FPQ). This Ghana-specific FPQ was based on the European-FPQ adjusted to the Ghanaian diet and validated using 24 h dietary recalls. The usual food intake in grams per day was translated into energy and nutrient intake using the West African Food Composition [24]. The World Health Organisation STEPwise Approach to NCD Risk Factor Surveillance (WHO-STEPS) questionnaire was used to derive physical activity in metabolic equivalents (METs, hours/-week), which included physical activity at work, while commuting, and in leisure time [25].

Physical examination was performed using validated devices. Weight and height were measured in light clothing without shoes using SECA 877 weighing scales and SECA 217 portable stadiometers. Body mass index (BMI, kg/m^2) was calculated by dividing the weight in kilograms by the squared height in meters. Waist circumference (cm) and hip circumference (cm) were measured using measuring tape at the midpoint between the lower rib and the upper margin of the iliac crest and around the major trochanter, respectively. Waist-to-hip ratio (WHR) was calculated by dividing the waist by hip circumference. All anthropometric measurements were performed twice, and the average of the two measurements was used for analysis. BP was measured three times using a validated semi-automated device (Microlife WatchBP home) with appropriate cuffs in a sitting position after 5 min rest. The average of the last two BP readings was used for the analysis. Hypertension was defined as systolic BP (SBP) ≥ 140 mm Hg, and/or diastolic BP (DBP) ≥ 90 mm Hg, and/or the use of BP-lowering medication [26,27].

Overnight fasting venous blood samples were collected for biochemistry analysis. All blood samples were analysed in the same laboratory in Berlin to prevent inter-laboratory differences in results. Concentration of fasting plasma glucose (mmol/L) was measured using an enzymatic method (hexokinase). Diabetes mellitus (DM) was defined according to the self-reported diagnosis of DM, a fasting glucose level ≥7.0 mmol/l, and/or the use of glucose-lowering medication [28]. Heparin blood was centrifuged, and plasma was aliquoted directly after sample taking, thereby minimising the risk of haemolysis impacting potassium concentrations. Serum potassium and serum natrium concentrations were measured at the analyser ABX Pentra 400 (Horiba ABX SAS, Montpellier, France) by potentiometry using an ion-selective electrode with an associated reference solution, calibrators, and controls. Concentration of plasma creatinine (μmol/L) was determined by a kinetic colorimetric spectrophotometric isotope dilution mass spectrometry calibration method (Roche Diagnostics). Urinary creatinine concentration (mmol/L) was measured by a kinetic spectrophotometric method (Roche Diagnostics). Estimated glomerular filtration rate (eGFR) was calculated using CKD-EPI (Chronic Kidney Disease - Epidemiology Collaboration) creatinine equation. Chronic kidney disease was considered when eGFR ≤60 ml/min/1.73 m^2 [29].

2.3. Data analysis

For the RODAM study, 6385 individuals agreed to participate in the study for all sites. For our analysis, initial data was used from 5898 participants with complete data of physical examination and blood sample collection. After exclusion of participants aged <25 or >70 years, with missing serum potassium values, and the highest and lowest one percent of the serum potassium distribution (<3.3 or >5.5 mmol/L), 5328 participants were included in the analysis (Supplementary Fig. 1).

Data on categorical variables were presented by frequencies and percentages with corresponding 95% confidence intervals (CI). Continuous variables were either presented by mean and 95% CI for variables showing a normal distribution, or by the median and interquartile range (IQR) for variables showing a skewed distribution. To evaluate whether the mean serum potassium concentrations differed between the geographical locations, one-way ANOVA was used.

Multivariate linear regression analyses were performed to assess the associations between serum potassium and SBP and DBP, and results were presented as the beta coefficient (β) with corresponding 95% CI. Multivariate logistic regression analysis was used to assess the association between serum potassium concentration and hypertension. Results

were presented as odds ratios (OR) with corresponding 95% CIs. Correlation between potassium intake and serum potassium was assessed using Spearman's regression coefficient rho, because of skewed distribution of potassium intake. Association between log-transformed potassium intake and BP was assessed using linear regression analysis, whereas logistic regression was used to assess the association between (non-transformed) potassium intake and hypertension. The regression analyses were run in models including various covariates potentially

Table 1
Population characteristics.

