



# BMJ Open Cardiovascular risk factors and markers of myocardial injury and inflammation in people living with HIV in Nairobi, Kenya: a pilot cross-sectional study

Hassan Adan Ahmed <sup>1</sup>, Jeilan Mohamed,<sup>1</sup> Isaiah G Akuku,<sup>2</sup> Kuan Ken Lee,<sup>3</sup> Shirjel R Alam <sup>4,5</sup>, Pablo Perel,<sup>4</sup> Jasmit Shah,<sup>1</sup> Mohammed K Ali,<sup>6,7</sup> Sherry Eskander,<sup>8</sup> Michael H Chung,<sup>9</sup> Anoop SV Shah<sup>4,10</sup>

**To cite:** Ahmed HA, Mohamed J, Akuku IG, *et al*. Cardiovascular risk factors and markers of myocardial injury and inflammation in people living with HIV in Nairobi, Kenya: a pilot cross-sectional study. *BMJ Open* 2022;**12**:e062352. doi:10.1136/bmjopen-2022-062352

► Prepublication history and additional supplemental material for this paper are available online. To view these files, please visit the journal online (<http://dx.doi.org/10.1136/bmjopen-2022-062352>).

MHC and ASS contributed equally.

Received 28 February 2022  
Accepted 20 May 2022



© Author(s) (or their employer(s)) 2022. Re-use permitted under CC BY-NC. No commercial re-use. See rights and permissions. Published by BMJ.

For numbered affiliations see end of article.

## Correspondence to

Dr Anoop SV Shah;  
[Anoop.Shah@ishtm.ac.uk](mailto:Anoop.Shah@ishtm.ac.uk)

## ABSTRACT

**Objectives** To determine the prevalence of cardiovascular disease (CVD) risk factors and explore associations with high-sensitivity cardiac troponin I (hsctnI) and high-sensitivity C-reactive protein (hsCRP) in people living with HIV (PLHIV) in Kenya.

**Design** Pilot cross-sectional study.

**Setting** Data were collected from community HIV clinics across two sites in Nairobi, Kenya, from July 2019 to May 2020.

**Participants** Convenience sample of 200 PLHIV (≥30 years with no prior history of CVD).

**Outcome measures** Prevalence of cardiovascular risk factors and its association with hsctnI and hsCRP levels.

**Results** Across 200 PLHIV (median age 46 years, IQR 38–53; 61% women), the prevalence of hypercholesterolaemia (total cholesterol >6.1 mmol/L) and hypertension were 19% (n=30/199) and 30% (n=60/200), respectively. Smoking and diabetes prevalence was 3% (n=5/200) and 4% (n=7/200). HsctnI was below the limit of quantification (<2.5 ng/L) in 65% (n=109/169). High (>3 mg/L), intermediate (1–3 mg/L) and low (<1 mg/L) hsCRP levels were found in 38% (n=75/198), 33% (n=65/198) and 29% (n=58/198), respectively. Framingham laboratory-based risk scores classified 83% of PLHIV at low risk with 12% and 5% at intermediate and high risk, respectively. Older age (adjusted OR (aOR) per year increase 1.05, 95% CI 1.01 to 1.08) and systolic blood pressure (140–159 mm Hg (aOR 2.96; 95% CI 1.09 to 7.90) and >160 mm Hg (aOR 4.68, 95% CI 1.55 to 14) compared with <140 mm Hg) were associated with hsctnI levels. No associations were observed between hsCRP and CVD risk factors.

**Conclusion** The majority of PLHIV—using traditional risk estimation systems—have a low estimated CVD risk likely reflecting a younger aged population predominantly consisting of women. Hypertension and hypercholesterolaemia were common while smoking and diabetes rates remained low. While hsctnI values were associated with increasing age and raised blood pressure, no associations between hsCRP levels and traditional cardiovascular risk factors were observed.

## INTRODUCTION

More than 35 million people are infected with the HIV with two-thirds being resident

## STRENGTHS AND LIMITATIONS OF THIS STUDY

- ⇒ Involvement of people living with HIV from a low-income and middle-income settings and from distinct socioeconomic backgrounds.
- ⇒ Assessment of relatively novel biochemical markers of cardiovascular risk alongside more traditional cardiovascular risk factors.
- ⇒ Due to the cross-sectional design, we were unable to evaluate the associations between novel biochemical markers and future cardiovascular events.
- ⇒ The study population was from an urban setting, so generalisability to rural settings is limited.
- ⇒ There was no age-matched and sex-matched uninfected control group.

in sub-Saharan Africa.<sup>1</sup> Although the global incidence for HIV has stabilised, the wide availability of combined antiretroviral therapy (ART) has dramatically improved survival, resulting in a steady increase in prevalence over the last two decades.<sup>2,3</sup> This improvement in survival has been primarily attributed to a reduction in opportunistic infections especially in low-income and lower-middle-income nations. Conversely, mortality due to non-communicable illnesses especially cardiovascular disease (CVD) has been rising and now account for the majority of deaths in people living with HIV (PLHIV).<sup>1,4–7</sup>

PLHIV-based on studies in high-income countries—have a higher risk of CVD.<sup>8,9</sup> Despite this higher risk, previous studies have indicated that PLHIV in sub-Saharan Africa have a lower prevalence of traditional cardiovascular risk factors in comparison to uninfected individuals.<sup>8,10</sup> Strategies to risk stratify and mitigate CVD in this population is now urgently required but is challenging in resource limited nations<sup>11</sup> and it remains

unclear on optimal approaches with recommendations differing across regions globally.<sup>12</sup>

In this cross-sectional pilot study of PLHIV in Kenya, we evaluate the prevalence of traditional cardiovascular risk factors and the distribution of estimated cardiovascular risk using traditional risk scores. We further explore the distribution of markers of myocardial injury and inflammation in this population. Our additional objectives are to evaluate the logistic feasibility, including recruitment rates, for a full-scale study investigating mechanisms in HIV-associated CVD.

## METHODS

### Study setting and population

This was a pilot, prospective, cross-sectional study of PLHIV  $\geq 30$  years in Nairobi, Kenya. Population sample size was determined based on the fixed recruitment period from July 2019 to May 2020. Patients were recruited based on convenient sampling and invited to participate as long as they received care at the two clinical sites (Aga Khan University Hospital and Coptic Hope Center for Infectious Diseases) where the researchers and their research teams were based. Aga Khan University Hospital is a fee-for-service tertiary care centre generally serving a more affluent population while the Coptic Hope Center for Infectious Diseases is a Centre of Disease Control President's Emergency Plan For AIDS Relief funded institution to provide free ART to Kenyans who are unable to afford HIV care and treatment.<sup>13</sup> Participants with known CVD (previous myocardial infarction or stroke) were excluded.

### Study procedures and blood sampling

All participants completed a standardised questionnaire to capture data on demographics, including self-reported cardiovascular risk factors, medical history, current medication and HIV factors including time since diagnosis. Data were captured on handheld devices electronically. Anthropometric and haemodynamic data including office blood pressure, height, weight and heart rate were captured.

### Blood sampling

Blood samples were obtained from participants through standard venepuncture. Basic clinical chemistry and haematology was performed. This included assessment of renal function, glycaemic control, non-fasted lipid profiles, high-sensitivity cardiac troponin I (hsTnI) and high-sensitivity C-reactive protein (hsCRP). Given laboratory constraints, haemoglobin A1c (HbA1c) and haematology was only measured in the Aga Khan University Hospital population.

