Original Article

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Hypertension determinants among Ghanaians differ according to location of residence: RODAM study

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Objective: Hypertension prevalence is high among African migrants, but the determinants of hypertension in migrants in Europe in relation to the population in the country of origin still needs to be elucidated. Therefore, the aim of this study was to assess the determinants of hypertension in Ghanaians residing in Ghana and Europe.

Methods: The current study used baseline data of 5659 participants, aged 25–70 years, of the Research on Obesity and Diabetes among African Migrants study. Multivariate logistic regression analysis was used to assess sociodemographic, lifestyle, psychosocial, anthropometric and health factors independently associated with hypertension in Ghanaians living in rural and urban Ghana, and Ghanaian migrants living in Europe.

Results: Across all sites, older age (both sexes; odds ratio 1.07, 95% confidence interval 1.06–1.08) and diabetes (females only; 2.02, 1.54–1.67) were independently associated with hypertension. The other determinants of hypertension differed between geographical locations. Higher waist circumference (1.12, 1.05–1.20) was independently associated with hypertension in rural-Ghanaian males, as was higher body mass index (1.15, 1.03– 1.28) in urban-Ghanaian males, higher waist circumference (1.04, 1.01–1.07) and diabetes (1.75, 1.17–2.63) in European-Ghanaian males. In European-Ghanaian females, high alcohol intake (1.88, 1.01 –3.53) and waist circumference (1.04, 1.02– 1.06) were associated with hypertension, whereas in rural-Ghanaian females, a higher educational level (0.28, 0.08–0.98) was inversely associated with hypertension.

Conclusion: The current study identified several modifiable determinants of hypertension in Ghanaians, with differences between populations residing in various geographical locations. This highlights the importance of development and implementation of context-specific interventions targeting these determinants to reduce the burden of hypertension among Ghanaian migrants and nonmigrants.

Keywords: Ghana, hypertension, migrant health, risk factors, Research on Obesity and Diabetes among African Migrants, sub-Sahara Africa

Abbreviations: ATC, anatomical therapeutic chemical; BP, blood pressure; MET, metabolic equivalent; RODAM, Research on Obesity and Diabetes among African Migrants; SSA, sub-Saharan Africa

INTRODUCTION

During the past four decades, the age-standardized prevalence of hypertension has steadily decreased in Western world regions [1], whereas sub-Saharan Africa (SSA), in particular South and West Africa, has seen an increase in prevalence of hypertension and hypertension-mediated complications [1,2]. In this regard, the even higher prevalence of hypertension among West African migrants residing in Europe does not offer an optimistic perspective for future hypertension burden in SSA. Results from the Research on Obesity and Diabetes among African Migrants (RODAM) study have shown that among Ghanaians residing in Europe hypertension prevalence is up to 57%, which is over two times higher compared with their nonmigrating counterparts residing in rural Ghana [3]. This suggests the important role of contextual factors on hypertension [4]. This high burden of hypertension appears to be the main contributor to the increased risk of stroke [5,6] and renal disease [7] observed among SSA migrants in Europe.

Previous studies conducted in Ghana [8,9] and among Ghanaian migrants in high-income countries [10–12] have shown several sociodemographic, health, lifestyle and psychosocial factors to be associated with hypertension. However, while location of residence has shown to be associated with hypertension prevalence [3,13], determinants of hypertension have not yet been assessed in a homogenous population of Ghanaians, that is of primarily Akan ethnicity, residing in different geographical locations in Ghana and Europe. Identifying context-specific determinants of hypertension in these Ghanaian populations

Journal of Hypertension 2022, 40:1010–1018

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Received 9 December 2021 **Revised** 17 January 2022 **Accepted** 26 January 2022

DOI:10.1097/HJH.0000000000003108

residing in different settings can inform targeted interventions aiming to halt the rising prevalence of hypertension in both SSA and SSA migrants living in high-income countries. Therefore, the aim of this study was to assess the determinants of hypertension in Ghanaian nonmigrants residing in rural and urban Ghana, and Ghanaian migrants residing in Europe.

METHODS

The rationale, conceptual framework and methods of the RODAM study have been published elsewhere [14], as summarized below.

