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Dyslipidaemia among Ghanaian migrants in three European countries and their compatriots in rural and urban Ghana: The RODAM study

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HIGHLIGHTS

- Total cholesterol and LDL-C rates were similar for men in urban Ghana and Europe.
- High total cholesterol and LDL-C were most prevalent in urban Ghanaian women.
- High triglycerides were more prevalent in Ghanaian women in Ghana than in Europe.
- Low HDL-C was most prevalent in rural Ghana, followed by urban Ghana and Europe.
- TC/HDL-C-ratio was the highest in urban Ghanaian men and women.

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ABSTRACT

Background and aims: African populations have a favourable lipid profile compared to European populations. However, the extent to which they differ between rural and urban settings in Africa and upon migration to Europe is unknown. We assessed the lipid profiles of Ghanaians living in rural- and urban-Ghana and Ghanaian migrants living in three European countries.

Methods: We used data from a multi-centre, cross-sectional study among Ghanaian adults residing in rural- and urban-Ghana and London, Amsterdam and Berlin (n = 5482). Dyslipidaemias were defined using the 2012 European Guidelines on Cardiovascular Prevention. Comparisons between groups were made using age-standardised prevalence and prevalence ratios (PRs) with adjustments for important covariates.

Results: In both sexes, the age-standardised prevalence of high total cholesterol (TC) and LDL-cholesterol (LDL-C) was lower in rural- than in urban-Ghana and Ghanaian migrants in Europe. Adjusted PRs of high TC and LDL-C were higher in urban-Ghana (TC PR = 2.15, 95%confidence interval 1.69–2.73) and Ghanaian migrant men (TC PR = 2.03 (1.56–2.63)) compared to rural-Ghana, but there was no difference between rural- and Ghanaian migrant women (TC PR = 1.01 (0.84–1.22)). High triglycerides levels were as prevalent in rural-Ghana (11.6%)

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as in urban-Ghana (12.8%), but were less prevalent in Ghanaian migrant women (2.0%). In both sexes, low HDL-cholesterol was most prevalent in rural-Ghana (50.1%) and least prevalent in Europe (12.9%).
Conclusion: The lipid profile varied among ethnically homogeneous African populations living in different geographical locations in Africa and Europe. Additional research is needed to identify factors driving these differential risks to assist prevention efforts.

1. Introduction

The prevalence of hypercholesterolemia is markedly lower in sub-Saharan African (SSA) populations compared to the worldwide prevalence. Prevalence rates of high total cholesterol (TC) range from 5% in Lesotho to 26% in mainland Tanzania [1], compared to around 30% globally [2]. Moreover, migrants originating from SSA are believed to have a more favourable lipid profile compared to European descent populations, with lower triglyceride (TG) and higher high-density lipoprotein cholesterol (HDL-C) levels [3].

This favourable lipid profile has previously been thought to contribute to the relatively low prevalence of coronary heart disease (CHD) among African descent populations in Europe [4]. However, Harding et al. showed worrying results analysing the CHD mortality trends in the UK: in 2003, for the first time since 1979, Jamaican born women had a higher age-standardised CHD death rate than those born in England and Wales [5]. Additionally, the prevalence of cardiovascular disease (CVD) is not only increasing among African descent migrants, but also in countries in SSA where these populations originate form [6]. This suggests that the cardio-protective effect of the favourable lipid profile of the African origin populations is fading [7]. Ongoing urbanisation, accompanied by consumption of energy-dense, processed food and a sedentary lifestyle, might affect the lipid profile and possibly reflects on the CVD risk of the population in SSA [8]. Moreover, contextual factors in the place of settlement after migration, such as access to healthcare and preventative services or nutrition supply, may be shaping the dyslipidaemia risk of SSA populations in Europe [9]. For instance, geographical differences have been observed in the prevalence of low HDL-C and high triglycerides among Dutch-African Caribbeans compared to English-African Caribbeans [10]. This suggests the influence of unique environmental factors on the cholesterol profile of SSA migrant populations.

Migration studies offer the opportunity to assess the influence of environmental factors on the occurrence of dyslipidaemia. However, this has never been studied in a homogenous migrant population. So far, only migration surrogates, e.g. comparing African populations residing in West Africa to African Americans and African Caribbeans that have migrated centuries ago, have been used to compare lipid profiles among African descent populations residing in different geographical locations [11,12]. However, African diaspora residents originate from heterogeneous ancestry and show high levels of genetic diversity as well as admixture with other ethnic groups [13], which makes it difficult to assess the potential impact of migration on the lipid profile of African populations [14]. Moreover, migration studies including the source population residing in the country of origin in SSA provide innovative ways of assessing the role of contexts and migration on the occurrence of dyslipidaemia, hereby increasing the understanding of factors that predispose migrant populations to the increasing CVD prevalence [15].

Therefore, the aim of this study was to compare the prevalence of dyslipidaemias among a homogenous population of Ghanaians living in rural and urban Ghana, as well as among Ghanaians living in three different European countries.

2. Materials and methods

The rationale, conceptual framework, design and methodology of the Research on Obesity and Diabetes among African Migrants (RODAM) study have been previously described elsewhere in detail [9], and will be summarized here.

2.1. Study population and study design

The RODAM study was carried out between 2012 and 2015, including Ghanaians aged ≥25–70 years, living in rural (Ashanti region) and urban Ghana (Kumasi and Obuasi), and in the cities of London, Amsterdam and Berlin. Various recruitment strategies were necessary at the different study sites, due to differences in population registration systems across European countries as well as in Ghana. For instance, in Amsterdam, participants were drawn from the municipal population registration, whereas in London and Berlin, Ghanaian organisations and churches served as the sampling frame. In rural and urban Ghana, participation rates were 76% and 74%, respectively. In Europe, the participation rates were 53% in Amsterdam, 75% in London and 68% in Berlin. In the different locations, non-respondents were younger than respondents, and men were more frequently non-respondents than women in all sites except for Berlin.