### High-sensitivity troponin I

The Siemens Atellica IM High Sensitivity Troponin I assay (Siemens Healthineers) is a three-site sandwich immunoassay with a limit of detection of 1.6 ng/L and

limit of quantification of 2.5 ng/L. The upper reference limit 99th centile was determined in 2007 samples from healthy individuals as 34 ng/L in women, and 53 ng/L in men, with a single threshold of 45 ng/L. In the reference range population, 75% of patients had values greater than the limit of detection. The level where the interassay coefficient of variation is  $< 10\%$  is 6 ng/L.<sup>14</sup>

### HsCRP

The Siemens Atellica hsCRP assay was used to measure hsCRP levels in stored serum. The assay range is from 0.1 to 50 mg/L with a coefficient of variation of 6.8% at 1.16 mg/L.<sup>15</sup>

### Study definitions

Traditional cardiovascular risk factors were defined as those routinely measured in cardiovascular risk estimation systems and include basic anthropometry, diabetes and smoking status, lipid profile and arterial blood pressure assessment. Body mass index was calculated from measured height and weight and classified as normal weight (18.5–24.9 kg/m<sup>2</sup>), overweight (25.0–29.9 kg/m<sup>2</sup>) and obese (equal to or greater than 30.0 kg/m<sup>2</sup>). Current or past smoking history was self-reported by participants. Hypertension was defined as self-reported hypertension or measured systolic blood pressure (SBP)  $\geq 140$  mm Hg or diastolic blood pressure (DBP)  $\geq 90$  mm Hg, or physician-prescribed blood pressure-lowering medications.<sup>16</sup> Dyslipidaemia was defined as a self-reported history. Hypercholesterolaemia was defined as a total cholesterol  $\geq 6.21$  mmol/L. A high low-density lipoprotein (LDL) was defined as levels  $> 4.1$  mmol/L.<sup>17</sup> Diabetes mellitus was defined as self-reported type 1 or 2 diabetes mellitus. Patients, in whom HbA1c was measured, were classified as those with high ( $\geq 6.5\%$ ), intermediate (5.7%–6.4%) and low levels ( $< 5.7\%$ ).<sup>18</sup> The hsCRP was categorised as low ( $< 1$  mg/L), intermediate (1–3 mg/L) or high ( $> 3$  mg/L).<sup>19</sup> HscTnI levels were categorised as below the limit of quantification (2.5 ng/L), above the limit of quantification but below the 99th centile upper reference limit and above the 99th centile upper reference limit (45 ng/L).<sup>20</sup>

### Statistical analysis

Baseline demographics, clinical and lifestyle variables, laboratory biomarkers including markers of myocardial injury, inflammation, glycaemic control and lipid profiles were summarised overall and stratified by gender. Continuous variables were reported as median and IQR, while the categorical variables were summarised as frequencies and percentages. Statistical differences between groups were assessed using Pearson's  $\chi^2$  test or Fisher's exact test and unpaired two-samples Wilcoxon test or Student's t-test as indicated. Sex-specific Framingham laboratory-based risk equations were used to quantify the estimated 10-year CVD risk for each study participant. The equation used age, gender, smoking status, use of anti-hypertensive medications, prevalent diabetes and SBP.

**Table 1** Baseline demographics and clinical characteristics\*

Characteristics	All patients (n=200)	Sex		P value†
		Females (n=121)	Males (n=79)	
Age, median (Q1, Q3), years	45.5 (37.7, 52.6)	44.2 (37.3, 50.5)	47.3 (38.0, 53.1)	0.206
Years of education, median (Q1, Q3)	14.0 (12.0, 16.0)	14.0 (12.0, 16.0)	15.0 (12.0, 16.5)	0.174
Highest level of education attained				
Primary/none/do not know, %	30/200 (15.0)	18/121 (14.9)	12/79 (15.2)	0.825
Secondary, %	45/200 (22.5)	29/121 (24.0)	16/79 (20.3)	
Higher education/university, %	125/200 (62.5)	74/121 (61.2)	51/79 (64.6)	
Marital status				
Married (monogamous/polygamous), %	128/200 (64.0)	64/121 (52.9)	64/79 (81.0)	<0.001
Single	26/200 (13.0)	23/121 (19.0)	3/79 (3.8)	
Separated/widowed/divorced/refused/cohabiting/others, %	46/200 (23.0)	34/121 (28.1)	12/79 (15.2)	
Employment status				
Salaried Job or self-employed, %	180/200 (90.0)	105/121 (86.8)	75/79 (94.9)	0.148
Unemployed/housewife/retiree, %	13/200 (6.5)	11/121 (9.1)	2/79 (2.5)	
Casual labourer, %	7/200 (3.5)	5/121 (4.1)	2/79 (2.5)	
Household income per month				
<15001 KES, %	34/198 (17.2)	26/119 (21.8)	8/79 (10.1)	0.051
>15001 KES, %	164/198 (82.8)	93/119 (78.2)	71/79 (89.9)	
Cardiovascular risk factors				
Smoking				
Current smoker, %	5/200 (2.5)	2/121 (1.7)	3/79 (3.8)	<0.001
Ex-smoker, %	44/200 (22.0)	11/121 (9.1)	33/79 (41.8)	
Never smoker, %	151/200 (75.5)	108/121 (89.3)	43/79 (54.4)	
Diabetes, %	7/200 (3.5)	4/121 (3.3)	3/79 (3.8)	0.661
Self-reported hypertension,‡ %	44/200 (22.0)	30/121 (24.8)	14/79 (17.7)	0.315
Cumulative hypertension,§ %	60/200 (30.0)	34/121 (28.1)	26/79 (32.9)	0.570
Self-reported dyslipidaemia, %	1/197 (0.5)	1/119 (0.8)	0/78 (0.0)	0.153
Chronic kidney disease, %	2/200 (1.0)	1/121 (0.8)	1/79 (1.3)	0.863
HIV				
Time since (months) HIV infection, median (Q1, Q3)	143.0 (59.0, 191.0)	144.0 (62.0, 191.0)	131.0 (56.5, 191.0)	0.574
Currently on ART, %	195/200 (97.5)	119/121 (98.3)	76/79 (96.2)	0.385
Medical history				
Malaria, %	21/200 (10.5)	10/121 (8.3)	11/79 (13.9)	0.298
Tuberculosis, %	12/200 (6.0)	7/121 (5.8)	5/79 (6.3)	1.000
Clinical characteristics				
Body mass index, BMI (Kg/m <sup>2</sup> ), median (Q1, Q3)	26.8 (23.4, 30.8)	27.9 (23.8, 32.3)	26.0 (23.2, 29.6)	<b>0.010</b>
BMI <25, %	71/200 (35.5)	37/121 (30.6)	34/79 (43.0)	0.100
BMI 25–29, %	71/200 (35.5)	43/121 (35.5)	41/79 (33.9)	
BMI >30, %	58/200 (29.0)	41/121 (33.9)	17/79 (21.5)	
Systolic blood pressure (mm Hg), median (Q1, Q3), n=200	120.0 (110.0, 133.0)	120.0 (110.0, 130.0)	122.0 (111.5, 133.0)	0.272