Study population and design

The RODAM study is a multicentre, prospective cohort study. For the current analysis, cross-sectional baseline data, collected between 2011 and 2015, were used. Ghanaians aged at least 18 years were recruited in rural Ghana (Ashanti region), urban Ghana (Kumasi and Obuasi) and in the European cities of London, Amsterdam and Berlin. Participant recruitment strategies needed to be tailored to the different locations, as the population registration system varied across the European countries as well as in Ghana. In Ghana, a multistage random sampling procedure of enumeration areas was performed to select urban and rural enumeration areas from which participants were drawn. In Europe, participants were drawn from municipalities (Amsterdam, Berlin) and Ghanaian organization registrations (London and Berlin). Participation rates were 76% in rural and 74% in urban Ghana, and 75% in London, 53% in Amsterdam and 68% in Berlin.

The current study was conducted in accordance with the ethical principles of the Declaration of Helsinki and the study protocol was approved by the medical ethical committees of the various research centres prior to the start of data collection. Before enrolment in the study, participants provided written informed consent.

Measurements and definitions

Data collection was highly standardized using uniform protocols across all study locations and was conducted by trained research assistants.

Sociodemographic, lifestyle and psychosocial information were obtained using questionnaires, either self-completed or through an interview by a Ghanaian-speaking interviewer. Educational level and occupational attainment were used as proxies for socioeconomic status. Educational level was classified lower (never or elementary and lower) and higher level. Occupational attainment was dichotomized into being unemployed yes or no. Physical activity was assessed using the WHO Global Physical Activity Questionnaire V.2 questionnaire [15] and expressed in metabolic equivalents (METs) per day [16]. Former and never smokers were contrasted against participants who reported as currently smoking. Alcohol (units) and total energy intake [kilocalories (kcal)] per day were estimated using a Ghana-adapted version of the European Food Propensity Questionnaire [17]. Alcohol intake was dichotomized into low (males <2 units/day, females <1 unit/day) and high intake (males >2 units/day, females >1 unit/day), based on recommendations of the European Society of Cardiology [18]. Depressed mood was defined as having a score of at least 10 on the Patient Health Questionnaire 9, a questionnaire assessing the prevalence of depressive symptoms over the preceding 2 weeks [19]. Psychosocial stress was assessed with the stress scale used in the INTERHEART study and classified into no (never experienced stress at home and/or work) or yes (experienced periods of stress at home and/or work) [20].

Physical examination was used to collect anthropometric and blood pressure (BP) measurements. All anthropometric measurements were performed twice, and the mean of both readings was used. Weight and height were measured in light clothing without shoes using validated, portable weighing scales (SECA877) and stadiometers (SECA217). BMI was calculated by dividing weight in kilograms by height in meters squared (kg/m^2). Waist circumference was measured using measuring tape at the midpoint between the lower rib and the upper margin of the iliac crest. After at least 5 min of rest BP was measured three times on the participant's left arm, in a sitting position using an appropriate cuff size, with a semi-automated Oscillometric device (Microlife WatchBP Home; Microlife AG, Widnau, Switzerland). The mean of the second and third measurements was used in the analysis. BP-lowering medication was classified according to the anatomical therapeutic chemical (ATC) Classification [21], based on the medication packages brought by the participant to the research location. Hypertension was defined as having a SBP of at least 140 or DBP of at least 90 mmHg and/or using BP-lowering medication [18].

Blood samples were collected after an overnight fast. Fasting plasma lipids and fasting plasma glucose was measured using ABX Pentra 400 chemistry analyse (ABX Pentra 400; Hiroba ABX, Darmstadt, Germany). Diabetes mellitus was defined based on self-reported diagnosis of diabetes, on fasting plasma glucose at least 7 mmol/l and/or use of glucose-lowering medication (based on ATC coding), according to WHO diagnostic criteria [22].

Statistical analysis

For the total 5898 participants who underwent physical examination and attempted blood sample collection, the percentage of cases with complete data on all variables of interest was 68.3%, with percentage of missing values varying between 0 and 21.9% (Table 1). Participants with missing values did not differ in terms of age, sex, education, anthropometric measures or hypertension status, but were more often located in Amsterdam and London and more frequently employed fulltime, compared with those with complete data. We therefore concluded missing values to be missing at random. Imputation was performed using multiple imputation by chained equations, in which missing data is randomly imputed from a conditional distribution based on regression models including predictors of the missing variables [23]. These predictors included all sociodemographic, lifestyle, psychosocial, anthropometric and health factors, which also served as covariates in the main analysis (see below). Predictive mean matching method