Males	**Rural Ghana**	**Urban Ghana**	**London**	**Berlin**	**Amsterdam**
n	370	404	398	276	565
Age (mean (SD))	45.95 (12.73)	46.34 (11.93)	46.01 (10.88)	45.57 (10.91)	48.37 (9.41)
Education (n (%))					
Never been to school	92 (26.6)	50 (13.1)	6 (1.7)	6 (2.2)	25 (4.7)
Elementary schooling	47 (13.6)	40 (10.4)	10 (2.9)	12 (4.4)	91 (17.0)
Lower vocational schooling or lower secondary schooling	134 (38.7)	173 (45.2)	101 (29.4)	133 (48.4)	230 (42.9)
Intermediate vocational schooling or intermediate/higher secondary schooling	51 (14.7)	84 (21.9)	67 (19.5)	77 (28.0)	146 (27.2)
Higher vocational schooling or university	22 (6.4)	36 (9.4)	159 (46.4)	47 (17.1)	44 (8.2)
BMI (mean (SD))	20.97 (2.95)	24.09 (3.85)	27.45 (3.80)	26.35 (4.03)	27.01 (3.84)
WHR (mean (SD))	0.89 (0.06)	0.90 (0.06)	0.90 (0.07)	0.92 (0.07)	0.95 (0.06)
Physical activity, min/day (median[IQR])	6480 [3600, 11,130]	5280 [1680, 10,530]	1440 [0, 7200]	5760.00 [915, 12,000]	5700 [1110, 17,520]
Alcohol intake, mg/day (median [IQR])	0.59 [0.00, 3.46]	0.14 [0.00, 1.49]	0.73 [0.00, 2.09]	3.67 [0.00, 19.42]	2.70 [0.12, 9.18]
Current smoking, yes (n (%))	19 (5.5)	13 (3.4)	4 (1.1)	43 (15.6)	43 (8.4)
K intake, mg/day (median [IQR])	4791 [3732, 6266]	3993 [3336, 4724]	6405 [4114, 7960]	6071 [4052, 7873]	4822 [3737, 7048]
Na intake, mg/day (mean (SD))	2647 (1173)	3222 (1092)	3373 (1259)	3277 (1451)	2940.57 (1002)
Energy intake, kcal/day (mean (SD))	2950 (1432)	2443 (798)	3138 (1164)	3227 (1407)	2659.69 (1053)
Diabetes ((n %))	15 (4.1)	46 (11.4)	38 (9.5)	43 (15.6)	81 (14.3)
eGFR<60 ml/min (n (%))	11 (3.0)	19 (4.7)	8 (2.0)	7 (2.5)	16 (2.9)
Use of blood pressure lowering medication, incl. combinations (n (%))	15 (4.1)	23 (5.7)	87 (21.9)	78 (28.3)	149 (26.4)
ACE or ARB, yes (%)	10 (2.7)	11 (2.7)	34 (8.5)	56 (20.3)	72 (12.7)
Beta blocker, yes (%)	2 (0.5)	6 (1.5)	9 (2.3)	16 (5.8)	48 (8.5)
Calcium channel blocker, yes (%)	12 (3.2)	19 (4.7)	73 (18.3)	32 (11.6)	99 (17.5)
Diuretics, yes (%)	4 (1.1)	6 (1.5)	22 (5.5)	13 (4.7)	53 (9.4)
Antihypertensive medication, other class, yes (%)	0 (0.0)	0 (0.0)	5 (1.3)	3 (1.1)	6 (1.1)
SBP, mmHg (mean (SD))	123.73 (18.35)	130.86 (20.88)	136.66 (17.47)	138.90 (18.48)	137.94 (17.33)
DBP, mmHg (mean (SD))	77.19 (11.00)	82.20 (13.37)	84.72 (10.93)	88.72 (11.62)	87.72 (11.33)
Hypertension (n (%))	80 (21.6)	136 (33.7)	201 (50.5)	160 (58.0)	323 (57.2)
Females	**Rural Ghana**	**Urban Ghana**	**London**	**Berlin**	**Amsterdam**
n	592	1015	629	239	840
Age (mean (SD))	46.87 (12.56)	44.69 (11.21)	47.53 (10.49)	44.61 (9.26)	45.37 (8.61)
Education (n (%))					
Never been to school	284 (51.9)	349 (35.2)	30 (5.5)	2 (0.9)	109 (13.9)
Elementary schooling	81 (14.8)	164 (16.5)	35 (6.4)	25 (10.7)	234 (29.8)
Lower vocational schooling or lower secondary schooling	153 (28.0)	364 (36.7)	192 (35.2)	128 (54.7)	256 (32.7)
Intermediate vocational schooling or intermediate/higher secondary schooling	18 (3.3)	86 (8.7)	149 (27.3)	61 (26.1)	152 (19.4)
Higher vocational schooling or university	11 (2.0)	28 (2.8)	140 (25.6)	18 (7.7)	33 (4.2)
BMI (mean (SD))	23.73 (4.61)	27.98 (5.47)	30.86 (4.99)	29.16 (4.97)	30.18 (5.13)
WHR (mean (SD))	0.89 (0.07)	0.90 (0.06)	0.87 (0.09)	0.88 (0.06)	0.89 (0.07)
Physical activity, min/day (median [IQR])	4320 [1440, 8400]	2880 [160, 8880]	1200 [120, 5620]	3360 [410, 11520]	3840.00 [1200, 12240]
Alcohol intake, mg/day (median [IQR])	0.06 [0.00, 0.58]	0.06 [0.00, 0.58]	0.06 [0.00, 1.47]	1.05 [0.00, 2.92]	0.73 [0.00, 2.96]
Current smoking, yes (n (%))	0 (0.0)	1 (0.1)	1 (0.2)	7 (3.0)	14 (1.8)
K intake, mg/day (median [IQR])	4635 [3646, 6025]	3811 [3185, 4656]	5652 [3964, 7623]	6339 [4323, 7800]	4527 [3648, 6938]
Na intake, mg/day (mean (SD))	2628 (1061)	3116 (1147)	3153 (1226)	3456 (1447)	2886 (955)
Energy intake, kcal/day (mean (SD))	2814 (1254)	2292 (709)	2966 (1132)	3236 (1440)	2451 (940)
Diabetes ((n (%))	33 (5.6)	85 (8.4)	54 (8.6)	23 (9.6)	78 (9.3)
eGFR<60 ml/min (n (%))	26 (4.4)	33 (3.3)	18 (2.9)	2 (0.8)	24 (2.9)
Use of blood pressure lowering medication, incl. combinations (n (%))	54 (9.1)	123 (12.1)	181 (28.8)	78 (32.6)	234 (27.9)
ACE or ARB, yes (%)	21 (3.5)	50 (4.9)	73 (11.6)	52 (21.8)	93 (11.1)
Beta blocker, yes (%)	4 (0.7)	16 (1.6)	15 (2.4)	22 (9.2)	54 (6.4)
Calcium channel blocker, yes (%)	49 (8.3)	101 (10.0)	134 (21.3)	25 (10.5)	126 (15.0)
Diuretics, yes (%)	9 (1.5)	31 (3.1)	67 (10.7)	15 (6.3)	96 (11.4)
Antihypertensive medication, other class, yes (%)	3 (0.5)	8 (0.8)	15 (2.4)	1 (0.4)	5 (0.6)
SBP, mmHg (mean (SD))	123.96 (22.00)	124.67 (19.66)	134.38 (17.16)	131.94 (18.54)	131.19 (16.99)
DBP, mmHg (mean (SD))	77.18 (12.28)	78.31 (11.62)	82.34 (10.32)	83.69 (11.29)	81.64 (10.12)
Hypertension (n (%))	168 (28.4)	298 (29.4)	321 (51.0)	120 (50.2)	395 (47.0)

SD, standard deviation; IQR, interquartile range; BMI, body mass index; WHR, waist-hip-ratio; K, potassium; Na, sodium; eGFR, estimated glomerular filtration rate; ACE, angiotensin converting enzyme; ARB, angiotensin receptor blocker; SBP, systolic blood pressure; DBP, diastolic blood pressure.

impacting the associations. Covariates were chosen based on previously reported direct or indirect effects on potassium intake, serum potassium and/or BP. Collinearity between the covariates was tested using the R package 'car'. Multicollinearity was considered unlikely if the variation inflation factor was ≤2. Model 1 was adjusted for age; model 2 was adjusted for age and level of education; model 3 was adjusted for age, level of education, physical activity, smoking, alcohol consumption, potassium and sodium intake, BMI, and WHR; and model 4 was adjusted for model 3 plus DM, eGFR, and the use of any BP-lowering medication (use of ACE-inhibitors and ACE-receptor blockers, beta blockers, calcium antagonists, diuretics, or combination therapy). In model 4 we adjusted for the use of any BP-lowering medication, rather than for the drug classes separately, because this variable also included combination therapy, and the separate drug classess include relatively small numbers.