The population of Ghana constitutes of numerous different ethnic groups, of which Akan forms the largest group [16]. About half of the Ghanaian population is of Akan ethnicity, of whom the majority lives in the Central, Western and Ashanti region.

2.2. Measurements and definitions

Data collection was standardised by using standard operation procedure across all study sites. Information on demographics, ethnicity ("Which group do you belong to?"), educational level, past medical history, and lifestyle factors were obtained through questionnaires. Smoking status was classified into current and former smokers, and never smoked. Alcohol, total energy, fat, carbohydrate, and protein intake in grams per day were estimated using standard portion seizes combined with frequencies of intake based on a standardised Food Propensity Questionnaire (Ghana-FPQ). This Ghana-FPQ was based on the European-FPQ adjusted to the Ghanaian diet [17]. The WHO-STEPS questionnaire was used to derive physical activity in metabolic equivalent (MET, hours/week), which included physical activity at work, while commuting and in leisure time [18]. Answers were subsequently classified based on the guidelines of The IPAQ group [19], into low, moderate or high level of total physical activity. The use of lipid-lowering medication was assessed using the question: "Do you use cholesterol-lowering medication?". 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 waist by hip circumference. All anthropometric measurements were performed twice and the average of the two measurements was used for analysis.

Fasting venous blood samples were collected by trained research assistants after an overnight fast of at least 10 h. All samples were transported from the local research centres to Berlin, to avoid inter-laboratory bias. Information on fasting plasma glucose (FPG) concentration was obtained using an enzymatic method (hexokinase method by colorimetry). For TC, LDL-C, HDL-C and TG concentration, a ready-to-use reagent for colorimetry was used. All analyses were performed using an ABX Pentra 400 chemistry analyser (ABX Pentra; Horiba ABX, Germany). We chose to use the European Guidelines on Cardiovascular Prevention 2012 guideline [20], as this provided the most complete definition of all four dyslipidaemias

included in this study. High TC was defined as a plasma cholesterol concentration of ≥5.0 mmol/L, high TG concentration ≥1.7 mmol/L, high LDL-C concentration ≥3.0 mmol/L, and low HDL-C concentration as < 1.0 mmol/L in men and < 1.2 mmol/L in women. Dichotomisation of these variables will make it possible to identify participants at increased CVD risk, and may be clinically relevant with regard to initiation of lipid-lowering therapy. There is no international threshold for an increased TC/HDL-C ratio, and this value was therefore presented as a continuous variable.

2.3. Statistical analysis

Participants outside the age range of 25–70 and those who did not participate in the physical examination were excluded from the data analyses as were participants with missing data on lipids (Fig. 1).

All analyses were stratified by sex. Data on categorical variables were presented as frequencies and percentages with 95% confidence interval (CI), and as means and 95% CI for continuous variables, per study site and sex. Because of skewed distribution, alcohol intake was reported as median with interquartile range (IRQ). Age-standardised prevalence rates of the dyslipidaemias were calculated using the direct method, with the age distribution of the total RODAM population as standard population. Prevalence ratios (PRs) were calculated by means of Poisson regression with robust variance to examine the differences in prevalence of dyslipidaemia between the different study sites [10,21]. PRs indicate the ratio between the prevalence of an outcome in the exposed versus non-exposed population, with 'migration' being the exposing factor. Therefore, the population of rural Ghana served as the reference group, as this was conceptualised as the non-exposed group. In addition, a linear regression analysis was performed to assess geographical differences in the TC/HDL-C-ratio. Results were presented as the linear regression coefficients (β) with corresponding 95% confidence intervals. To assess the potential role of environmental factors and to adjust for confounding factors, the regression analyses were adjusted in six models. Model 1 was adjusted for age; model 2 for age and level of education; model 3 for model 2 plus physical activity and smoking (lifestyle model); model 4 for model 3 plus alcohol and daily energy intake (dietary model); model 5 for model 4 plus BMI, WHR and FPG (pathological condition model); and model 6 for model 5 plus the use of lipid-lowering medication [22]. Full case analysis was performed. Model 1 included 100% of the participants, model 2 94%, model 3 81%, and model 4 to 6 71% of the participants.

Analyses were performed using IBM SPSS Statistics version 24 (SPSS Inc. Released 2016. SPSS for Windows, Version 24.0. Chicago, SPSS Inc.). Age-standardised prevalence was calculated using R Statistics version 3.4.1 (R Core Team. 2017, R for Windows, version 3.4.1. R Foundation for Statistical Computing, Vienna, Austria).

2.4. Ethical considerations

This study was performed in accordance with the Declaration of Helsinki. Ethical approval of the study protocols was requested at all sites from the respective ethics 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) before data collection began in each country. Written informed consent was obtained from each participant prior to the enrolment in the study.

3. Results

3.1. Population characteristics

6385 Ghanaians agreed on participation, of whom 5898 completed the questionnaire, physical examination and blood sample collection. After exclusion of participants outside the age range and with missing values on blood lipid profile, 5482 participants were eligible for analysis (Fig. 1). The majority of the participants (84%) reported to be of Akan ethnicity, which was consistent between the study locations (rural Ghana 87%, urban Ghana 79%, Amsterdam 85%, Berlin 82%, and London 86%). The mean age of the population differed per geographical location, with Amsterdam-Ghanaian men, and rural- and London-Ghanaian women being slightly older compared to their counterparts at the other study sites (Table 1). Men and women in rural Ghana had the lowest level of education, whereas London- Ghanaians were most frequently highly educated. More than 95% of the European-Ghanaians were first generation migrants. Of all study populations, Berlin-Ghanaian men had the highest mean use of alcohol per day, and did smoke most frequently (15%). Ghanaians living in rural Ghana and Amsterdam were most frequently highly physical active, whereas London-Ghanaians had the lowest level of physical activity. The total energy intake was highest in Berlin and London, followed by rural Ghana, Amsterdam and urban Ghana. However, this was not reflected in BMI and waist circumference, which showed a positive gradient from