TABLE 1. Population characteristics

Males	Rural Ghana	Urban Ghana	Europe	Missing (%)
n	405	415	1316	
Age, years [mean (SD)]	46.22 (12.85)	46.51 (11.86)	47.11 (10.33)	0
Education, higher level (%)	77 (20.2)	123 (31.5)	576 (47.0)	6.5
Unemployed (%)	65 (16.0)	79 (19.0)	405 (30.8)	0
Physical activity, METs/day [mean (SD)]	8734.92 (7374.15)	6636.43 (5896.79)	7757.62 (9545.51)	17.5
Smoking, yes (%)	22 (5.8)	13 (3.3)	94 (7.8)	7.1
Alcohol intake, high (%)	26 (6.4)	10 (2.4)	79 (6.0)	0
Total energy intake (kcal/day) [mean (SD)]	3040.72 (1499.35)	2431.14 (799.06)	2965.53 (1250.95)	21.5
Depressed mood (%)	19 (5.1)	11 (2.8)	75 (6.4)	9.6
Psychosocial stress (%)	48 (12.8)	62 (15.9)	142 (12.1)	9.3
BMI (kg/m^2) [mean (SD)]	20.88 (2.96)	24.14 (3.84)	27.01 (3.89)	0.2
Waist circumference (cm) [mean (SD)]	76.81 (8.24)	84.72 (10.48)	92.61 (10.84)	0.3
Diabetes mellitus (%)	15 (3.7)	46 (11.1)	173 (13.1)	0
TC/HDL-C-ratio, mmol/l [mean (SD)]	3.87 (1.56)	4.41 (1.28)	3.96 (1.10)	2.5
Hypertension (%)	90 (22.2)	142 (34.2)	727 (55.2)	0
SBP (mmHg) [mean (SD)]	123.86 (18.31)	131.00 (20.96)	137.87 (17.64)	0.1
DBP (mmHg) [mean (SD)]	77.36 (10.97)	82.22 (13.26)	87.04 (11.37)	0.1
Prescribed antihypertensive medication (%)	17 (4.2)	26 (6.3)	340 (25.8)	0
Length of stay in Europe, years [median (IQR)]	NA (NA, NA)	NA (NA, NA)	17.57 (10.35, 23.97)	11.6
Females	**Rural Ghana**	**Urban Ghana**	**Europe**	**Missing (%)**
n	638	1034	1851	
Age, years [mean (SD)]	46.66 (12.49)	44.73 (11.20)	46.22 (9.53)	0
Education, higher level (%)	31 (5.2)	116 (11.5)	592 (35.1)	6.6
Unemployed (%)	100 (15.7)	178 (17.2)	806 (43.5)	0
Physical activity, METs/day [mean (SD)]	6066.16 (5740.40)	5203.09 (5919.95)	5794.01 (7466.01)	14.9
Smoking, yes (%)	0 (0.0)	1 (0.1)	27 (1.6)	6.9
Alcohol intake, high (%)	4 (0.6)	4 (0.4)	51 (2.8)	0.1
Total energy intake (kcal/day) [mean (SD)]	2917.53 (1351.72)	2293.08 (710.39)	2756.29 (1160.89)	21.9
Depressed mood (%)	47 (8.0)	42 (4.2)	134 (8.3)	8.7
Psychosocial stress (%)	129 (21.8)	137 (13.7)	265 (16.2)	8.3
BMI (kg/m^2) [mean (SD)]	23.64 (4.57)	28.00 (5.47)	30.33 (5.05)	0.3
Waist circumference (cm) [mean (SD)]	83.77 (11.26)	91.20 (11.89)	95.91 (12.08)	0.3
Diabetes mellitus (%)	36 (5.6)	89 (8.6)	171 (9.2)	0
TC/HDL-C-ratio, mmol/l [mean (SD)]	4.16 (1.72)	4.26 (1.16)	3.54 (0.89)	3.5
Hypertension (%)	178 (27.9)	304 (29.4)	924 (49.9)	0
SBP (mmHg) [mean (SD)]	123.74 (22.00)	124.67 (19.64)	132.83 (17.58)	0.3
DBP (mmHg) [mean (SD)]	76.94 (12.29)	78.27 (11.58)	82.33 (10.50)	0.3
Prescribed antihypertensive medication (%)	56 (8.8)	125 (12.1)	548 (29.6)	0
Length of stay in Europe, years [median (IQR)]	NA (NA, NA)	NA (NA, NA)	17.47 (10.26, 24.02)	13.8

HDL-C, HDL cholesterol; IQR, interquartile range; kcal, kilocalories; MET, metabolic equivalent; NA, not available; TC, total cholesterol.

was applied for continuous variables, polytomous logistic regression for unordered categorical, proportional odds modelling for ordered categorical, and logistic regression for dichotomous variables, using the 'mice' package for R (version 3.11.0; R Foundation, Vienna, Austria) [24], generating 20 imputed datasets. In addition to all predictor variables, SBP and DBP were included as predictors in the multiple imputation [25]. Quality of the imputed datasets was checked visually using plots. After multiple imputation, those aged less than 25 or more than 70 years were excluded to allow for equal age-distribution between the geographical locations, resulting in 5659 participants included in the analyses. Participants residing in rural and urban Ghana are referred to as nonmigrant populations and those residing in Europe are referred to as migrant populations.