All analyses were stratified by sex and geographical location because of significant interaction between serum potassium and location and sex ($p < 0.05$).

Additionally, sensitivity analysis was performed running the regression analysis excluding n = 1022 participants with prescribed BP-lowering medication.

All analyses were performed using R software, version 4.0.3 (R Core Team (2020). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.)

2.4. Ethical considerations

This study was conducted following the Declaration of Helsinki. This study was approved by the respective medical ethical committees in Ghana (School of Medical Sciences/Komfo Anokye Teaching Hospital Committee on Human Research, Publication & Ethical Review Board), the Netherlands (Institutional Review Board of the AMC, University of Amsterdam), Germany (Ethics Committee of Charité-Universitätsmedizin Berlin) and the UK (London School of Hygiene and Tropical Medicine Research Ethics Committee). Consent of all participants of the RODAM study was obtained before enrollment in the study.

3. Results

3.1. Population characteristics

Population characteristics are presented in Table 1. Compared to the other study sites, mean age was highest in Amsterdam-Ghanaian males and London-Ghanaian females. Educational level was highest in London, where close to half of the male and a quarter of the female participants completed higher vocational training or university, whereas this was lowest in rural Ghana, where a half of the female and a quarter of the male participants had never been to school. BMI was lowest in rural Ghana and highest in Europe, especially among females, while WHR did not vary much between the locations. Physical activity showed a stepwise decrease from rural Ghana to urban Ghana and Europe. On average, Berlin-Ghanaians consumed more alcohol and smoked more than the other sites in both sexes. Daily dietary potassium and sodium intake were highest in Berlin and London. Energy intake was highest in Berlin, while energy intake was lowest in rural-Ghanaian males and urban-Ghanaian females. DM was most prevalent in Berlin, whereas reduced eGFR was most prevalent in rural Ghana. Use of BP-lowering medication was generally low with 46% of those with hypertension having been prescribed BP-lowering medication. Having prescribed BP-lowering medication was least prevalent in rural Ghana, followed by urban Ghana, and most prevalent in Berlin. SBP, DBP, and the prevalence of hypertension showed a stepwise increase from rural Ghana through urban to Europe in both sexes.

Mean serum potassium was highest in Berlin (4.57 mmol/L males, 4.48 mmol/L females), followed by urban Ghana (4.38 mmol/L males, 4.28 mmol/L females), rural Ghana (4.28 mmol/L males, 4.16 mmol/L females), London (4.11 mmol/L males, 4.11 mmol/L females), and Amsterdam (3.90 mmol/L males, 3.81 mmol/L females) in both males and females, with females tending to have a lower potassium concentration than males in rural Ghana, Berlin and Amsterdam (Fig. 1). Mean serum potassium levels did not change after exclusion of participants using BP-lowering medication.

3.2. Association between serum potassium and blood pressure

Fig. 2 (males) and Fig. 3 (females) show the association between serum potassium and SBP and DBP with adjustment for various covariates. The age-adjusted model (Model 1) showed an inverse association between serum potassium and SBP in urban- and London-Ghanaian males (Fig. 2A), and in rural- and London-Ghanaian females (Fig. 3A). In London-Ghanaians, this associaten attenuated after adjustment for lifestyle factors and BMI (model 3), whereas the associaten persisted in urban-Ghanaian males and rural-Ghanaians females in the fully adjusted model (model 4). Serum potassium was associated with DBP in urban-Ghanaian males (model 1, Fig. 2B), but this association disappeared after adjustment for lifestyle factors and BMI (model 3). For females, higher serum potassium was associated with lower DBP in rural-, London- and Amsterdam-Ghanaians, but only persisted in rural Ghana in the fully adjusted model (Fig. 3B).

Sensitivity analysis excluding participants with prescribed BP-lowering medication did not impact the findings (Supplementary Table 1).

3.3. Association between serum potassium and hypertension

Fig. 4 displays the association between mean serum potassium and hypertension, stratified by geographical location and sex. The age-adjusted model (Model 1) showed an inverse association in urban-, London-, and Amsterdam-Ghanaian males (Fig. 4A), while in females, this inverse association was present in rural-, London-, Amsterdam-Ghanaians (Fig. 4B). After adjustment for all covariates, the inverse association remained only in Amsterdam-Ghanaian males.

Excluding participants with prescribed BP-lowering medication did not impact the results (Supplementary Table 1).

3.4. Association between potassium intake and serum potassium, blood pressure and hypertension

Potassium intake showed a weak negative correlation with serum potassium concentration in rural-Ghanaian females (rho −0.10, $p = 0.01$), and a weak positive correlation in Berlin-Ghanaian males (rho 0.15, $p = 0.01$). Log-transformed potassium intake was no associated with either SBP or DBP in linear regression analyses (Supplementary Table 2), nor was potassium intake with hypertension in model 1–4 in logistic regression analysis (Supplementary Table 3).