Continued



Table 1 Continued

Characteristics	All patients (n=200)	Sex		P value†
		Females (n=121)	Males (n=79)	
SBP <130 mm Hg, %	136/200 (68.0)	86/121 (71.1)	50/79 (63.3)	0.173
SBP 130–139 mm Hg, %	30/200 (15.0)	19/121 (15.7)	11/79 (13.9)	
SBP 140–159 mm Hg, %	19/200 (9.5)	7/121 (5.8)	12/79 (15.2)	
SBP >160 mm Hg, %	15/200 (7.5)	9/121 (7.4)	6/79 (7.6)	
Diastolic blood pressure (mm Hg), median (Q1, Q3), n=200	78.0 (71.0, 85.0)	77.0 (71.0, 84.0)	80.0 (72.0, 85.0)	0.301
DBP <85 mm Hg, %	149/200 (74.5)	92/121 (76.0)	57/79 (72.2)	0.417
DBP 85–89 mm Hg, %	22/200 (11.0)	10/121 (8.3)	12/79 (15.2)	
DBP 90–99, %	17/200 (8.5)	12/121 (9.9)	5/79 (6.3)	
DBP >100, %	12/200 (6.0)	7/121 (5.8)	5/79 (6.3)	
Heart rate (bpm) median (Q1, Q3)	78.0 (74.0, 82.0)	76.5 (74.8, 84.2)	78.0 (72.0, 81.0)	0.474
Current cardiovascular medications				
RAAS modulators, %	16/200 (8.0)	11/121 (9.1)	5/79 (6.3)	0.662
Calcium channel blockers, %	8/200 (4.0)	5/121 (4.1)	3/79 (3.8)	1.000
Beta-blockers, %	8/200 (4.0)	5/121 (4.1)	3/79 (3.8)	1.000
Diuretics, %	10/200 (5.0)	8/121 (6.6)	2/79 (2.5)	0.321
Statins, %	2/200 (1.0)	1/121 (0.8)	1/79 (1.3)	1.000

\*Number of patients may not sum to the corresponding column totals where there are missing data for the variable.  
†P value from  $\chi^2$  test or Fisher's exact test for categorical variables and unpaired two-sample Wilcoxon test for continuous variables, two-sided; bold p values indicate statistical significance ( $p < 0.05$ ).  
‡Self-reported physician-diagnosed hypertension.  
§Self-reported hypertension or measured systolic blood pressure (SBP)  $\geq 140$  mm Hg or diastolic blood pressure (DBP)  $\geq 90$  mm Hg, or physician-prescribed blood pressure-lowering medications.  
ART, antiretroviral therapy; HDL, high density lipoprotein; KES, Kenya shillings currency code; RAAS, Renin-angiotensin-aldosterone system.

The risk estimations were computed according to algorithms accessed at <https://framinghamheartstudy.org/fhs-risk-functions/cardiovascular-disease-10-year-risk/>. Predicted cardiovascular event risk percentage over the next 10 years was classified as low (<10%), intermediate (10%–20%) and high risk (>20%).

In further analysis, we evaluated the relationship between baseline markers of myocardial injury and inflammation and traditional cardiovascular risk factors. We calculated the 25th and 75th percentiles of observed hscTnI data and ordinally scaled it as <2.50 ng/L (undetectable), 2.50–3.02 ng/L, 3.02–7.12 ng/L,  $\geq 7.12$  ng/L given the skewness of the variable.<sup>21</sup> Three multivariable ordinal (cumulative logit) models and linear regression models with hscTnI and hsCRP as the response variable, respectively, were fitted. The independent variables were age, sex and cardiovascular risk factors. Model I adjusted for age per year increase, sex, study site as a surrogate for socioeconomic status and creatinine. Model II additionally adjusted for hypertension, diabetes and smoking status (never smoker, former smoker, current smoker). Model III adjusted for variables in Model I plus SBP (SBP <130 mm Hg, SBP 130–139 mm Hg, SBP 140–159 mm Hg, SBP >160 mm Hg) and hsCRP or hscTnI. Models

were constructed on complete cases with no imputation. All analysis was carried out in R (V.4.1.2).

Patients were enrolled only after providing written informed consent prior to participation. Site approval was obtained from the Coptic Hope Center for Infectious Diseases in Nairobi. The research was carried out in accordance with the Helsinki Declaration's principles.

### Patient and public involvement

No patient involvement.

### RESULTS

Two hundred patients (median age 46 years (IQR 38–53 years), 61% women) were recruited in this cross-sectional study consisting (online supplemental figure S1). Prevalence of smoking was 2.5% across the cohort and higher in men compared with women. Hypertension was the most common cardiovascular risk factor at 30% with rates higher in men (33%) compared with women (28%). Self-reported dyslipidaemia was low at 0.5% but much higher when classified according to a total cholesterol concentration >6.1 mmol/L (19%). The prevalence of elevated LDL  $\geq 4.2$  mmol/L was 14%. Seventeen per cent of the



**Table 2** Biochemistry and haematology\*

Characteristics	All patients (n=200)	Sex		P value†
		Females (n=121)	Males (n=79)	
Creatinine, median (Q1, Q3), n=197	85.0 (73.0, 101.0)	77.5 (69.0, 89.3)	99.0 (89.0, 113.0)	<b>&lt;0.001</b>
Urea, median (Q1, Q3), n=196	3.7 (3.1, 4.6)	3.6 (3.0, 4.3)	3.8 (3.2, 5.0)	<b>0.013</b>
Haemoglobin, mean (SD), n=98*‡	14.01 (2.06)	12.90 (1.77)	15.31 (1.55)	<b>&lt;0.001</b>
Glucose, median (Q1, Q3), n=197	4.8 (4.4, 5.3)	4.8 (4.3, 5.3)	4.9 (4.5, 5.3)	0.169
HbA1c, median (Q1, Q3), n=98*‡	5.6 (5.4, 5.9)	5.6 (5.4, 5.8)	5.8 (5.4, 6.1)	<b>0.013</b>
HbA1c <5.7, %	50/98 (51.0)	34/53 (64.2)	16/45 (35.6)	<b>0.004</b>
HbA1c 5.7–6.4, %	45/98 (45.9)	19/53 (35.8)	26/45 (57.8)	
HbA1c ≥6.5, %	3/98 (3.1)	0/53 (0.0)	3/45 (6.7)	
Lipid profiles				
Total cholesterol, median (Q1, Q3), n=196	4.6 (3.9, 5.1)	4.7 (3.9, 5.2)	4.5 (3.9, 5.1)	0.706
TC <4.7, %	107/196 (54.6)	59/118 (50.0)	48/78 (61.5)	0.393
TC 4.8–5.1, %	22/196 (11.2)	15/118 (12.7)	7/78 (9.0)	
TC 5.2–6.1, %	30/196 (15.3)	21/118 (17.8)	9/78 (11.5)	
TC ≥6.2, %	37/196 (18.9)	23/118 (19.5)	14/78 (17.9)	
LDL, median (Q1, Q3), n=196	3.0 (2.3, 3.6)	3.0 (2.4, 3.7)	3.0 (2.3, 3.5)	0.747
LDL <2.6	75/196 (38.3)	46/118 (39.0)	29/78 (37.2)	0.619
LDL 2.6–3.3	53/196 (27.0)	30/118 (25.4)	23/78 (29.5)	
LDL 3.4–4.1	41/196 (20.9)	23/118 (19.5)	18/78 (23.1)	
LDL ≥4.2	27/196 (13.8)	19/118 (16.1)	8/78 (10.3)	
HDL, median (Q1, Q3), n=196	1.2 (1.0, 1.5)	1.2 (1.1, 1.5)	1.1 (1.0, 1.3)	<b>0.001</b>
Triglycerides, median (Q1, Q3), n=196	1.4 (0.9, 2.0)	1.2 (0.9, 1.7)	1.7 (1.0, 2.7)	<b>0.0005</b>
Trig <1.7	123/196 (62.8)	86/118 (72.9)	37/78 (47.4)	<b>&lt;0.0001</b>
Trig 1.7–2.2	32/196 (16.3)	19/118 (16.1)	13/78 (16.7)	
Trig >2.3	41/196 (20.9)	13/118 (11.0)	28/78 (35.9)	
Cardiac and inflammatory biomarkers				
High sensitivity troponin I, median (Q1, Q3), n=169	2.5 (2.5, 3.0)	2.5 (2.5, 2.5)	2.7 (2.5, 3.8)	<b>&lt;0.0001</b>
hscTnI <2.5 ng/L, %	109/169 (64.5)	78/103 (75.7)	31/66 (47.0)	<b>&lt;0.001</b>
hscTnI 2.5–45 ng/L	59/169 (34.9)	24/103 (23.3)	35/66 (53.0)	
hscTnI ≥45 ng/L	1/169 (0.6)	1/103 (1.0)	0/66 (0.0)	
High-sensitivity CRP, median (Q1, Q3), n=198	2.0 (0.8, 4.2)	2.2 (0.9, 4.5)	1.5 (0.8, 3.8)	0.144
hsCRP <1 mg/L	58/198 (29.3)	31/120 (25.8)	27/78 (34.6)	0.300
hsCRP 1–3 mg/L	65/198 (32.8)	39/120 (32.5)	26/78 (33.3)	
hsCRP >3 mg/L	75/198 (37.9)	50/120 (41.7)	25/78 (32.1)	