Population characteristics were presented by frequencies and percentages for categorical variables, and by means and standard deviations for normally distributed continuous variables, stratified by sex and geographical location (rural Ghana, urban Ghana, Europe), because of significant interaction. To compare population characteristics between the locations, chi-square test was used for categorical variables, one-way analysis of variance for normally distributed continuous variables, and Kruskal—Wallis test for nonnormally distributed variables. Difference between locations were considered statistically significant at a P value less than 0.05.

Sociodemographic (age, education, employment), lifestyle (physical activity, smoking, alcohol and energy intake), psychosocial (depressed mood, psychosocial stress) and health factors [BMI, waist circumference, diabetes, total cholesterol to HDL cholesterol ratio] were assessed as potential determinants of hypertension. These factors were identified based on previous literature, in which these were shown to be associated with hypertension directly or indirectly [3,8–13]. To assess which of these factors were independently associated with hypertension in the total population (stratified by sex), logistic regression models were developed in which variables selection was performed using backward stepwise selection of variables based on the Akaike information criterion in each of the 20 imputed datasets, followed by the Wald test to determine whether variables should be included in the final model [24], using the R package 'mice'. Factors were included in the final model if the result of Wald test was statistically significant at a P value of less than 0.05. Hereafter, the factors included in the final model in the total population were included in a multiple logistic regression analysis stratified per geographical location. A factor of interest was considered to be a hypertension determinant if it was independently associated with hypertension at a P value of less than 0.05. To test the robustness of this model building method, backward selection of variables was compared with combined forward/backward selection of variables and with forced entry of all variables, resulting in selection of the same variables in each of the methods. Physical activity and total energy intake were rescaled in the regression analysis to allow for better interpretation of the odds ratios and 95% confidence intervals. Variation inflation factor (VIF) was used to assess multicollinearity between the variables included in the regression analysis, using 'car' package (version 3.0-7). As the VIF was less than five, multicollinearity between variables included in the final model was considered low. All analyses were performed in R Statistics version4.0.3.

RESULTS

Population characteristics

Population characteristics are described in Table 1. Ghanaian migrants in Europe had a higher level of education (males 47.0%, females 35.1%, $P<0.001$), and were more frequently unemployed (males 30.8%, females 43.5%, $P<0.001$) compared with the other sites. Rates of physical activity were higher in rural-Ghanaian (8743.92 METs/day, $P<0.001$) and European-Ghanaian males (7757.62 METs/day, $P=0.031$) compared with urban-Ghanaian males (6636.43 METs/day), and was lowest among urban-Ghanaian females (5203.09 METs/day), both compared with their rural (6066.16 METs/day, $P=0.004$) and European-Ghanaian counterparts (5794.01 METs/day, $P=0.037$). Total daily energy intake was higher in rural Ghana (males 3040 kcal/day, females 2917 kcal/day, $P<0.001$) compared with urban Ghana, but did not differ between rural Ghana and Europe. Prevalence of smoking was less than 8% in males and less than 2% in females, and prevalence of high alcohol intake was less than 6% in males and less than 3% females. Depressed mood was more frequently reported by rural-Ghanaians and European-Ghanaians than urban-Ghanaians ($P<0.001$), whereas psychosocial stress was mainly present among females in rural Ghana (21.8%, $P<0.001$). BMI and waist circumference were highest among European-Ghanaians and lowest among rural-Ghanaians ($P<0.001$). Compared to rural-Ghanaian males (3.7%), diabetes was more prevalent in urban-Ghanaian (11.1%, $P<0.001$) and European-Ghanaians males (13.1%, $P<0.001$); similar patterns could be observed in females. total cholesterol/high-density cholesterol-ratio was highest in urban-Ghanaian males (4.41 mmol/l, $P<0.001$) and females (4.26 mmol/l, $P<0.001$). In males, prevalence of hypertension was lowest in rural Ghana, and highest in Europe, with prevalence rates ranging from 22% in rural Ghana to over 55% in Europe ($P<0.001$). In females, prevalence of hypertension was similar in rural and urban Ghana, around 29% ($P=0.539$), but was higher in the Europe, where half of the participants had hypertension ($P<0.001$). Use of BP-lowering medication was highest in Europe (males 25.8%, females 29.6%) and lowest in rural Ghana (males 4.2%, females 8.8%, $P<0.001$).