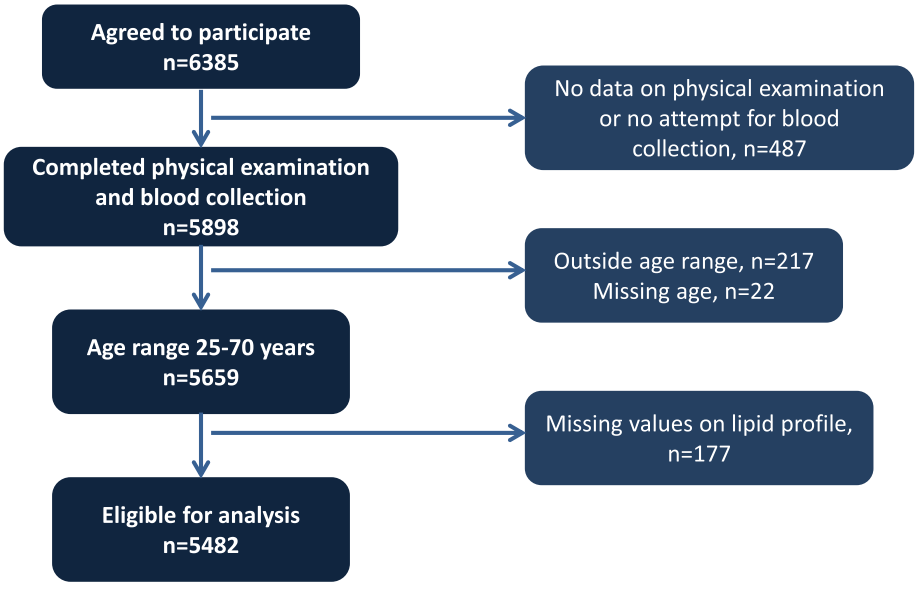

Fig. 1. Flow chart of participants eligible for analysis.

Table 1
Population characteristics by locality and sex.