\*Number of patients may not sum to the corresponding column totals where there are missing data for the laboratory marker.

†P value from  $\chi^2$  test or Fisher's exact test for categorical variables and unpaired two-sample Wilcoxon test or Student's t-test for continuous variables, two-sided; bold p values indicate statistical significance ( $p < 0.05$ ).

‡\* Haemoglobin and haemoglobin A1c (HbA1c) summaries are from Aga Khan University Hospital only.

hsCRP, high-sensitivity C-reactive protein ; hscTnI, high-sensitivity cardiac troponin I; LDL, low-density lipoprotein .

population had a SBP  $\geq 140$  mm Hg and 15% of the population had a DBP  $\geq 90$  mm Hg. Obesity rates were high with 29% considered obese and 36% overweight. Obesity rates were higher in women at 34% compared with men (22%). Prior history of malaria and tuberculosis remained high at 11% and 6%, respectively. Over 90% of participants were receiving ART and

median duration of diagnosis to study recruitment was 12 years (tables 1 and 2). Given differences in the population served at Aga Khan University and Coptic hospitals, we observed important differences in baseline characteristics. Patient treated at Coptic hospital has lower income levels and higher rates of elevated blood pressure (online supplemental table S1).

**Table 3** Cardiovascular risk factors, markers of myocardial injury and inflammation by cardiovascular risk category\*

Variable	Framingham risk score classification (lipid)†			P value for trend‡	
	Low	Intermediate	High	Increasing	Two-sided
<b>Males</b>					
All (%)	58 (73.4)	14 (17.7)	7 (8.9)		
Smoking				–	0.503
Current smoker, %	3/58 (5.2)	0/14 (0.0)	0/7 (0.0)		
Ex-smoker, %	22/58 (37.9)	6/14 (42.9)	5/7 (71.4)		
Never smoker, %	33/58 (56.9)	8/14 (57.1)	2/7 (28.6)		
Diabetes, %	3/58 (5.2)	0/14 (0.0)	0/7 (0.0)	0.163	0.326
Hypertension,§ %	12/58 (20.7)	6/14 (42.9)	7/7 (100.0)	<b>&lt;0.001</b>	<b>&lt;0.001</b>
Hyperlipidaemia, %	0/58 (0.0)	0/13 (0.0)	0/7 (0.0)	–	–
Lipid profiles					
Total cholesterol, median (Q1, Q3)	4.3 (3.8, 4.9)	4.5 (4.3, 5.4)	6.2 (5.0, 6.8)	<b>0.005</b>	<b>0.007</b>
TC <4.7, %	39/57 (68.4)	8/14 (57.1)	1/7 (14.3)	–	<b>&lt;0.001</b>
TC 4.8–5.1, %	7/57 (12.3)	0/14 (0.0)	0/7 (0.0)		
TC 5.2–6.1, %	5/57 (8.8)	4/14 (28.6)	0/7 (0.0)		
TC ≥6.2, %	6/57 (10.5)	2/14 (14.3)	6/7 (85.7)		
LDL, median (Q1, Q3)	3.0 (2.3, 3.4)	3.2 (2.3, 3.5)	3.9 (3.5, 5.2)	<b>0.016</b>	<b>0.039</b>
Cardiac and inflammatory biomarkers					
High sensitivity troponin I, median (Q1, Q3)	2.5 (2.5, 3.4)	3.4 (2.8, 5.2)	4.1 (2.9, 7.1)	<b>0.013</b>	<b>0.020</b>
hscTnI <2.5 ng/L, %	26/48 (54.2)	3/11 (27.3)	2/7 (28.6)	–	0.083
hscTnI 2.5–45 ng/L	22/48 (45.8)	8/11 (72.7)	5/7 (71.4)		
hscTnI ≥45 ng/L	0/48 (0.0)	0/11 (0.0)	0/7 (0.0)		
High-sensitivity CRP, median (Q1, Q3)	1.5 (0.8, 4.0)	2.3 (0.8, 3.1)	1.0 (0.7, 3.6)	0.523	0.95
hsCRP <1 mg/L	19/57 (33.3)	5/14 (35.7)	3/7 (42.9)	–	0.782
hsCRP 1–3 mg/L	20/57 (35.1)	4/14 (28.6)	2/7 (28.6)		
hsCRP >3 mg/L	18/57 (31.6)	5/14 (35.7)	2/7 (28.6)		
Creatinine, median (Q1, Q3)	100.0 (89.5, 113.2)	98.5 (94.8, 115.0)	91.0 (79.0, 104.5)	0.702	0.610
<b>Females</b>					
All (%)	108 (89.3)	9 (7.4)	4 (3.3)		
Smoking					
Current smoker, %	2/108 (1.9)	0/9 (0.0)	0/4 (0.0)	–	0.241
Ex-smoker, %	11/108 (10.2)	0/9 (0.0)	0/4 (0.0)		
Never smoker, %	95/108 (88.0)	9/9 (100.0)	4/4 (100.0)		
Diabetes, %	0/108 (0.0)	2/9 (22.2)	2/4 (50.0)	1.000	<b>&lt;0.0001</b>
Hypertension,§ %	24/108 (22.2)	7/9 (77.8)	3/4 (75.0)	<b>&lt;0.0001</b>	<b>&lt;0.001</b>
Hyperlipidaemia, %	0/106 (0.0)	1/9 (11.1)	0/4 (0.0)	0.976	<b>0.048</b>
Lipid profiles					
Total cholesterol, median (Q1, Q3)	4.6 (3.8, 5.1)	5.4 (4.9, 6.1)	4.4 (4.3, 4.7)	0.07	<b>0.031</b>
TC <4.7, %	54/105 (51.4)	2/9 (22.2)	3/4 (75.0)	–	0.883
TC 4.8–5.1, %	13/105 (12.4)	2/9 (22.2)	0/4 (0.0)		
TC 5.2–6.1, %	18/105 (17.1)	2/9 (22.2)	1/4 (25.0)		
TC ≥6.2, %	20/105 (19.0)	3/9 (33.3)	0/4 (0.0)		
LDL, median (Q1, Q3)	2.9 (2.4, 3.5)	4.0 (3.3, 4.2)	2.9 (2.6, 3.2)	<b>0.042</b>	0.082
Cardiac and inflammatory biomarkers					