Determinants of hypertension

Results of the univariate regression analysis are presented in Supplementary Table 1, http://links.lww.com/HJH/B886, showing that, generally, sociodemographic, lifestyle and anthropometric and biochemical factors were significantly associated with hypertension, but psychosocial factors were not. The multivariate logistic regression analysis, showed an independent association of older age, high alcohol intake, higher BMI, higher waist circumference and diabetes with higher odds of hypertension in the total population (Figs. 1a and 2a). In addition, in males, being unemployed was associated with higher odds of hypertension (Fig. 1a), whereas higher level of education was associated with a higher odds of hypertension in females (Fig. 2a).

When applying the final model built in the total population to the subpopulations residing in the different geographical locations, differences in factors associated with hypertension were observed. In rural-Ghanaian males, older age and higher waist circumference were associated with higher odds of hypertension (Fig. 1b), whereas in urban Ghana older age and higher BMI were associated with higher odds of hypertension (Fig. 1c). In European-Ghanaian males, older age, higher waist circumference and diabetes were associated with higher odds of hypertension (Fig. 1d). In females residing in rural Ghana, older age was associated with higher odds of hypertension, whereas higher level of education was associated with lower odds of hypertension (Fig. 2b). In urban-Ghanaian females, older age was associated with hypertension (Fig. 2c). Older age, high alcohol intake, higher waist circumference and diabetes were associated with higher odds of hypertension in European-Ghanaian females (Fig. 2d).

Stratifying the analyses by the three European locations, showed minor deviations in the determinants that were associated with hypertension Ghanaians residing in London, Berlin or Amsterdam (Supplementary Fig. 1, http://links.lww.com/HJH/B886 and 2, http://links.lww.com/HJH/B886). In all European sites and in both sexes, older age was associated with higher odds of hypertension, higher waist circumference was associated with higher odds of hypertension in Amsterdam and London, and diabetes was associated with higher odds of hypertension in Amsterdam. In addition in Berlin-Ghanaian males, being unemployed was associated with higher odds of hypertension.

DISCUSSION

Key findings

Our findings show that the determinants of hypertension differ according to geographical location of residence. Age was a consistent determinant of hypertension in all