4. Discussion

4.1. Key findings

Mean serum potassium concentration differed between geographical locations and sex with highest concentration among Berlin-Ghanaian males and lowest among Amsterdam-Ghanaian females. There was a negative association between serum potassium concentration and SBP in urban- and London-Ghanaian males and in rural- and London-Ghanaian females. For DBP, a negative association with serum potassium concentration could be observed in urban-Ghanaian males and rural-, London- and Amsterdam-Ghanaian females. In rural-Ghanaian females, urban-Ghanaian males, and London- and Amsterdam-Ghanaian males and females, a negative association between serum potassium concentration and hypertension could be observed. However, these associations were largely explained by lifestyle factors and BMI and only persisted in urban-Ghanaian males (SBP), rural-Ghanaian females (SBP

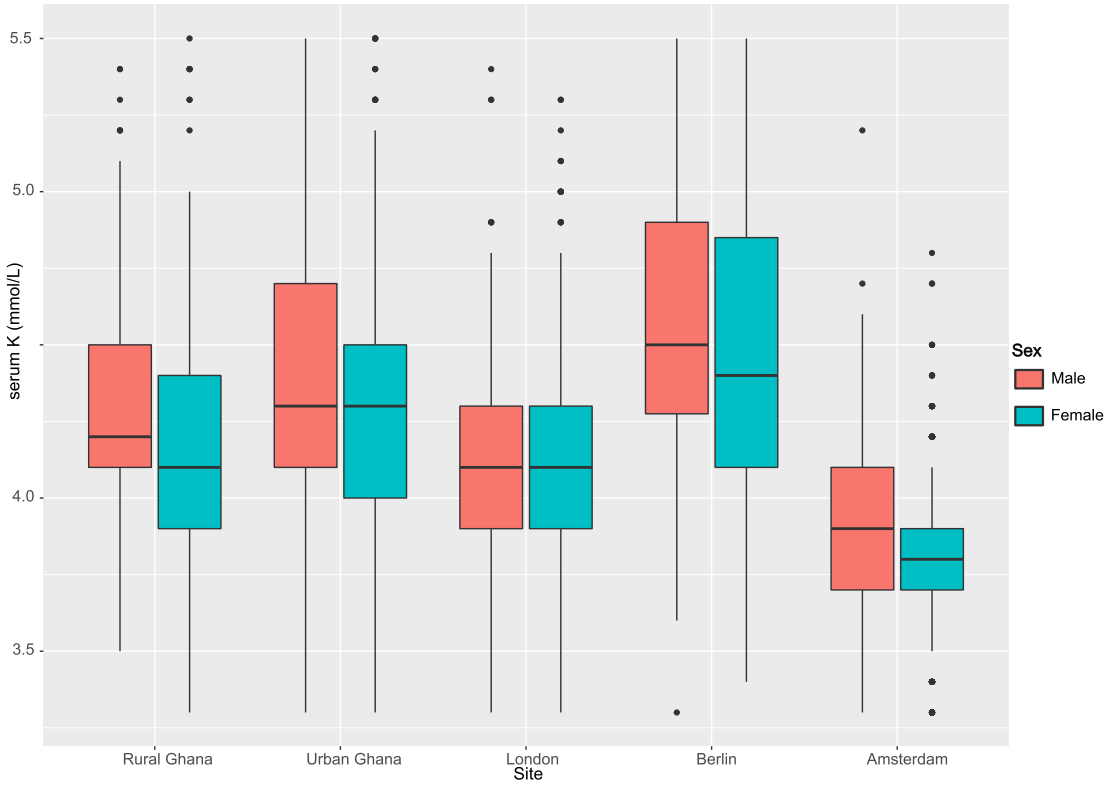

Fig. 1. Boxplot of serum potassium concentration by geographical location and sex.