Continued

Table 3 Continued

Variable	Framingham risk score classification (lipid)†			P value for trend‡	
	Low	Intermediate	High	Increasing	Two-sided
High sensitivity troponin I, median (Q1, Q3)	2.5 (2.5, 2.5)	2.8 (2.5, 4.1)	2.7 (2.6, 5.2)	<b>0.003</b>	<b>0.006</b>
hscTnI <2.5 ng/L, %	74/92 (80.4)	3/7 (42.9)	1/4 (25.0)	–	<b>0.003</b>
hscTnI 2.5–45 ng/L	17/92 (18.5)	4/7 (57.1)	3/4 (75.0)		
hscTnI ≥45 ng/L	1/92 (1.1)	0/7 (0.0)	0/4 (0.0)		
High-sensitivity CRP, median (Q1, Q3)	2.0 (0.9, 4.3)	6.9 (2.2, 10.3)	2.6 (2.5, 4.4)	<b>0.012</b>	<b>0.022</b>
hsCRP <1 mg/L	30/107 (28.0)	1/9 (11.1)	0/4 (0.0)	–	0.128
hsCRP 1–3 mg/L	34 (31.8)	2/9 (22.2)	3/4 (75.0)		
hsCRP >3 mg/L	43 (40.2)	6/9 (66.7)	1/4 (25.0)		
Creatinine, median (Q1, Q3)	76.0 (69.0, 85.5)	88.0 (75.0, 94.0)	91.0 (84.2, 99.5)	<b>0.047</b>	<b>0.047</b>

\*Number of patients may not sum to the corresponding column totals where there are missing data for the cardiovascular risk factor/marker.  
 †Risk categories classified as low (<10%), intermediate (10%–19%) and high (≥20%).  
 ‡P values for trend were calculated Jonckheere-Terpstra for continuous variables and Cochran-Armitage, or Cochran-Mantel-Haenszel tests, appropriate, for categorical variables.  
 §Self-reported hypertension or measured systolic blood pressure ≥140 mm Hg or diastolic blood pressure ≥90 mm Hg, or physician-prescribed blood pressure-lowering medications.  
 hsCRP, high-sensitivity C-reactive protein; hscTnI, high-sensitivity cardiac troponin I; LDL, low-density lipoprotein.

Stored serum was available to measure hscTnI concentrations in 169 of the 200 participants. Despite using a hscTnI assay, the majority had concentrations below the limit of quantification at <2.5 ng/L (n=109/169, 65%). Fifty-nine patients (n=59/169, 35%) had concentration levels above the limit of quantification but below the 99th centile upper reference limit. Serum hsCRP was measured in 198 of the 200 participants. The median hsCRP was 2 mg/L (IQR 0.8–4.2 mg/L). Levels were numerically higher in women compared with men (2.2 mg/L vs 1.5 mg/L). HsCRP categorised 75 (38%) patients as having a high level (>3 mg/L) with 65 (33%) and 58 (29.3) at intermediate (1–3 mg/L) and low (<1 mg/L) levels. Levels of hscTnI and hsCRP did not differ when stratified by site (online supplemental table S2).

Using the sex stratified Framingham laboratory-based risk score with lipids, the majority of the HIV population was classified at low risk (83%) with 12% at intermediate risk and 5% at high risk. Although sample sizes remained limited when stratified by sex and risk category, the prevalence of hypertension remained higher in women compared with men (table 3) and as expected higher in the intermediate and high-risk groups across the population (online supplemental table S3).

Association between hscTnI and hsCRP and traditional cardiovascular risk factors were also evaluated (table 4). The findings from cumulative logit models showed that older patients were more likely to have higher hscTnI levels (adjusted OR (aOR) per year: 1.05, 95% CI 1.01 to 1.09, p<0.011). Female patients, compared with male patients, were identified as having lower hscTnI levels. SBP of 140–159 mm Hg and SBP >160 mm Hg were associated with higher hscTnI concentrations (aOR 2.96 (95% CI 1.09 to 7.90, p=0.030) and 4.68 (95% CI 1.55

to 14.1, p=0.006), respectively) compared with those with SBP <130 mm Hg. Our study did not find any strong associations between hsCRP and traditional cardiovascular risk factors including age, hypertension, diabetes and smoking. We also did not find any association between SBP levels and hsCRP. Levels of hsCRP were higher for HIV-patients with higher hscTnI levels. Study site—as a surrogate for socioeconomic status—was not associated with hscTnI or hsCRP.

## DISCUSSION

In this small, descriptive, cross-sectional study across two sites in urban Kenya, we evaluated the prevalence of traditional cardiovascular risk factors. We also explored how biochemical markers of inflammation and myocardial injury are associated with traditional cardiovascular risk factors in PLHIV. We make a number of observations. First, in a relatively young population with HIV, some traditional cardiovascular risk factors were common. Smoking and diabetes rates, however, were low. Second, using traditional risk estimation systems, the majority of the young HIV population were categorised as low-risk for future cardiovascular events. Third, across the majority of patients, hsTnI values were below the limit of detection. Fourth, in exploratory analysis we found no associations between hsCRP levels and traditional cardiovascular risk factors but did observe a positive association between hscTnI levels and increasing age and higher SBP.

Some traditional cardiovascular risk factors were common in the HIV population studied. Hypertension was self-reported in one in five individuals and higher, at one in three, when classified by office SBP measurement and/or use of anti-hypertensives. Self-reported

**Table 4** Relationship between baseline markers of myocardial injury and inflammation and traditional cardiovascular risk factors, displayed as multivariable-adjusted ORs\* for high-sensitivity cardiac troponin I and multivariable-adjusted mean differences† for hsCRP

Risk factor	High-sensitivity troponin I			High-sensitivity C-reactive protein		
	Model I AOR (95% CI)	Model II AOR (95% CI)	Model III AOR (95% CI)	Model I Adjusted Coef. (95% CI)	Model II Adjusted Coef. (95% CI)	Model III Adjusted Coef. (95% CI)
Age (years)	1.05 (1.02 to 1.09, p=0.004)	1.05 (1.01 to 1.09, p=0.021)	1.04 (1.00 to 1.08, p=0.032)	0.004 (-0.12 to 0.12, p=0.952)	0.01 (-0.11 to 0.14, p=0.860)	0.02 (-0.13 to 0.17, p=0.775)
Sex						
Male	Reference	Reference	Reference	Reference	Reference	Reference
Female	0.32 (0.14 to 0.70, p=0.004)	0.39 (0.16 to 0.93, p=0.035)	0.38 (0.17 to 0.84, p=0.018)	1.66 (-0.85 to 4.18, p=0.194)	1.49 (-1.28 to 4.25, p=0.290)	0.04 (-3.39 to 3.47, p=0.980)
Study site						
AKUNH	Reference	Reference	Reference	Reference	Reference	Reference
Coptic	1.08 (0.54 to 2.16, p=0.832)	0.97 (0.48 to 1.99, p=0.941)	0.91 (0.44 to 1.90, p=0.805)	0.78 (-1.70 to 3.27, p=0.536)	0.91 (-1.63 to 3.45, p=0.481)	0.87 (-2.02 to 3.76, p=0.553)
Hypertension	-	2.76 (1.36 to 5.63, p=0.005)	-	-	-1.23 (-3.91 to 1.45, p=0.366)	-
Diabetes	-	0.53 (0.06 to 3.37, p=0.513)	-	-	0.41 (-6.24 to 7.06, p=0.903)	-
Smoking						
Never smoker	Reference	Reference	-	-	Reference	-
Former smoker	-	1.19 (0.51 to 2.70, p=0.685)	-	-	-0.45 (-3.61 to 2.72, p=0.781)	-
Current smoker	-	1.36 (0.15 to 9.11, p=0.762)	-	-	0.22 (-7.47 to 7.92, p=0.954)	-
Systolic blood pressure						
SBP <130 mm Hg	Reference	-	Reference	-	-	Reference
SBP 130–139 mm Hg	-	-	2.29 (0.87 to 5.87, p=0.087)	-	-	-2.40 (-6.37 to 1.58, p=0.235)
SBP 140–159 mm Hg	-	-	3.08 (1.13 to 8.34, p=0.026)	-	-	-3.47 (-8.13 to 1.19, p=0.143)
SBP >160 mm Hg	-	-	5.40 (1.75 to 16.6, p=0.003)	-	-	-2.09 (-7.45 to 3.26, p=0.441)
High-sensitivity CRP mg/L	-	-	1.05 (1.01 to 1.10, p=0.014)	-	-	-
High-sensitivity troponin-I						
<2.50 ng/L	Reference	Reference	Reference	Reference	Reference	Reference
2.50–3.02 ng/L	-	-	-	-	-	4.42 (0.78 to 8.07, p=0.018)
3.02–7.12 ng/L	-	-	-	-	-	1.20 (-2.43 to 4.84, p=0.514)
≥7.12 ng/L	-	-	-	-	-	0.57 (-3.23 to 4.38, p=0.766)