	Total n (%)	Rural-Ghanaians	Urban-Ghanaians	Amsterdam-Ghanaians	Berlin-Ghanaians	London-Ghanaians
Men, n (%)		401 (19.3)	412 (19.8)	573 (27.5)	297 (14.3)	399 (19.2)
Age, years (CI)	2082 (100)	46.2 (44.9–47.4)	46.5 (45.4–47.7)	48.4 (47.6–49.2)	45.8 (44.5–47.1)	46.0 (44.9–47.1)
Education level, % (CI)	2082 (100)					
None or elementary		39.4 (34.7–44.2)	22.1 (18.3–26.3)	20.2 (17.1–23.7)	6.1 (3.8–9.2)	4.0 (2.4–6.3)
Lower secondary		35.7 (31.1–40.4)	42.7 (38.0–47.5)	41.4 (37.4–45.4)	47.8 (42.2–53.5)	25.3 (12.2–29.7)
Higher secondary		13.2 (10.2–16.8)	20.6 (16.9–24.7)	25.5 (22.0–29.2)	28.3 (23.4–33.6)	16.8 (13.4–20.7)
Tertiary		5.7 (3.8–8.3)	9.0 (6.5–12.0)	7.7 (5.7–10.1)	17.5 (13.5–22.1)	40.4 (35.6–45.2)
Unknown		6.0 (4.0–8.6)	5.6 (3.7–8.1)	5.2 (3.6–7.3)	0.3 (0.0–1.6)	13.5 (10.4–17.1)
Duration of stay in Europe, years (CI)	1121 (100)	n/a	n/a	18.5 (17.8–19.2)	16.8 (15.5–18.2)	14.9 (13.9–15.9)
First generation migrant, % (CI)	2082 (100)	n/a	n/a	98.5 (97.1–99.3)	99.3 (37.9–99.9)	98.6 (96.9–99.5)
Current smoking, yes, % (CI)	1937 (93.0)	5.8 (3.8–8.5)	3.3 (1.9–5.5)	8.0 (5.9–10.6)	14.8 (11.1–19.2)	1.4 (0.5–3.0)
Alcohol use, g/day (median, IQR)	1648 (79.2)	0.64 (3.73)	0.14 (1.5)	2.90 (9.05)	4.22 (22.15)	0.73 (2.09)
Physical activity, % (CI)	1731 (83.1)					
Low level		10.9 (8.0–14.3)	22.3 (18.3–26.6)	20.9 (17.0–25.2)	24.2 (19.6–29.3)	41.4 (36.4–46.6)
Moderate level		16.7 (13.2–20.7)	18.4 (14.8–22.5)	14.7 (11.4–18.6)	20.9 (16.5–25.8)	18.5 (14.8–22.8)
High level		71.6 (66.9–76.0)	57.8 (52.9–62.6)	59.1 (54.1–64.0)	52.2 (46.5–57.8)	30.9 (26.3–35.8)
Energy intake, kcal/day (CI)	1648 (79.2)	3023 (2877–3169)	2435 (2357–2512)	2655 (2548–2761)	3277 (3112–3442)	3146 (2972–3319)
Fat intake, g/day (CI)	1648 (79.2)	94.7 (91.1–98.4)	83.5 (80.3–86.6)	98.8 (93.4–104.2)	125.4 (117.8–133.0)	127.9 (119.0–136.8)
Carbohydrates, g/day (CI)	1648 (79.2)	446 (419–473)	334 (321–347)	332 (318–347)	393 (371–416)	385 (360–409)
Protein, g/day (CI)	1648 (79.2)	82.6 (79.1–86.2)	81.9 (79.4–84.4)	93.3 (90.2–96.3)	105.9 (101.0–110.8)	108.6 (102.9–114.3)
BMI, kg/m^2 (CI)	2078 (99.8)	20.9 (20.6–21.2)	24.2 (23.8–24.5)	27.0 (26.7–27.3)	26.4 (26.0–26.9)	27.4 (27.1–27.8)
Waist circumference, cm (CI)	2075 (99.7)	76.7 (75.9–77.5)	84.7 (83.7–85.7)	93.2 (92.3–94.1)	91.2 (89.9–92.4)	92.8 (91.7–93.8)
Waist-hip ratio (CI)	2075 (99.7)	0.89 (0.88–0.89)	0.90 (0.90–0.91)	0.95 (0.94–0.95)	0.92 (0.91–0.93)	0.90 (0.90–0.91)
Fasting plasma glucose, mmol/L (CI)	2079 (99.9)	5.1 (5.0–5.2)	5.8 (5.5–6.0)	5.7 (5.5–5.9)	5.5 (5.2–5.7)	5.3 (5.1–5.5)
Total cholesterol, mmol/L (CI)	2082 (100)	4.2 (4.1–4.3)	5.1 (5.0–5.2)	5.1 (5.0–5.1)	5.2 (5.0–5.3)	5.0 (4.9–5.1)
LDL-C, mmol/L (CI)	2082 (100)	2.5 (2.4–2.6)	3.3 (3.2–3.4)	3.3 (3.2–3.4)	3.3 (3.1–3.4)	3.3 (3.2–3.4)
HDL-C, mmol/L (CI)	2082 (100)	1.2 (1.1–2.2)	1.2 (1.2–1.2)	1.3 (1.3–1.4)	1.4 (1.4–1.5)	1.3 (1.3–1.3)
Triglycerides, mmol/L (CI)	2082 (100)	1.1 (1.0–1.1)	1.2 (1.1–1.2)	1.0 (1.0–1.1)	1.1 (1.0–1.2)	1.0 (0.9–1.0)
Use of lipid lowering medication, yes, % (CI)	2082 (100)	0	0.2 (0.0–1.1)	8.9 (6.8–11.4)	4.4 (2.5–7.2)	8.5 (6.1–11.6)
		Rural-Ghanaians	**Urban-Ghanaians**	**Amsterdam-Ghanaians**	**Berlin-Ghanaians**	**London-Ghanaians**
Women, n (%)		625 (18.4)	1030 (30.3)	860 (25.3)	250 (7.4)	365 (18.7)
Age, years (CI)	3400 (100)	46.6 (45.6–47.6)	44.7 (44.0–45.4)	44.9 (44.9–46.0)	44.7 (43.5–45.9)	47.6 (46.8–48.4)
Education level, % (CI)	3400 (100)					
None or elementary		62.2 (58.4–66.0)	50.5 (47.4–53.5)	40.7 (37.5–44.1)	11.6 (8.1–16.0)	10.2 98.1–12.8)
Lower secondary		25.6 (22.3–29.10	35.9 (33.0–38.9)	30.5 (27.5–33.6)	54.0 (47.8–60.1)	30.2 (26.8–33.9)
Higher secondary		3.0 (1.9–4.6)	8.5 (7.0–10.4)	18.3 (15.8–21.0)	24.8 (19.8–30.4)	24.3 (21.0–27.7)
Tertiary		1.9 (1.1–3.2)	2.7 (1.9–3.8)	3.8 (2.7–5.3)	7.6 (4.8–11.4)	21.9 (18.8–25.2)
Unknown		7.2 (5.4–9.4)	2.3 (1.5–3.4)	6.6 (5.1–8.4)	2.0 (0.8–4.3)	13.4 (10.9–16.2)
Duration of stay in Europe, years (CI)	1509 (100)	n/a	n/a	17.5 (16.9–18.0)	16.9 (15.7–18.2)	17.4 (16.4–18.3)
First generation migrant, % (CI)	3400 (100)	n/a	n/a	99.6 (99.0–99.9)	99.6 (98.1–100.0)	96.8 (95.1–98.0)
Current smoking, yes, % (CI)	3172 (93.3)	0.0 (0.0–0.0)	0.1 (0.0–0.5)	2.0 (1.2–3.2)	3.3 (1.5–6.0)	0.2 (0.0–0.8)
Alcohol use, g/day (median, IQR)	2685 (79.0)	0.06 (0.61)	0.06 (0.58)	0.73 (3.14)	1.13 (3.02)	0.06 (1.47)
Physical activity, % (CI)	2907 (85.5)					
Low level		23.4 (20.1–27.0)	40.3 (37.3–43.3)	16.6 (13.7–19.7)	31.3 (25.8–37.3)	42.3 (38.4–46.4)
Moderate level		23.4 (20.1–27.0)	15.8 (13.6–18.1)	21.1 (17.9–24.5)	18.3 (13.8–23.5)	23.0 (19.8–26.6)
High level		53.0 (48.9–57.0)	43.4 (40.3–46.4)	56.5 (52.5–60.5)	45.5 (39.4–51.8)	24.6 (21.2–28.2)
Energy intake, kcal/day (CI)	1648 (79.2)	2891 (2786–2996)	2292 (2249–2336)	2449 (2372–2527)	3232 (3050–3415)	2974 (2836–3111)
Fat intake, g/day (CI)	1648 (79.2)	95.3 (92.6–98.1)	81.1 (79.2–83.0)	93.0 (88.6–97.3)	123.0 (114.8–131.2)	114.0 (106.9–121.0)
Carbohydrates, g/day (CI)	1648 (79.2)	427 (407–447)	313 (306–294)	308 (298–318)	411 (383–439)	382 (363–402)
Protein, g/day (CI)	1648 (79.2)	79.5 (76.9–82.0)	76.6 (75.1–78.2)	89.0 (86.6–91.3)	107.5 (102.3–112.7)	101.2 (96.9–105.5)
BMI, kg/m^2 (CI)	3390 (99.7)	23.7 (23.3–24.0)	28.0 (27.7–28.3)	30.3 (29.9–30.6)	29.1 (28.5–29.7)	30.9 (30.5–31.3)
Waist circumference, cm (CI)	3388 (99.6)	83.8 (82.9–84.7)	91.2 (90.5–91.9)	95.8 (95.0–96.6)	93.7 (92.3–95.1)	96.7 (95.7–97.6)
Waist-hip ratio (CI)	3388 (99.6)	0.89 (0.89–0.90)	0.90 (0.90–0.91)	0.89 (0.89–0.90)	0.88 (0.87–0.89)	0.87 (0.87–0.88)
Fasting plasma glucose, mmol/L (CI)	3399 (100)	5.2 (5.0–5.3)	5.5 (5.4–5.7)	5.4 (5.3–5.4)	4.8 (4.7–5.0)	5.2 (5.1–5.3)
Total cholesterol, mmol/L (CI)	3400 (100)	4.7 (4.6–4.8)	5.3 (5.2–5.3)	5.0 (4.9–5.1)	5.1 (5.0–5.2)	5.0 (4.9–5.1)
LDL-C, mmol/L (CI)	3400 (100)	3.0 (2.9–3.0)	3.5 (3.4–3.5)	3.2 (3.1–3.2)	3.2 (3.0–3.3)	3.2 (3.1–3.2)
HDL-C, mmol/L (CI)	3400 (100)	1.2 (1.2–1.2)	1.3 (1.3–1.3)	1.5 (1.4–1.5)	1.6 (1.5–1.6)	1.5 (1.4–1.5)
Triglycerides, mmol/L (CI)	3400 (100)	1.1 (1.1–1.2)	1.1 (1.1–1.2)	0.8 (0.8–0.8)	0.9 (0.8–0.9)	0.8 (0.8–0.9)
Use of lipid lowering medication, yes, % (CI)	3399 (100)	0	0.4 (0.1–0.9)	6.7 (5.2–8.6)	4.0 (2.1–7.0)	8.5 (6.5–10.9)