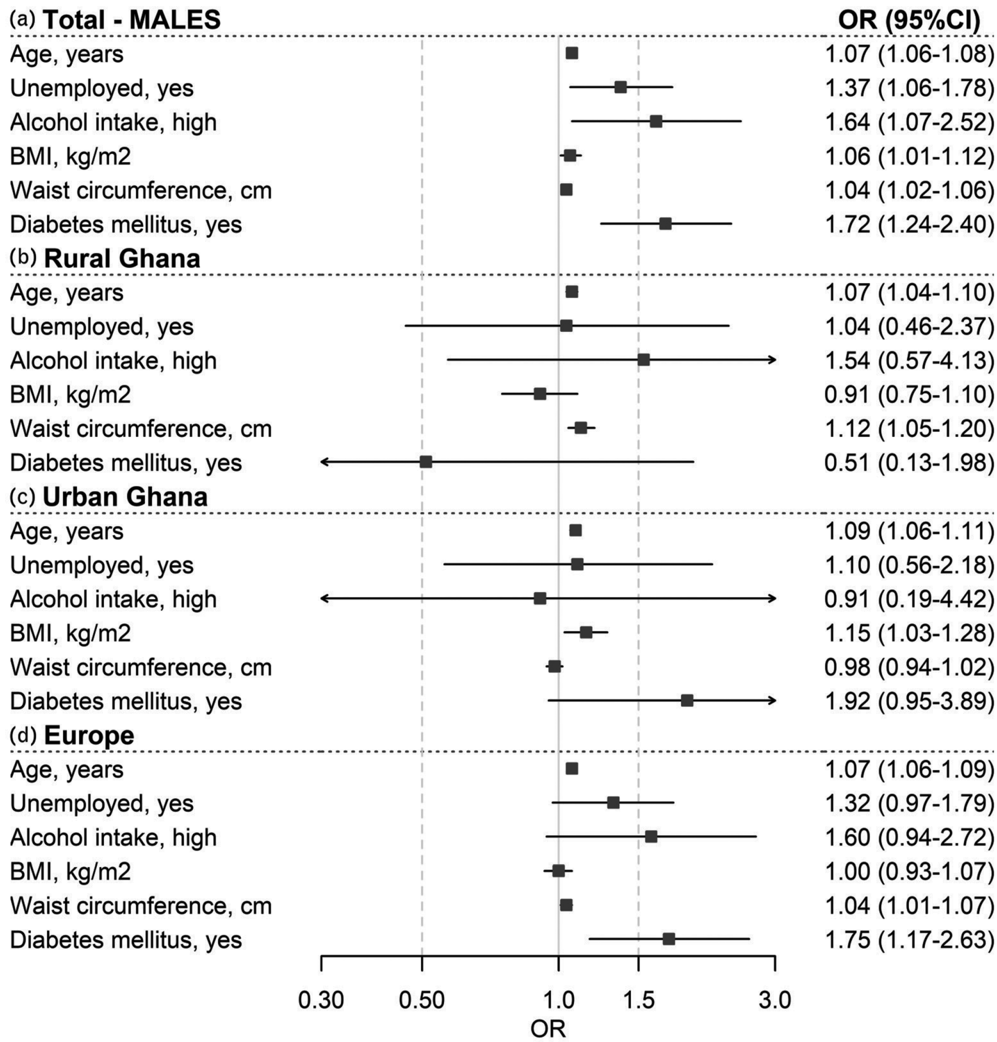

FIGURE 1 Determinants of hypertension for males, for total population and per location of residence. Error bars are 95% confidence intervals; CI, confidence interval; OR, odds ratio.

geographical locations and in both sexes, as was diabetes in females. The other determinants of hypertension varied between nonmigrant Ghanaians residing in Ghana and Ghanaian migrants in Europe. Depending on geographical location, different measures of body composition were associated with hypertension in Ghanaian males, while diabetes was only associated with hypertension in European-Ghanaian males. In rural-Ghanaian females, higher educational level was associated with lower odds of hypertension, whereas in European-Ghanaian females, high alcohol intake and higher waist circumference were associated with higher odds of hypertension.

Discussion of key findings

For decades, it has been known that both rural-urban [26] and international migration [27] impacts BP levels and hypertension prevalence, and several studies have identified determinants of hypertension [3,8–13], but comprehensive studies assessing context-specific determinants of hypertension in the light of migration are lacking. Our study among a homogenous population, that is, all Ghanaians of primarily Akan ethnicity, residing in rural and urban settings in Ghana and in urban settings in Europe, show differences in determinants of hypertension among migrant and non-migrant populations. For instance, waist circumference was associated with hypertension in females in Europe, but not in Ghana, and diabetes was associated with hypertension in European-Ghanaian males, but not in males residing in Ghana. This demonstrates that different geographical settings might generate a context-specific risk factor profile, as has previously been reflected upon in other cross-national comparative studies [4,28–31], explaining the geographical differences in hypertension determinants. When stratifying the analysis for the European sites, additional variations in the different hypertension determinants were observed in European migrants too. For instance, despite the high rate of diabetes in Berlin-Ghanaians [32] diabetes was not a determinant of hypertension in this setting, in contrast to Ghanaians with diabetes in Amsterdam, who had an over two-fold higher risk of hypertension. Likely, other factors that influence the relation between diabetes and hypertension equal out the association in this context. Also, in