Continued



Table 4 Continued

Risk factor	High-sensitivity troponin I			High-sensitivity C-reactive protein		
	Model I AOR (95% CI)	Model II AOR (95% CI)	Model III AOR (95% CI)	Model I Adjusted Coef. (95% CI)	Model II Adjusted Coef. (95% CI)	Model III Adjusted Coef. (95% CI)
Creatinine mg/L	1.00 (0.98 to 1.03, p=0.671)	1.01 (0.99 to 1.03, p=0.399)	1.01 (0.99 to 1.04, p=0.177)	-0.01 (-0.05 to 0.02, p=0.568)	-0.01 (-0.04 to 0.03, p=0.644)	-0.11 (-0.20 to -0.03, p=0.010)

\*Cumulative logit model with high-sensitivity troponin-I response as myocardial injury marker. Bold p values indicate statistical significance ( $p < 0.05$ ). Model I adjusts for age, sex, creatinine and study site; Model II as for Model I plus history of hypertension, diabetes and smoking status; Model III as Model I plus systolic blood pressure and hsCRP levels.

†Linear regression with high-sensitivity C-reactive protein (hsCRP) response as inflammation marker. Bold p values indicate statistical significance ( $p < 0.05$ ). Model I adjusts for age, sex and creatinine; Model II as for Model I plus history of hypertension, diabetes and smoking status; Model III as Model I plus systolic blood pressure and hsCRP levels.

AKUHN, Aga Khan University Hospital, Nairobi; AOR, adjusted OR; Coef., coefficient as multivariable mean difference; Coptic, Coptic Hope Center for Infectious Diseases.

dyslipidaemia was low at 1 in 20 but much higher when based on total cholesterol concentration  $>6.1$  mmol/L (19%). This discordance likely reflects individuals being unaware of their cholesterol status. Smoking and diabetes rates, however, remained relatively low in contrast to PLHIV in high-income countries.<sup>22</sup> Our prevalence rates of traditional cardiovascular risk factors are in agreement with other studies from the sub-Saharan African region<sup>23–25</sup> and discordant to those evaluating PLHIV in high-income settings.<sup>22–26</sup> While North American/European studies contribute to most of the evidence evaluating CVD in HIV, the region only hosts 6% of the global HIV population compared with 75% for sub-Saharan Africa.<sup>27–28</sup> PLHIV in sub-Saharan Africa and North America/Europe are different by virtue of the factors associated with HIV acquisition. HIV remains firmly established in the general population in sub-Saharan Africa but overwhelmingly affects men who have sex with men and intravenous drug users in North America/Europe.<sup>29</sup> These differences probably account for regional discordance in the association between HIV status and prevalence of cardiovascular risk factors that has been observed in the published literature. Positive associations in North America/Europe either become null or even reverse in sub-Saharan Africa.<sup>22–26 30–33</sup>

Using the sex stratified Framingham laboratory-based risk score, the overwhelming majority of the HIV population was classified at low risk (83%) with 12% at intermediate risk and 5% at high risk. Similar risk categorisations were obtained when using the Framingham non-laboratory-based risk scores. All established cardiovascular risk estimation systems—predominantly developed in high-income countries and not accounting for HIV status are highly influenced by age. As such, our findings likely reflect the younger age distribution in our study.<sup>12 34</sup> Whether this estimation of low-risk, using generalised risk scores developed predominantly in high-income countries, reflects the observed cardiovascular risk of HIV individuals in sub-Saharan Africa remains uncertain.

Previous studies have shown how biochemical markers, such as hsCRP and hscTnI, may hold promise in

improving cardiac risk estimation systems.<sup>35</sup> Our study showed that the majority of individuals had undetectable levels of hscTnI with only one in three patients demonstrating levels above the limit of detection. Previous studies in high-income settings have shown that during acute HIV infection, troponin levels are higher but drop threefold once viremic control is achieved.<sup>36</sup> A large proportion of our patients were established on ART and with the duration of diagnosis to study recruitment being nearly 12 years. Two studies showed contrasting results when evaluating the association between troponin levels and presence of coronary plaques, with results primarily applicable to men with HIV in non-endemic regions.<sup>37 38</sup> Levels of hsCRP, suggestive of underlying inflammation, were high in this study with women having higher concentrations. Whether higher baseline hsCRP levels relate to increased risk of cardiovascular events in HIV, however, remains uncertain with contrasting data in the published literature.<sup>39 40</sup> Higher levels of hsCRP in people with HIV is biologically plausible and supported by previous studies,<sup>28 41</sup> but may not just be reflective of vascular disease.<sup>42</sup> As such the specificity of hsCRP for CVD in PLHIV may be low.

Our study showed, hscTnI levels were higher in men, associated with increasing age, measured SBP and reported history of hypertension. This is similar to what has been observed in the general population.<sup>43 44</sup> However, surprisingly, in our study, much of the population had troponin concentrations below the limit of quantification despite using a high-sensitivity assay likely reflective of a younger population. Unlike in the general population,<sup>45</sup> we did not show any robust association between hsCRP and traditional cardiovascular risk factors. This may reflect the younger age of our population with previous studies showing higher hsCRP values in the elderly.<sup>46</sup>

This is one of the few studies that has quantified the prevalence of cardiovascular risk factors and explored their association with biochemical markers of inflammation and myocardial injury in HIV populations from two distinct centres in urban Kenya. However, several limitations should be considered. First, our study was cross-sectional and we were unable to evaluate the associations



between novel biochemical markers and future cardiovascular events. Second, HIV populations in our study were recruited across two centres in Nairobi, representing a predominantly urban population. Whether our findings are generalisable to rural populations remains uncertain. Third, given resource limitations, we did not study age-matched and sex-matched non-HIV populations and were limited to a finite choice of biochemical biomarkers. As such our study is unable to comment on associations between a wider range of biochemical markers and cardiovascular risk factors in the general population and how these may differ to those infected with HIV. For the same reason we were also unable to measure metric if infection control (viral load and CD4 count) at the time of recruitment. Fourth, some of the risk factors such as diabetes status depended on self-reporting—as such, the absence of associations may reflect exposure misclassification. Lastly, we cannot exclude the possibility that associations between biomarkers and outcomes may in part be due to residual confounding or unmeasured confounders.