Values are means or percentages with corresponding 95% confidence intervals.
CI, 95% confidence interval; IQR, Interquartile range; n/a, not available.

rural, through urban Ghana to Europe in both men and women. In men, WHR followed the same gradient. In contrast, in women WHR was highest in urban Ghana, and lowest in Berlin and London, suggesting a less favourable body fat distribution in urban Ghanaian women. FPG was comparable between rural-Ghanaian and London-Ghanaian men, and between the other three sites. In women, Berlin-Ghanaians had the lowest FPG, followed by rural- and London-Ghanaians. The use of lipid-lowering medication was more prevalent in European-Ghanaians compared to their homeland counterparts.

3.2. Total cholesterol

The age-standardised prevalence and PR of high TC were substantially higher in urban-Ghanaian compared to rural-Ghanaian man,

and comparable between urban- and European-Ghanaian men (Figs. 2A and 3A). In women, high TC was more prevalent in urban-Ghanaian compared to rural-Ghanaian women, but PRs did no longer differ between European-Ghanaian and rural-Ghanaian women after adjustment was made for BMI, WHR and FPG (Fig. 3B and Supplementary Table 1). Adjustment for the use of lipid-lowering medication or length of stay in Europe did not affect the PRs.

3.3. LDL-cholesterol

A high LDL-C level was more prevalent in all sites compared to rural Ghana, and was as prevalent in urban-Ghanaian men and even more prevalent in urban-Ghanaian women, compared to the European sites (Fig. 2A and B). In men, the PR did not differ between urban Ghana and the European sites and was about twice as high compared to rural Ghana, in various models (Fig. 3B, Supplementary Table 1). In women, the PR was higher in urban Ghana compared to rural Ghana (Fig. 3B), but did not differ from rural Ghana in European-Ghanaian women after adjustment for physical activity, smoking, energy and alcohol intake, BMI, WHR and FPG (Fig. 3B, Supplementary Table 1). Adjustment for the use of lipid-lowering medication and length of stay in Europe did not affect the PRs.

3.4. HDL-cholesterol

36% of the rural-Ghanaian men and 50% of the rural-Ghanaian women had a low HDL-C level (Fig. 2A and B). These prevalence rates were higher in the rural-Ghanaians compared to urban-Ghanaian and migrant Ghanaian counterparts, which was reflected in the PRs (Fig. 3A and B). Adjusting for multiple factors did not affect the PRs.

3.5. Triglycerides

In men, the prevalence of high TG levels did not vary between the geographical locations (Fig. 2A), whereas in women, high TG was more prevalent in rural and urban Ghana than in Europe (Fig. 2B). In men, the adjusted models showed lower PRs in migrants although the differences were non-significant (Fig. 3A). In women, PRs were higher in rural and urban Ghana compared to Europe, even after adjusting for various factors (Fig. 3B and Supplementary Table 1).

3.6. TC/HDL-C-ratio

In men, the TC/HDL-C-ratio was highest in urban Ghana (Fig. 2A). In women, the TC/HDL-C-ratio was higher in rural and urban Ghana compared to the European sites (Fig. 2B). These patterns were reflected in the PRs (Fig. 4). In Ghanaian migrant men, the coefficient became significantly different from rural Ghanaians after adjustment for BMI, WHR and FPG was made (Supplementary Table 1). In urban-Ghanaian women, the coefficient became non-significant from rural Ghana after adjustment for physical activity and smoking was made, but the differences persisted in European sites after adjusting for other factors.