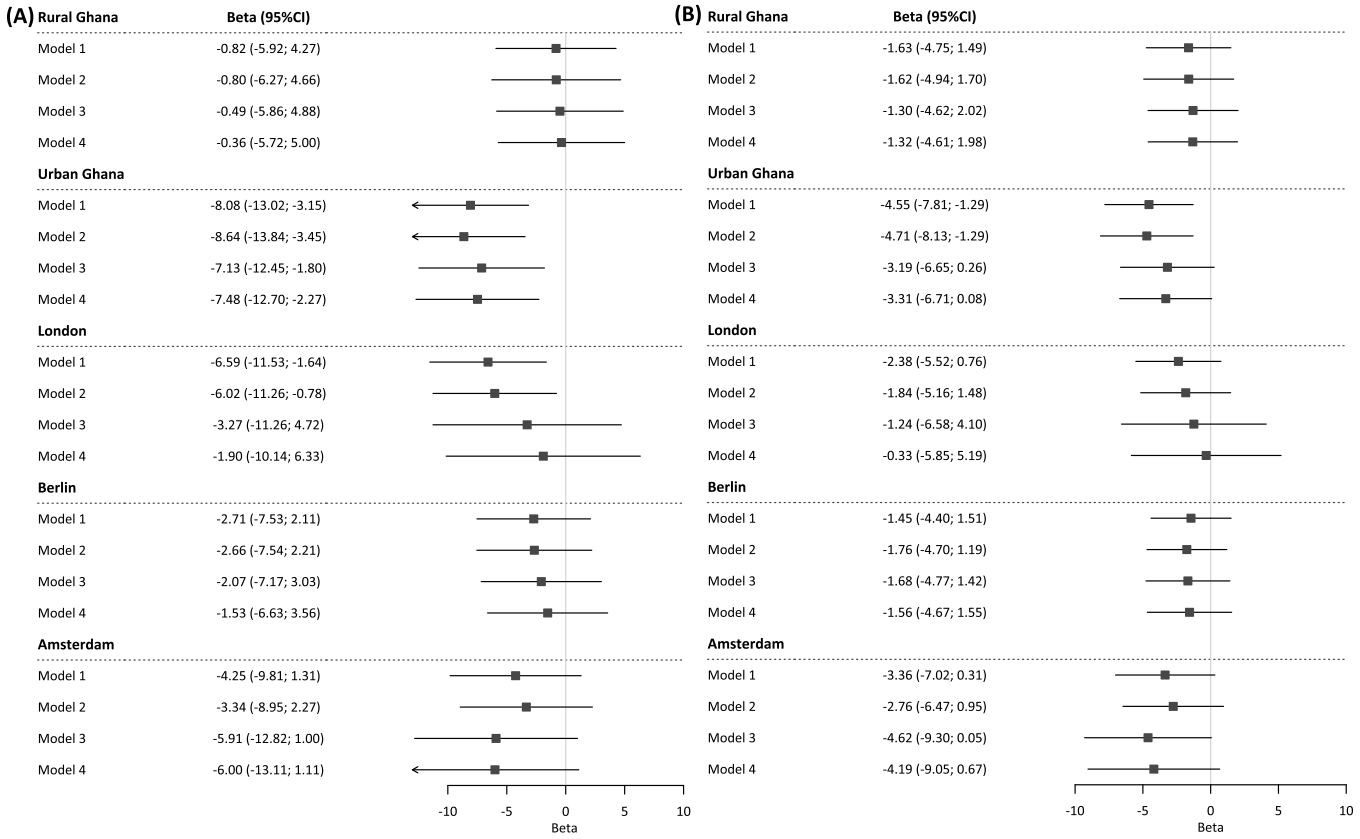

Fig. 2. Association between serum potassium concentration and systolic (A) and diastolic (B) blood pressure, per geographical location in males.
CI, confidence interval; Model 1 adjusted for age; Model 2 adjusted for age and education; Model 3 adjusted for age, education, physical activity, smoking, alcohol intake, sodium intake, potassium intake, body mass index and waist-hip-ratio; Model 4 adjusted for model 3 plus diabetes mellitus, eGFR<60 and blood pressure lowering medication.

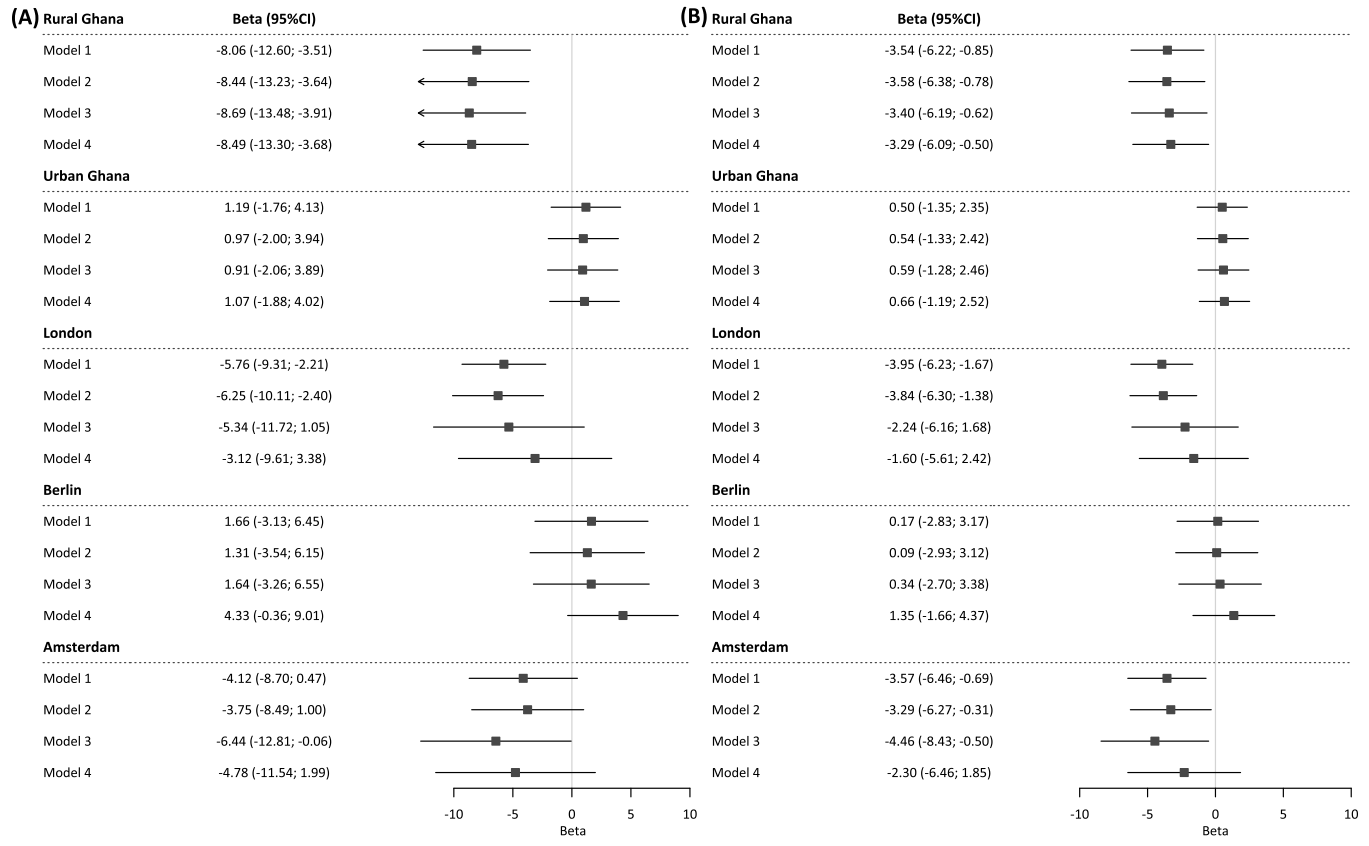

Fig. 3. Association between serum potassium concentration and systolic (A) and diastolic (B) blood pressure, per geographical location in females.
Model 1 adjusted for age; Model 2 adjusted for age and education; Model 3 adjusted for age, education, physical activity, smoking, alcohol intake, sodium intake, potassium intake, body mass index and waist-hip-ratio; Model 4 adjusted for model 3 plus diabetes mellitus, eGFR<60 and blood pressure lowering medication; CI, confidence interval.