## CONCLUSIONS

In conclusion, we show that while some traditional cardiovascular risk factor prevalences remain high in HIV populations in sub-Saharan Africa, important ones such as smoking are low. This is in contrast to HIV populations in non-endemic regions.<sup>22</sup> The majority of PLHIV—using traditional risk estimation systems—have a low estimated CVD risk likely reflecting a younger aged population predominantly consisting of women. While hscTnI values were associated with increasing age and higher blood pressure, no associations between hsCRP levels and traditional cardiovascular risk factors were observed.

## Author affiliations

<sup>1</sup>Internal Medicine, The Aga Khan University Hospital Nairobi, Nairobi, Kenya

<sup>2</sup>Institute of Tropical and Infectious Diseases, University of Nairobi, Nairobi, Kenya

<sup>3</sup>BHF Centre for Cardiovascular Science, University of Edinburgh, Edinburgh, UK

<sup>4</sup>Department of Non-communicable Disease Epidemiology, London School of Hygiene & Tropical Medicine, London, UK

<sup>5</sup>Cardiology, North Bristol Trust, Bristol, UK

<sup>6</sup>Hubert Department of Global Health, Rollins School of Public Health, Emory University, Atlanta, Georgia, USA

<sup>7</sup>Department of Family and Preventive Medicine, School of Medicine, Emory University, Atlanta, Georgia, USA

<sup>8</sup>Department of Medicine, Coptic Hospital and Coptic Hope Center for Infectious Diseases, Nairobi, Kenya

<sup>9</sup>Department of Medicine, Emory University, Atlanta, Georgia, USA

<sup>10</sup>Department of Cardiovascular Medicine, Imperial College Healthcare NHS Trust, London, UK

**Twitter** Isaiah G Akuku @IAkuku

**Contributors** ASVS and MHC conceived and designed the study. HAA recruited the patients. ASVS and HAA wrote the first draft of the manuscript. IGA, HAA and JS analysed the data. ASVS, JM, IGA, KKL, SRA, PP, JS, MKA, SE and MHC made critical revisions on the paper. ASVS is the author acting as guarantor for the study.

**Funding** Supported by the Global Challenges Research Fund UKRI and the British Heart Foundation Intermediate Clinical Research Fellowship.

**Competing interests** ASVS's institution has received speaker fees from Abbott Diagnostics. The authors declare no other conflicts of interest.

**Patient and public involvement** Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

**Patient consent for publication** Not applicable.

**Ethics approval** This study involves human participants and was approved by The Aga Khan University Hospital Research Ethics Committee. Ref: 2018-REC-24. Participants gave informed consent to participate in the study before taking part.

**Provenance and peer review** Not commissioned; externally peer reviewed.

**Data availability statement** Data are available upon reasonable request. Data will be available on request to the corresponding author (anoop.shah@lshtm.ac.uk).

**Supplemental material** This content has been supplied by the author(s). It has not been vetted by BMJ Publishing Group Limited (BMJ) and may not have been peer-reviewed. Any opinions or recommendations discussed are solely those of the author(s) and are not endorsed by BMJ. BMJ disclaims all liability and responsibility arising from any reliance placed on the content. Where the content includes any translated material, BMJ does not warrant the accuracy and reliability of the translations (including but not limited to local regulations, clinical guidelines, terminology, drug names and drug dosages), and is not responsible for any error and/or omissions arising from translation and adaptation or otherwise.

**Open access** This is an open access article distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited, appropriate credit is given, any changes made indicated, and the use is non-commercial. See: <http://creativecommons.org/licenses/by-nc/4.0/>.

## ORCID iDs

Hassan Adan Ahmed <http://orcid.org/0000-0003-3248-7418>

Shirjel R Alam <http://orcid.org/0000-0002-2099-612X>

## REFERENCES

- 1 Global AIDS Update. Joint United Nations programme on HIV/AIDS, 2016. Available: <https://www.unaids.org/en/resources/documents/2016/Global-AIDS-update-2016#:~:text=The%20world%20has%20committed%20to,8%20to%2010%20June%202016>
- 2 Mensah GA, Roth GA, Sampson UKA, *et al*. Mortality from cardiovascular diseases in sub-Saharan Africa, 1990-2013: a systematic analysis of data from the global burden of disease study 2013. *Cardiovasc J Afr* 2015;26:S6-10.
- 3 Murray CJL, Ortblad KF, Guinovart C, *et al*. Global, regional, and national incidence and mortality for HIV, tuberculosis, and malaria during 1990-2013: a systematic analysis for the global burden of disease study 2013. *Lancet* 2014;384:1005-70.
- 4 Palella FJ, Delaney KM, Moorman AC, *et al*. Declining morbidity and mortality among patients with advanced human immunodeficiency virus infection. HIV outpatient study Investigators. *N Engl J Med* 1998;338:853-60.
- 5 Neuhaus J, Angus B, Kowalska JD, *et al*. Risk of all-cause mortality associated with nonfatal AIDS and serious non-AIDS events among adults infected with HIV. *AIDS* 2010;24:697-706.
- 6 Mocroft A, Reiss P, Gasiowski J, *et al*. Serious fatal and nonfatal non-AIDS-defining illnesses in Europe. *J Acquir Immune Defic Syndr* 2010;55:262-70.
- 7 Antiretroviral Therapy Cohort Collaboration. Causes of death in HIV-1-infected patients treated with antiretroviral therapy, 1996-2006: collaborative analysis of 13 HIV cohort studies. *Clin Infect Dis* 2010;50:1387-96.
- 8 Shah ASV, Stelzle D, Lee KK, *et al*. Global burden of atherosclerotic cardiovascular disease in people living with HIV: systematic review and meta-analysis. *Circulation* 2018;138:1100-12.
- 9 Rao SG, Galaviz KI, Gay HC, *et al*. Factors associated with excess myocardial infarction risk in HIV-infected adults: a systematic review and meta-analysis. *J Acquir Immune Defic Syndr* 2019;81:224-30.
- 10 Gaziano TA, Abrahams-Gessel S, Gomez-Olive FX, *et al*. Cardiometabolic risk in a population of older adults with multiple co-morbidities in rural South Africa: the HAALSI (health and aging in Africa: longitudinal studies of in-depth communities) study. *BMC Public Health* 2017;17:206.
- 11 Gaziano TA, Bitton A, Anand S, *et al*. Growing epidemic of coronary heart disease in low- and middle-income countries. *Curr Probl Cardiol* 2010;35:72-115.
- 12 So-Armah K, Benjamin LA, Bloomfield GS, *et al*. HIV and cardiovascular disease. *Lancet HIV* 2020;7:e279-93.