Similar patterns were observed when all the European sites where combined, though the PR for high triglycerides in European-Ghanaian men became significantly lower compared to rural Ghanaian men (Supplementary Table 2). Sensitivity analysis excluding those

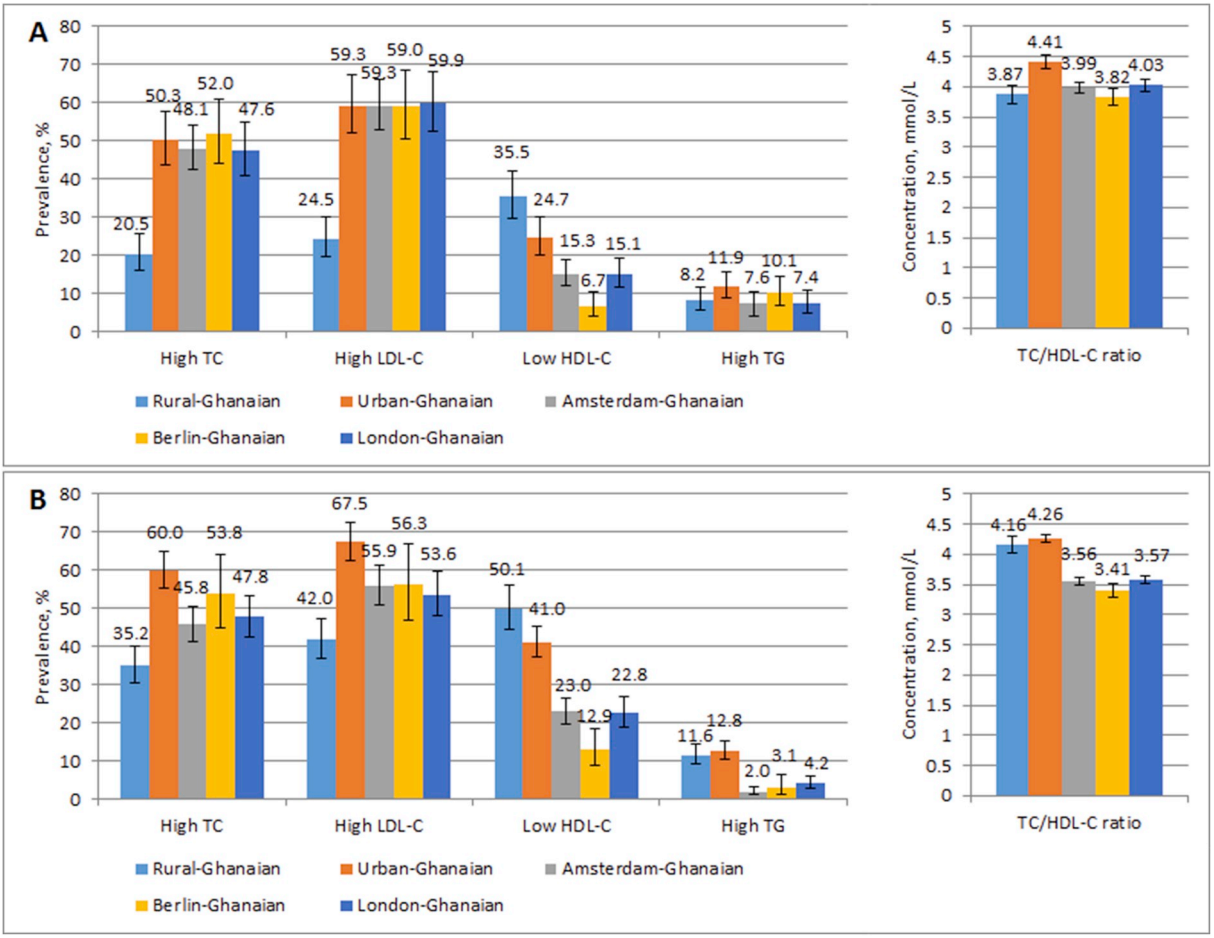

Fig. 2. Age-standardised prevalence of dyslipidaemias and TC/HDL-C ratio by locality and sex.
(A) Men, (B) women. Error bars are 95% confidence intervals.