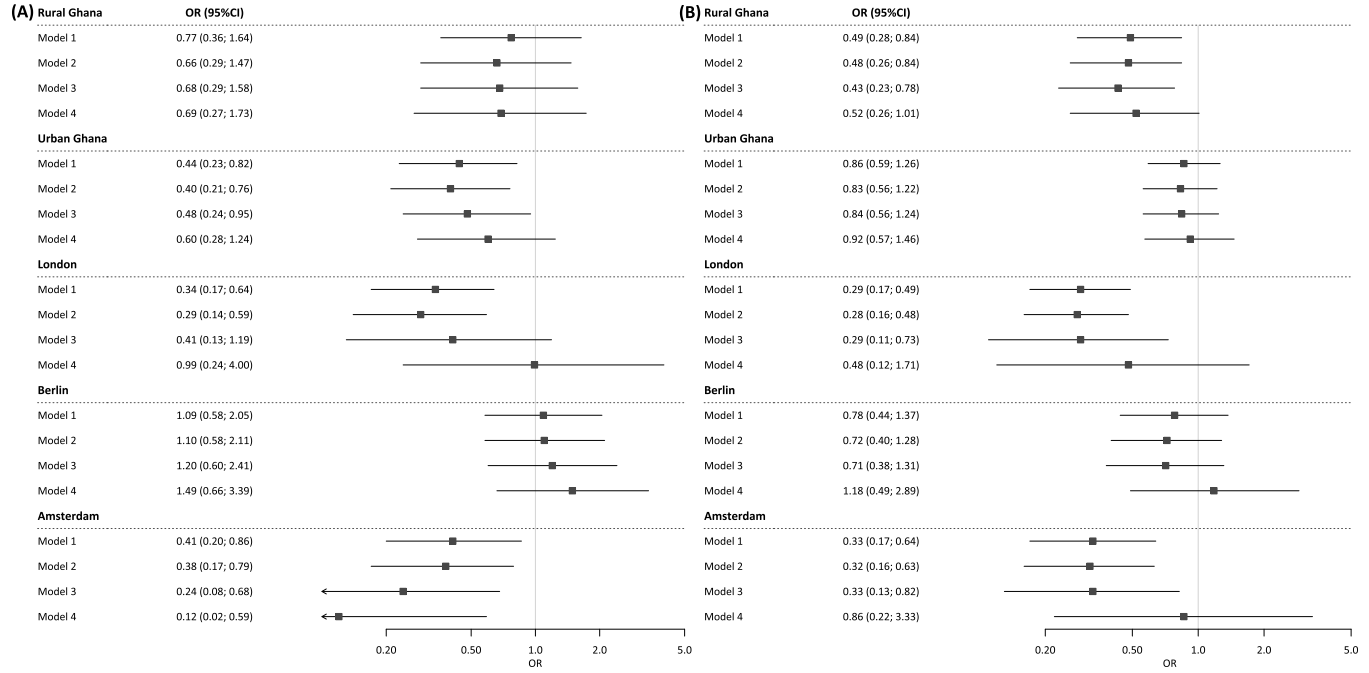

Fig. 4. Association between serum potassium concentration and hypertension, per geographical location and males (A) and females (B).
Model 1 adjusted for age; Model 2 adjusted for age and education; Model 3 adjusted for age, education, physical activity, smoking, alcohol intake, sodium intake, potassium intake, body mass index and waist-hip-ratio; Model 4 adjusted for model 3 plus diabetes mellitus, eGFR<60 and blood pressure lowering medication; OR, odds ratio; CI, confidence interval.

and DBP), and Amsterdam-Ghanaian males (hypertension) after adjustment for covariates. There was a weak correlation between potassium intake and serum potassium concentration in rural-Ghanaian females and Berlin-Ghanaian males, although the direction of association differed. There was not association between potassium intake and SBP, DBP or hypertension.

4.2. Discussion of the key findings

Difference in mean serum potassium concentrations among Ghanaian residing in different geographical locations might be due to diet modification after migration or to differential exposure to contextual factors. Prior studies among African migrant populations in high-income countries have shown substantial dietary modifications upon migration, changing from a low-salt/high-potassium to a high-salt/low-potassium diet [30,31]. This leads to sodium and water retention and, as a consequence, higher BP [32]. Prior RODAM results showed that compared to rural Ghana, potassium intake was lower in Amsterdam-Ghanaians but higher in London- and Berlin-Ghanaians, whereas sodium intake was higher in all European sites [24]. This suggests that diet modification after migration might contribute to the observed lower serum potassium levels in Amsterdam-Ghanaians. Additionally, as high sodium intake induces ineffective potassium conservation, higher potassium intake in London and Berlin might compensate for the potential adverse effects of high sodium intake. These differences in potassium intake between Ghanaian migrants in the Netherlands, the UK and Germany reflect differences in daily potassium intake of the respective host populations [33], implying the potential role of contextual factors such as the local food environment and national salt reduction policies on the difference in serum potassium. However, as our study only found a correlation between potassium intake and serum potassium concentration in rural-Ghanaian females and urban-Ghanaian males, more research is needed to establish the mechanism linking potassium intake and serum potassium concentration.

Serum potassium concentration was inversely associated with BP and hypertension among Ghanaian migrants in Europe and their compatriots in Ghana. This association persisted for SBP in rural-Ghanaian females and urban-Ghanaian males, for DBP in rural-Ghanaian females and for hypertension in Amsterdam-Ghanaian males, after adjustment for a wide range of covariates and after exclusion of participants using BP-lowering medication. This indicates the potential importance of serum potassium concentration on BP. As the renin-angiotensin system plays a pivotal role in regulating BP through potassium and sodium homeostasis, and aldosterone levels have shown to be higher among SSA migrants residing in Europe compared to their counterparts in SSA [22], future research into the role of renin and aldosterone could contribute to our understanding of the regulatory mechanism underlying this association, and could lead to better understanding of the pathophysiology of hypertension in SSA populations. However, as in the other populations the observed associations between serum potassium and BP/hypertension were explained by lifestyle factors and the use of BP-lowering medication suggesting that serum potassium might not be the most important determinant of BP in this SSA population residing in different settings.

There was no association between potassium intake and BP or hypertension, which is in contrast with previous literature [14]. This is potentially due to the way potassium intake was assessed. The gold standard to assess potassium intake in population studies is 24 h urinary potassium excretion, whereas in the current study potassium intake was assessed using a food propensity questionnaire. Although this questionnaire was developed in an extensive process including standardised description of portion sizes, 24 h-dietary recalls and the German Nutrient Database (BLS 3.01) (2010) and the West African Food Composition Table (2012) to translate usual food intake into energy consumption and intake of nutrients [24], the questionnaire was not validated against urinary excretion, and potassium intake could have been under- or overestimated. However, as recent studies from Ghana and South-Africa did not find an association between 24 h urinary sodium or potassium excretion and BP [34,35], it is unclear whether other measuring techniques would have impacted our results. Future research is needed using data of both FPQ as well as 24 h urinary excretion to disentangle the complex interplay between potassium intake, serum potassium concentration and BP.