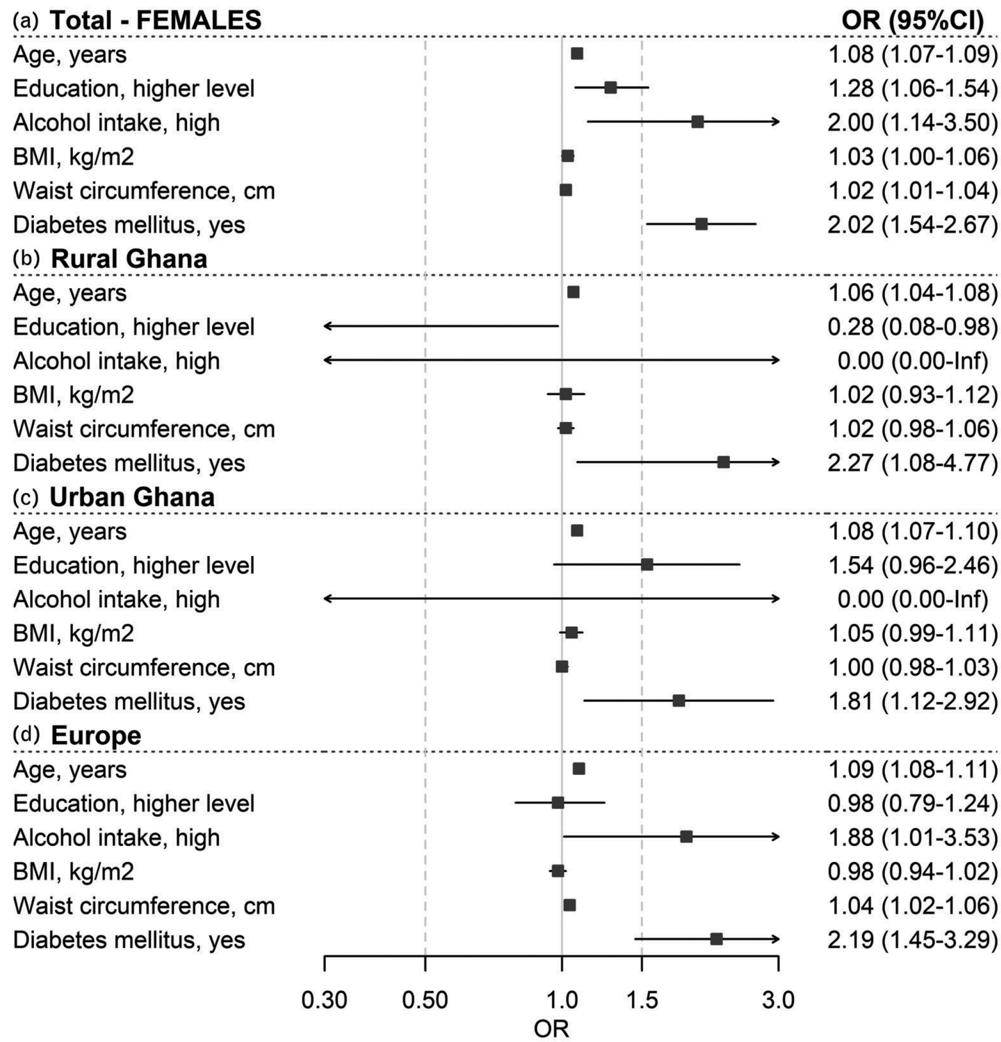

FIGURE 2 Determinants of hypertension for females, for total population and per location of residence. Error bars are 95% confidence intervals; CI, confidence interval; OR, odds ratio.

rural-Ghanaian and urban-Ghanaian males and females only few of the included determinants in the study were independently associated with hypertension. This suggests that in these locations other, unobserved or unmeasured factors, such as gene-environmental interaction, are at play, contributing to the burden of hypertension. An interesting finding in this light is the discovery of differences in DNA methylation of several epigenetic loci linked to cardiovascular disease risk factors between Ghanaian migrant and nonmigrant populations [33]. It is unclear what drives these epigenetic variations, but it is possible that contextual differences between the European settings, that is between London, Amsterdam and Berlin, and between migrants and nonmigrants result in distinctive epigenetic profiles, thereby impacting differences in hypertension risk between ocations.

Previous literature suggests that changes in BP upon migration can be attributed to rapid changes in environment after migration, accompanied by adoption of unhealthy lifestyle with sedentary behaviour and a high-sodium high-fat diet [34]. In our study, physical activity and energy intake were associated with hypertension in the univariate, but not in the multivariate regression analysis. This is likely the result of the mediating effect of BMI, waist circumference and diabetes in the association between lifestyle factors and hypertension. This supports the importance of prevention of (abdominal) obesity and diabetes in reducing the rising hypertension prevalence, for instance by lifestyle interventions. Significantly, the association between measures of body composition and hypertension was less consistent in females than in males, as only waist circumference was independently associated with hypertension in female migrants, but no association was observed with waist circumference or BMI in nonmigrants. In males, in contrast, BMI was associated with hypertension in urban Ghana, as was waist circumference in rural Ghana and Europe. This is in line with previous findings from South Africa, showing that when assessing the independent association of multiple parameters of body composition, only waist circumference was independently associated with hypertension [35]. As abdominal obesity and general obesity are usually correlated but seem to contribute to the pathophysiology of obesity-related hypertension through slightly different processes [36,37], studying both determinants independently provide insight into drivers of hypertension burden.

Older age was consistently associated with higher odds of hypertension across the geographical locations. This observation is in contrast with findings from the INTERSALT study, showing no age-related BP increase in rural communities [38]. Generally, an increase in BP with age is seen as a consequence of physiological age-related vascular stiffening [39], which can be accelerated by other conditions imposing vascular aging. For instance, evidence has shown that weight gain and salt intake are more important factors contributing to rise in BP than aging *per se* [38,40]. The observed association between older age and hypertension in rural communities, suggests that nutritional transition has reached rural areas in Ghana too [17,41], and implies that rural areas should not be forgotten in hypertension preventive efforts.