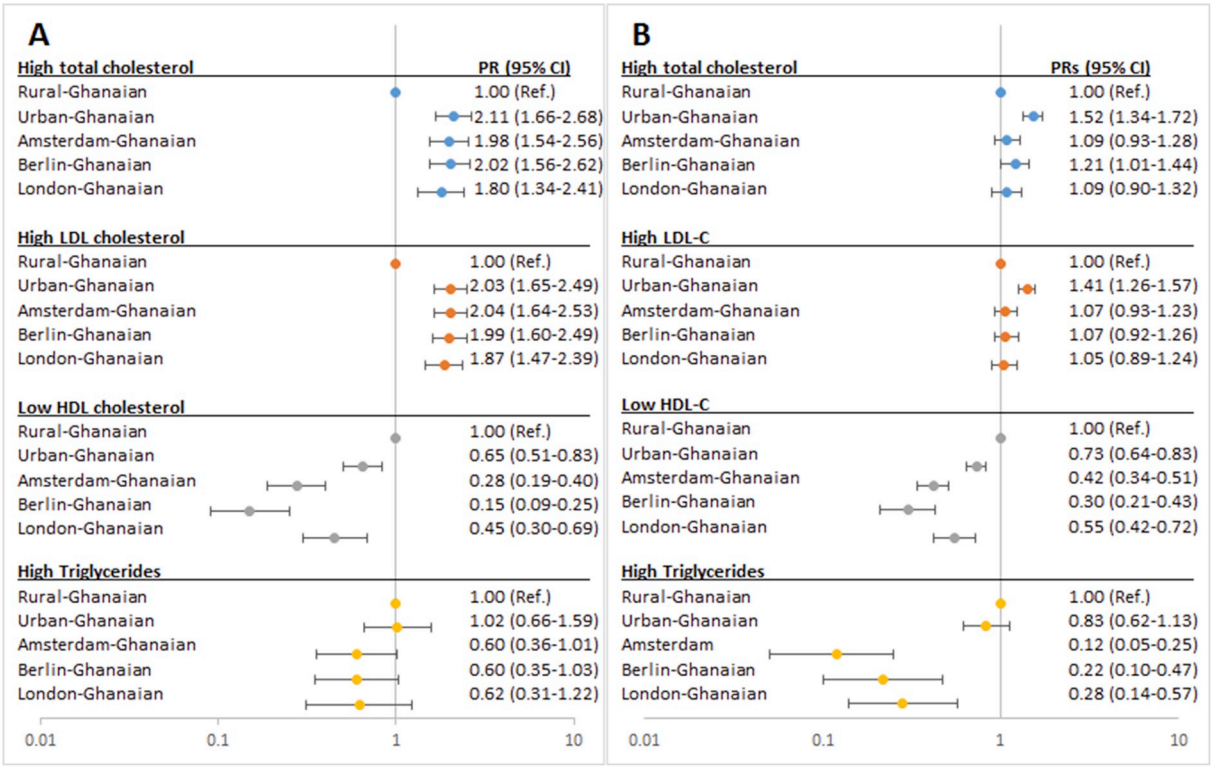

Fig. 3. Prevalence ratios of dyslipidaemias by locality and sex.
(A) Men, (B) women. Model adjusted for age, level of education, physical activity, smoking, alcohol use, total energy intake, BMI, WHR, fasting plasma glucose and use of lipid-lowering medication. Error bars are 95% confidence intervals.

participants using lipid-lowering medication did not show differences in PRs of dyslipidaemias.

4. Discussion

4.1. Key findings

The prevalence of the individual dyslipidaemias varied among homogenous African population living in different geographical locations. In men, high TC showed a positive gradient from rural to urban Ghana, but no difference between urban Ghana and Europe, reflecting the prevalence of a high LDL-C. In women, high TC and LDL-C were more prevalent in urban-Ghanaian compared to rural-Ghanaian and Ghanaian migrant women. High TG was as prevalent in rural-as in urban-Ghanaian men and women, and tended to be less prevalent in Europe, especially in women. The prevalence of low HDL-C showed a negative gradient from rural Ghana, through urban Ghana to Europe, in both men and women.

4.2. Discussion of the key findings

The observed rural-to-urban gradient in the prevalence of high TC and LDL-C levels is in line with previous Ghanaian findings, reporting that urban residency was significantly associated with higher TC and LDL-C levels [23]. This seems to suggest the influence of urbanisation on the development of dyslipidaemia. However, adjusting for variations

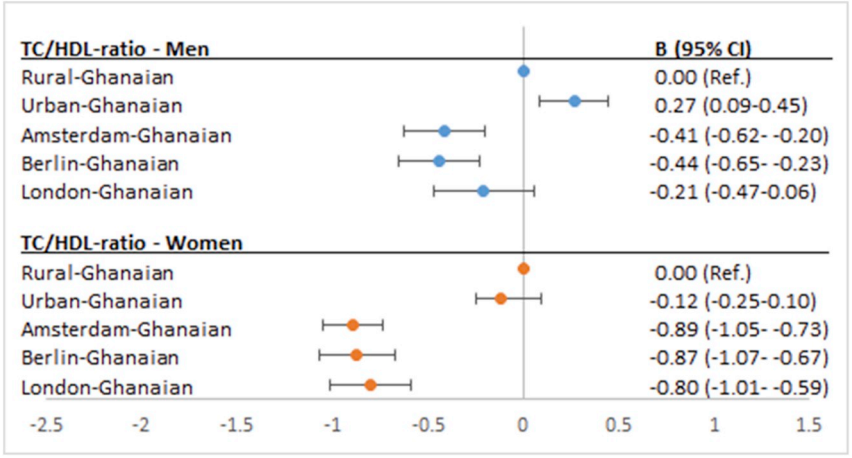

Fig. 4. Linear regression coefficients for TC/HDL-C-ratio by locality and sex.
Model adjusted for age, level of education, physical activity, smoking, alcohol use, total energy intake, BMI, WHR, fasting plasma glucose and use of lipid-lowering medication. Error bars are 95% confidence intervals.

in lifestyle and dietary factors associated with urbanisation, appeared not to explain the differences between urban-Ghanaians and rural-Ghanaians. In addition, remarkably, adjusting for BMI, WHR and FPG did not affect the rural-urban difference in lipid profile. Therefore, it seems that other factors underlie the poor lipid profile of the urban-Ghanaian population, such as the quality for dietary fat or other (micro-) nutrients, or unknown factors. In contrast, in Ghanaian migrant women, adjustment for BMI, WHR and FPG attenuated the differences in high TC and LDL-C PRs compared to their rural-Ghanaian counterparts. This suggests overweight and obesity to have an impact on the lipid profile of Ghanaian migrant women.

Within the Ghanaian population, the prevalence of low HDL-C was highest in rural Ghana, followed by urban Ghana and was lowest in their European residing counterparts. The low levels of HDL-C in rural and urban Ghana appear to outweigh the relatively high TC levels in the Ghanaian migrants, as could be observed by the TC/HDL-C-ratio. These high prevalence rates of low HDL-C in rural Ghana are in agreement with previous reports from Ghana, demonstrating a prevalence rate of 61% in rural residing women and 38% in rural residing men, with similar prevalence rates among urban residents [23]. In addition, high TG was more prevalent in the rural- and urban-Ghanaian than in the Ghanaian migrants women. A few studies from SSA reported the phenomenon of low levels of HDL-C with relatively high levels of triglycerides [23,24], a lipid pattern associated with insulin resistance [25]. As HDL-C has a key role in the transport of excessive cholesterol towards the liver for excretion, and has anti-thrombotic and anti-inflammatory properties, it fulfils an important cardio-protective role [26]. Individuals with low HDL-C levels were shown to have an increased risk for CHD, and this association was stronger in women than in men [27,28]. Thus, the high prevalence of low HDL-C in combination with high TG levels in the Ghanaian population points to an important CVD risk factor, especially among women.