4.3. Strengths and limitations

One of the strengths of the RODAM study is that it compared homogenous populations of migrants and non-migrant Ghanaians. Moreover, highly standardised data collection procedures were used at all sites, and all blood samples were analysed in the same laboratory to prevent inter-laboratory differences in results. Subsequently, the measurement technique of serum potassium was consistent between all sites. To our knowledge, this is the first study to examine the association between serum potassium and hypertension in an SSA population. Therefore, the findings of this study can serve as a reference for future research. Another strength is the deeply phenotyped dataset, allowing to adjust for multiple determinants of hypertension.

However, there are some limitations to consider. Conclusions on causality could not be drawn because of the cross-sectional design of the study. Also, given that some of the variables, such as educational level and physical activity, potassium, and sodium intake were based on self-report, the influence of reporting bias on the results cannot be ruled out, even though validated measurements were used. As this study did not collect data on plasma aldosterone concentrations, or urinary potassium excretion, the influence of aldonterone on potassium levels could not be assessed.

4.4. Conclusion

This study showed serum potassium concentration to vary between geographical locations and to be inverserly associated with BP and hypertension in Ghanaians residing in different geographical locations, indicating the potential role of serum potassium concentration on BP. There was no association between potassium intake and BP variables. More research is needed to establish the mechanism underlying sodium and potassium handling in SSA populations in order to increase our understanding of pathophysiological processes causing hypertension among SSA populations, thereby enhancing hypertension preventive measures among these populations.

Financial support

This work was supported by the European Commission under the Framework Program (Grant Number: 278901). K.A.C.M. is supported by the Intramural Research Program of the National Institutes of Health in the Center for Research on Genomics and Global Health (CRGGH). The CRGGH is supported by the National Human Genome Research Institute, the National Institute of Diabetes and Digestive and Kidney Diseases, the Center for Information Technology, and the Office of the Director at the National Institutes of Health (1ZIAHG200362).

Author contributions

AKN, ELL and CA conceived the study. CA, EJAJB, KACM, ID, SB, KKG, MBS, and JA designed and carried out the recruitment and data collection. AKN and ELL contributed equally to this work. AKN performed the initial analysis of the data and wrote the first version of the manuscript, and ELL performed additional data analysis, designed the figures and extensively contributed to the writing of the manuscript, supervised by CA and in cooperation with all co-authors. All authors read and approved the final version of the manuscript.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

The authors are very grateful to the advisory board members for their valuable support in shaping the methods, to the research assistants, interviewers, and other staff of the five research locations who have taken part in gathering the data and, most of all, to the Ghanaian volunteers participating in this project. We gratefully acknowledge Jan van Straalen from the Academic Medical Centre for his valuable support with standardisation of the lab procedures and the AMC Biobank for support in biobank management and storage of collected samples.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.atherosclerosis.2021.12.006.