Psychosocial factors like stress and depressed mood were not associated with hypertension, neither in the univariate nor in the multivariate regression analysis. This is remarkable as psychosocial stress is frequently perceived by Ghanaian migrants contributing to their high burden of hypertension [42]. Potentially, the impact of these psychosocial factors on hypertension was mediated by lifestyle factors, as previous literature has shown a higher prevalence of unhealthy behaviour such as high alcohol intake and physical inactivity are more prevalent among persons experiencing psychosocial stress [43].

Factors independently associated with hypertension appeared to be generally similar between males and females. The main difference was the impact of socioeconomic proxies, where among males being unemployed was associated with higher odds of hypertension, whereas among females, a higher level of education was associated with a higher odds of hypertension. The positive association between educational level and hypertension among females is in contrast to findings from high-income countries, where studies have found a higher level of education to be protective against hypertension [44,45]. Our finding, however, is supported by studies from Ghana and other low-income and middle-income countries, where higher socioeconomic status is associated with higher BP and hypertension prevalence [46,47]. In these settings, socioeconomic development is associated with the adoption of unhealthy lifestyles, such as less physical activity and a more sedentary lifestyle, resulting in more obesity and hypertension [48]. As in our study, the positive association between education and hypertension seems to be mainly present in urban-Ghanaian females, similar mechanisms could be at play. In rural-Ghanaian females, in contrast, a higher level of education was not associated with hypertension, potentially because the impact of socioeconomic status on physical activity is less pronounced in these areas [49]. However, conclusions for this population should be drawn with caution, as the number of rural-Ghanaian females with a higher level of education in the study was small.

The WHO Global Non-Communicable Disease Action Plan 2013–2020 has set the target of a 25% reduction in the prevalence of hypertension by 2025, compared with prevalence in 2010 [50]. In order to curb the rising prevalence of hypertension in SSA, and SSA migrants in Europe, effective, context-specific interventions are required. These should entail a complex systems approach, in which individual-level determinants of hypertension are considered within a broader scope of a dynamic interrelation of multiple elements across many systems [51,52], such as behavioural, social, environmental, economic and health systems [53]. In this regard, our study could serve as a first step in providing information on context-specific determinants of hypertension that are worth targeting.

Strengths and limitations

A strength of this study is the extensive and highly standardized data collection, allowing for cross-national comparison of many factors and their association with hypertension among a homogenous population (i.e. all Ghanaians). In addition, despite missing values, we were able to optimally analyse our data, by applying multiple imputation techniques for missing data, thereby reducing bias and preserving statistical power. A limitation of the study is the classification of participants as hypertensive based on two BP recordings on a single occasion, potentially resulting in an overestimation of the prevalence. However, as day-to-day variation in BP as well as the prevalence of white-coat hypertension is expected to be similar for the various locations, we do not expect this to have affected our comparison. Moreover, the mean of the second and third BP reading was used in the analyses, which has been suggested to improve diagnostic utility. On the contrary, data on family history of hypertension were not collected, and it was therefore not possible to assess its association with hypertension. Lastly, the cross-sectional nature of the design should be taken into consideration in the interpretation of the results.

In conclusion, the current study identified several modifiable determinants of hypertension, including BMI, waist circumference and diabetes, in Ghanaians, with differences between migrant populations in Europe and nonmigrant populations in Ghana. This implies that development and implementation of context-specific interventions targeting these determinants is worthwhile in the pursuit to reduce the burden of hypertension among SSA populations. More research into gene-environment interaction could potentially increase our understanding of the pathophysiological mechanism behind hypertension in the context of migration.

ACKNOWLEDGEMENTS

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 sites, 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 standardization of the laboratory procedures and the AMC Biobank for support in biobank management and storage of collected samples.

Author's contribution: E.L.L., B.J.B. and C.A. conceived the study. C.A., E.B., K.M., S.B. and K.K.G. designed and carried out the recruitment and data collection. E.L.L., B.J.B.

and C.A. were responsible for data analysis and interpretation. E.L.L. wrote the article, supervised by C.A. and B.J.B. and in cooperation with all co-authors. All authors read and approved the final version of the article.

The current work was supported by the European Commission under the Framework Programme (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). The study sponsors were not involved in the design of the study, the collection, analysis and interpretation of the data, in writing the report or in the decision to submit the paper for publication.

Data sharing statement: Data are available upon reasonable request.

Conflicts of interest

There are no conflicts of interest.

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