HDL-levels are positively influenced by the level of physical activity [29] and moderate alcohol use [30], and negatively affected by abdominal obesity [31] and smoking [32]. Moreover, HDL-levels are low during inflammation [33]. However, adjustment for these factors did not explain the observed geographical differences. Previous RODAM results showed distinct differences in source of dietary energy intake per geographical location [17], however, adjustments for fat, carbohydrate and/or protein intake did not affect the PRs (data available upon request), suggesting that other factors may play a part. Therefore, additional research is needed to assess potential factors, such as dietary components other than macronutrients, which may be driving this low HDL-C levels in the rural-Ghanaian population.

There were marked differences between the lipid profiles among Ghanaian migrants living in different European countries. For instance, there was a lower prevalence of low HDL-C in Berlin-Ghanaian men compared to Amsterdam- and London-Ghanaian men. These differences persisted after adjustment for duration of stay in Europe (data available on request), suggesting the potential influence of national contextual factors on the lipid profiles of the respective European countries. This is in line with a previous study, showing difference in dyslipidaemia rates between populations of the same African origin, living in different European countries [10]. Prevailing health behaviour, national public health policies or access to preventative services might vary between countries, leading to differences in health between migrant populations of the same ethnic background [9]. As we conducted this study among a genetically homogenous population, the geographical differences in lipid profile between Ghanaian migrants and non-migrants are unlikely to be attributed to genetic differences. Therefore, we hypothesize that these differences might be in part attributable to epigenetic modification. Multiple epigenetic loci have shown to be associated with lipid traits [34,35], and epigenetic modifications appeared to be highly dynamic [36]. As migration coincide with major changes in environment, lifestyle and psychosocial factors, this might potentiate epigenetic modifications, affecting the lipid profile of Ghanaian migrants. In addition, contextual factors specific to the country of destination after migration, might lead to epigenetic changes, thereby potentially affecting the lipid profile of the migrant population in a country-specific way [9]. Further research is needed to establish potential intercountry factors, such as epigenetic differences, contributing to the observed differences among Ghanaian migrants residing in different European countries.

Compared to the respective European host populations, Ghanaian migrants had lower levels of TC and TG [37–39]. For instance, the prevalence of high TC was 66% in Dutch, compared to 48% in Amsterdam-Ghanaians men [37], and TG was high in 13% of the German women compared to 8% in the Berlin-Ghanaian women in our study [40]. LDL-C levels were comparable between the Ghanaian migrant and the European host populations [39,41,42]. However, the prevalence of a low HDL-C level was higher in the Ghanaian migrant population compared to the European host populations, especially among women. 22% of the Dutch [43], 14% of the German [40], and 16% of the English women [10] have a low HDL-C level, compared to 38%, 30%, and 40% in Amsterdam-, Berlin-, and London-Ghanaian women in this study, respectively. These observed ethnic differences in lipid profile are possibly due to ethnic specific genetic differences between the Ghanaian migrants and European host population [44]. Despite the lower TC and TG levels in Ghanaian migrants compared to the European host population, the high prevalence of high LDL-C and even higher prevalence of low HDL-C levels in the Ghanaian migrants than in the European host population are of great concern with regard to the CHD risk of this SSA population.

Historically, African descent populations in the USA and Europe were shown to have lower CHD prevalence rates compared to the European descent population [3,45,46]. In SSA, the CHD mortality was far below the global CHD mortality rate [47]. However, 2016 data show a higher prevalence of CHD in African-American women compared to European-American women [48]. Moreover, in Europe a trend towards higher CHD event rates in SSA migrant women compared to women of the Western European host population could be observed [49]. In addition, in SSA, the number of CHD deaths increased by almost 90% in the 1990–2013 time period [6]. The high prevalence of dyslipidaemia in this current study does not bode well for the future trend in CHD burden in the African population in Europe and SSA, if preventive measurements are not put into place.

4.3. Strengths and limitations

The use of a study population of Ghanaians living in different geographical locations in Africa and Europe, is a unique strength of the RODAM study, hereby providing the opportunity to assess migration-related factors and intercountry differences in dyslipidaemia. One previous study has tried to assess the influence of international migration on the lipid profile of the SSA population [12], but this was based on heterogeneous (Ghanaians, Nigerians and African-Americans) African populations. Another strength of this study is the use of highly standardised operating procedures across all study locations, assuring for uniform data collection at the different study sites.

Given the cross-sectional nature of this study, conclusions regarding the causality should be drawn with caution. Due to differences in registration systems per geographical location, the recruitment strategies had to be adapted to suit the various study locations. In Amsterdam, participants were drawn from the municipality registration, whereas in London and Berlin, Ghanaians were recruited via membership lists of Ghanaian organisations and churches in these cities. However, given that a majority of the Ghanaian migrants is affiliated with Ghanaian organisations [9,50], we believe that the used recruitment strategy has led to a study population that is fairly representative of the Ghanaian population in Europe.

As non-respondents were younger compared to respondents, an overestimation of the prevalence of the dyslipidaemias could have

occurred. However, as the pattern of non-response was consistent across the geographical locations, we consider the comparison of lipid profile between the locations to be valid.

4.4. Conclusion

The prevalence of dyslipidaemias is high in the Ghanaian population, in both men and women, in rural and urban environments in Africa and in Ghanaian migrant population in Europe despite the important variations across sites. In order to create an effective strategy for the prevention and control of dyslipidaemia among SSA populations, additional research is needed to establish key factors driving these geographical differences in lipid profiles.

Conflicts of interest

The authors declared they do not have anything to disclose regarding conflict of interest with respect to this manuscript.

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Author contributions

CA and EL conceived the study. CA, EB, KM, FPM, AGA, EOD, and JA, LS, SB, MBS, ID, and KKG designed and carried out the recruitment and data collection. EL performed the statistical analysis and wrote the manuscript, supervised by CA and in cooperation with all co-authors. All authors read and approved the final version of the manuscript.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.atherosclerosis.2019.02.030.

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