References

[1] S.E. Kjeldsen, Hypertension and cardiovascular risk: general aspects, Pharmacol. Res. 129 (2018) 95–99.
[2] B. Zhou, J. Bentham, M. Di Cesare, H. Bixby, G. Danaei, M.J. Cowan, et al., Worldwide trends in blood pressure from 1975 to 2015: a pooled analysis of 1479 population-based measurement studies with 19·1 million participants, Lancet 389 (10064) (2017) 37–55.
[3] S. Dalal, J.J. Beunza, J. Volmink, C. Adebamowo, F. Bajunirwe, M. Njelekela, et al., Non-communicable diseases in sub-Saharan Africa: what we know now, Int. J. Epidemiol. 40 (4) (2011) 885–901.
[4] WHO. Raised Blood Pressure (SBP ≥ 140 OR DBP ≥ 90), age-standardized (%) 2017 [Available from: http://apps.who.int/gho/data/node.main.A875STANDARD.
[5] C. Agyemang, G. Nyaaba, E. Beune, K. Meeks, E. Owusu-Dabo, J. Addo, et al., Variations in hypertension awareness, treatment, and control among Ghanaian migrants living in Amsterdam, Berlin, London, and nonmigrant Ghanaians living in rural and urban Ghana - the RODAM study, J. Hypertens. 36 (1) (2018) 169–177.
[6] R. Cooper, C. Rotimi, S. Ataman, D. McGee, B. Osotimehin, S. Kadiri, et al., The prevalence of hypertension in seven populations of west African origin, Am. J. Publ. Health 87 (2) (1997) 160–168.
[7] C. Agyemang, R. Bhopal, Is the blood pressure of people from African origin adults in the UK higher or lower than that in European origin white people? A review of cross-sectional data, J. Hum. Hypertens. 17 (8) (2003) 523–534.
[8] C. Agyemang, S. Kieft, M.B. Snijder, E.J. Beune, B.J. van den Born, L.M. Brewster, et al., Hypertension control in a large multi-ethnic cohort in Amsterdam, The Netherlands: the HELIUS study, Int. J. Cardiol. 183 (2015) 180–189.
[9] C. Agyemang, A. Kunst, R. Bhopal, P. Zaninotto, N. Unwin, J. Nazroo, et al., A cross-national comparative study of blood pressure and hypertension between English and Dutch South-Asian–and African-origin populations: the role of national context, Am. J. Hypertens. 23 (6) (2010) 639–648.
[10] A.P. Carson, G. Howard, G.L. Burke, S. Shea, E.B. Levitan, P. Muntner, Ethnic differences in hypertension incidence among middle-aged and older adults: the multi-ethnic study of atherosclerosis, Hypertension 57 (6) (2011) 1101–1107.
[11] J.D. Bundy, K.T. Mills, J. Chen, C. Li, P. Greenland, J. He, Estimating the association of the 2017 and 2014 hypertension guidelines with cardiovascular events and deaths in US adults: an analysis of national data, JAMA Cardiol 3 (7) (2018) 572–581.
[12] A. Selassie, C.S. Wagner, M.L. Laken, M.L. Ferguson, K.C. Ferdinand, B.M. Egan, Progression is accelerated from prehypertension to hypertension in blacks, Hypertension 58 (4) (2011) 579–587.
[13] P.K. Whelton, J. He, J.A. Cutler, F.L. Brancati, L.J. Appel, D. Follmann, et al., Effects of oral potassium on blood pressure. Meta-analysis of randomized controlled clinical trials, Jama 277 (20) (1997) 1624–1632.
[14] N.J. Aburto, S. Hanson, H. Gutierrez, L. Hooper, P. Elliott, F.P. Cappuccio, Effect of increased potassium intake on cardiovascular risk factors and disease: systematic review and meta-analyses, BMJ 346 (2013) f1378.
[15] A.S. Terker, C. Zhang, J.A. McCormick, R.A. Lazelle, C. Zhang, N.P. Meermeier, et al., Potassium modulates electrolyte balance and blood pressure through effects on distal cell voltage and chloride, Cell Metabol. 21 (1) (2015) 39–50.
[16] A. Mente, M.J. O'Donnell, S. Rangarajan, M.J. McQueen, P. Poirier, A. Wielgosz, et al., Association of urinary sodium and potassium excretion with blood pressure, N. Engl. J. Med. 371 (7) (2014) 601–611.
[17] R.S. Vasan, J.C. Evans, M.G. Larson, P.W. Wilson, J.B. Meigs, N. Rifai, et al., Serum aldosterone and the incidence of hypertension in nonhypertensive persons, N. Engl. J. Med. 351 (1) (2004) 33–41.
[18] M.L. Gumz, L. Rabinowitz, C.S. Wingo, An integrated view of potassium homeostasis, N. Engl. J. Med. 373 (1) (2015) 60–72.
[19] A.A. McDonough, J.H. Youn, Potassium homeostasis: the knowns, the unknowns, and the health benefits, Physiology 32 (2) (2017) 100–111.
[20] L. Xi, Y.C. Hao, J. Liu, W. Wang, M. Wang, G.Q. Li, et al., Associations between serum potassium and sodium levels and risk of hypertension: a community-based cohort study, J Geriatr Cardiol 12 (2) (2015) 119–126.
[21] C.R. Walsh, M.G. Larson, R.S. Vasan, D. Levy, Serum potassium is not associated with blood pressure tracking in the Framingham Heart Study, Am. J. Hypertens. 15 (2 Pt 1) (2002) 130–136.
[22] L. Faconti, R.J. McNally, B. Farukh, O. Adeyemi, J.K. Cruickshank, I.B. Wilkinson, et al., Differences in hypertension phenotypes between Africans and Europeans: role of environment, J. Hypertens. 38 (7) (2020) 1278–1285.
[23] C. Agyemang, E. Beune, K. Meeks, E. Owusu-Dabo, P. Agyei-Baffour, A. Aikins, et al., Rationale and cross-sectional study design of the Research on Obesity and type 2 Diabetes among African Migrants: the RODAM study, BMJ Open 4 (3) (2014), e004877.
[24] C. Galbete, M. Nicolaou, K.A. Meeks, A. de-Graft Aikins, J. Addo, S.K. Amoah, et al., Food consumption, nutrient intake, and dietary patterns in Ghanaian migrants in Europe and their compatriots in Ghana, Food Nutr. Res. 61 (1) (2017) 1341809.
[25] B.E. Ainsworth, W.L. Haskell, S.D. Herrmann, N. Meckes, D.R. Bassett, C. Tudor-Locke, et al., Compendium of physical activities: a second update of codes and MET values, Med. Sci. Sports Exerc. 43 (8) (2011) 1575–1581, 2011.
[26] G. Mancia, R. Fagard, K. Narkiewicz, J. Redon, A. Zanchetti, M. Böhm, et al., ESH/ESC Practice guidelines for the management of arterial hypertension: ESH-ESC the Task Force for the management of arterial hypertension of the European Society of Hypertension (ESH) and of the European Society of Cardiology (ESC), Blood Pres. 23 (1) (2013) 3–16, 2014.
[27] P.A. James, S. Oparil, B.L. Carter, W.C. Cushman, C. Dennison-Himmelfarb, J. Handler, et al., evidence-based guideline for the management of high blood pressure in adults: report from the panel members appointed to the Eighth Joint National Committee (JNC 8), Jama 311 (5) (2014) 507–520, 2014.
[28] Organization WH, Definition and Diagnosis of Diabetes Mellitus and Intermediate Hyperglycaemia: Report of a WHO/IDF Consultation, 2006.
[29] G. Eknoyan, N. Lameire, K. Eckardt, B. Kasiske, D. Wheeler, A. Levin, et al., KDIGO 2012 clinical practice guideline for the evaluation and management of chronic kidney disease, Kidney Int. 3 (1) (2013) 5–14.
[30] H.J. Adrogue, N.E. Madias, Sodium and potassium in the pathogenesis of hypertension, N. Engl. J. Med. 356 (19) (2007) 1966–1978.
[31] A.M.N. Renzaho, C. Burns, Post-migration food habits of sub-Saharan African migrants in Victoria: a cross-sectional study, Nutr. Diet. 63 (2) (2006) 91–102.
[32] A.R. Subramanya, D.H. Ellison, Distal convoluted tubule, Clin. J. Am. Soc. Nephrol. 9 (12) (2014) 2147–2163.
[33] A.A. Welch, H. Fransen, M. Jenab, M.C. Boutron-Ruault, R. Tumino, C. Agnoli, et al., Variation in intakes of calcium, phosphorus, magnesium, iron and potassium in 10 countries in the European Prospective Investigation into Cancer and Nutrition study, Eur. J. Clin. Nutr. 63 (Suppl 4) (2009) S101–S121.
[34] E.K. Menyanu, B. Corso, N. Minicuci, I. Rocco, J. Russell, L.J. Ware, et al., Salt and potassium intake among adult Ghanaians: WHO-SAGE Ghana Wave 3, BMC Nutr 6 (2020) 54.
[35] L.J. Ware, K. Charlton, A.E. Schutte, M. Cockeran, N. Naidoo, P. Kowal, Associations between dietary salt, potassium and blood pressure in South African adults: WHO SAGE Wave 2 Salt & Tobacco, Nutr. Metabol. Cardiovasc. Dis. 27 (9) (2017) 784–791.