- 13 Chung MH, Drake AL, Richardson BA, *et al.* Impact of prior HAART use on clinical outcomes in a large Kenyan HIV treatment program. *Curr HIV Res* 2009;7:441–6.
- 14 Assay: Siemens Healthcare Diagnostics Inc. Performance evaluation of the Atellica high-sensitivity troponin, 2020. Available: <https://www.siemens-healthineers.com/en-uk/laboratory-diagnostics/assays-by-diseases-conditions/cardiac-assays/cardiac-troponin-assays> [Accessed 19 Mar 2021].
- 15 Healthineers S. High sensitivity C-reactive protein (hsCRP) assay. Available: <https://www.siemens-healthineers.com/en-uk/cardiac/cardiac-assays/high-sensitivity-c-reactive-protein> [Accessed 19 Mar 2021].
- 16 Whelton PK, Carey RM, Aronow WS, *et al.* 2017 ACC/AHA/AAPA/ABC/ACPM/AGS/APhA/ASH/ASPC/NMA/PCNA guideline for the prevention, detection, evaluation, and management of high blood pressure in adults: a report of the American College of Cardiology/American heart association Task force on clinical practice guidelines. *Hypertension* 2018;71:e13–115.
- 17 Roth GA, Fihn SD, Mokdad AH, *et al.* High total serum cholesterol, medication coverage and therapeutic control: an analysis of national health examination survey data from eight countries. *Bull World Health Organ* 2011;89:92–101.
- 18 Kramer CK, Araneta MRG, Barrett-Connor E. A1C and diabetes diagnosis: the Rancho bernardo study. *Diabetes Care* 2010;33:101–3.
- 19 Zacho J, Tybjaerg-Hansen A, Jensen JS, *et al.* Genetically elevated C-reactive protein and ischemic vascular disease. *N Engl J Med* 2008;359:1897–908.
- 20 Shah ASV, Newby DE, Mills NL. High sensitivity cardiac troponin in patients with chest pain. *BMJ* 2013;347:f4222.
- 21 Liu Q, Shepherd BE, Li C, *et al.* Modeling continuous response variables using ordinal regression. *Stat Med* 2017;36:4316–35.
- 22 Johnston PI, Wright SW, Orr M, *et al.* Worldwide relative smoking prevalence among people living with and without HIV. *AIDS* 2021;35:957–70.
- 23 Clark SJ, Gómez-Olivé FX, Houle B, *et al.* Cardiometabolic disease risk and HIV status in rural South Africa: establishing a baseline. *BMC Public Health* 2015;15:135.
- 24 Mugisha JO, Schatz EJ, Randell M, *et al.* Chronic disease, risk factors and disability in adults aged 50 and above living with and without HIV: findings from the wellbeing of older people study in Uganda. *Glob Health Action* 2016;9:31098.
- 25 Pioreschi A, Munthali RJ, Soepnel L, *et al.* Incidence and prevalence of type 2 diabetes mellitus with HIV infection in Africa: a systematic review and meta-analysis. *BMJ Open* 2017;7:e013953.
- 26 Triant VA, Lee H, Hadigan C, *et al.* Increased acute myocardial infarction rates and cardiovascular risk factors among patients with human immunodeficiency virus disease. *J Clin Endocrinol Metab* 2007;92:2506–12.
- 27 Lawal IO, Ankrah AO, Popoola GO, *et al.* Arterial inflammation in young patients with human immunodeficiency virus infection: a cross-sectional study using F-18 FDG PET/CT. *J Nucl Cardiol* 2019;26:1258–65.
- 28 Subramanian S, Tawakol A, Burdo TH, *et al.* Arterial inflammation in patients with HIV. *JAMA* 2012;308:379–86.
- 29 UNAIDS. UNAIDS data, 2020. Available: [https://www.unaids.org/sites/default/files/media\\_asset/2020\\_aids-data-book\\_en.pdf](https://www.unaids.org/sites/default/files/media_asset/2020_aids-data-book_en.pdf)
- 30 Brown TT, Cole SR, Li X, *et al.* Antiretroviral therapy and the prevalence and incidence of diabetes mellitus in the multicenter AIDS cohort study. *Arch Intern Med* 2005;165:1179–84.
- 31 van Zoest RA, Wit FW, Kooij KW, *et al.* Higher prevalence of hypertension in HIV-1-infected patients on combination antiretroviral therapy is associated with changes in body composition and prior stavudine exposure. *Clin Infect Dis* 2016;63:205–13.
- 32 Coetzee L, Bogler L, De Neve J-W, *et al.* HIV, antiretroviral therapy and non-communicable diseases in sub-Saharan Africa: empirical evidence from 44 countries over the period 2000 to 2016. *J Int AIDS Soc* 2019;22:e25364.
- 33 Davis K, Perez-Guzman P, Hoyer A, *et al.* Association between HIV infection and hypertension: a global systematic review and meta-analysis of cross-sectional studies. *BMC Med* 2021;19:105.
- 34 Cooney MT, Dudina AL, Graham IM. Value and limitations of existing scores for the assessment of cardiovascular risk: a review for clinicians. *J Am Coll Cardiol* 2009;54:1209–27.
- 35 Gilstrap LG, Wang TJ. Biomarkers and cardiovascular risk assessment for primary prevention: an update. *Clin Chem* 2012;58:72–82.
- 36 Schuster C, Mayer FJ, Wohlfahrt C, *et al.* Acute HIV infection results in subclinical inflammatory cardiomyopathy. *J Infect Dis* 2018;218:466–70.
- 37 Rahman F, Zhang Z, Zhao D, *et al.* Association of high-sensitivity troponin with cardiac CT angiography evidence of myocardial and coronary disease in a primary prevention cohort of men: results from MACS. *J Appl Lab Med* 2019;4:355–69.
- 38 Fitch KV, DeFilippi C, Christenson R, *et al.* Subclinical myocyte injury, fibrosis and strain in relationship to coronary plaque in asymptomatic HIV-infected individuals. *AIDS* 2016;30:2205–14.
- 39 De Luca A, de Gaetano Donati K, Colafigli M, *et al.* The association of high-sensitivity C-reactive protein and other biomarkers with cardiovascular disease in patients treated for HIV: a nested case-control study. *BMC Infect Dis* 2013;13:414.
- 40 Ford ES, Greenwald JH, Richterman AG, *et al.* Traditional risk factors and D-dimer predict incident cardiovascular disease events in chronic HIV infection. *AIDS* 2010;24:1509–17.
- 41 Subramanian S, Tawakol A, Burdo TH, *et al.* Arterial inflammation in patients with HIV. *JAMA* 2012;308:379–86.
- 42 Kulkarni M, Bowman E, Gabriel J, *et al.* Altered monocyte and endothelial cell adhesion molecule expression is linked to vascular inflammation in human immunodeficiency virus infection. *Open Forum Infect Dis* 2016;3:ofw224.
- 43 Willeit P, Welsh P, Evans JDW, *et al.* High-Sensitivity Cardiac Troponin Concentration and Risk of First-Ever Cardiovascular Outcomes in 154,052 Participants. *J Am Coll Cardiol* 2017;70:558–68.
- 44 Blankenberg S, Salomaa V, Makarova N, *et al.* Troponin I and cardiovascular risk prediction in the general population: the BiomarCaRE Consortium. *Eur Heart J* 2016;37:2428–37.
- 45 Saito M, Ishimitsu T, Minami J, *et al.* Relations of plasma high-sensitivity C-reactive protein to traditional cardiovascular risk factors. *Atherosclerosis* 2003;167:73–9.
- 46 Puzianowska-Kuznicka M, Owczarz M, Wieczorowska-Tobis K, *et al.* Interleukin-6 and C-reactive protein, successful aging, and mortality: the PolSenior study. *Immun Ageing* 2016;13:21.

## SUPPLEMENT

**Cardiovascular risk factors and markers of myocardial injury and inflammation in people living with HIV in Kenya**

Hassan A Ahmed, MD<sup>1</sup>; Mohammed Jeilan, MD<sup>1</sup>; Isaiah G Akuku, MSc<sup>2</sup>; Kuan Ken Lee, MD<sup>3</sup>; Shirjel R Alam, MD<sup>4</sup>; Pablo Perel, MD<sup>4</sup>; Jasmit Shah, PhD<sup>1</sup>; Mohammed K. Ali, MD;<sup>5</sup> Sherry Eskander, MD;<sup>6</sup> Michael H Chung, MD MPH<sup>5\*</sup> and Anoop S V Shah, MD<sup>4,7\*</sup>

\*Contributed equally

<sup>1</sup> Department of Medicine, Aga Khan University

<sup>2</sup> Institute of Tropical and Infectious Diseases, University of Nairobi

<sup>3</sup> BHF Centre for Cardiovascular Sciences, University of Edinburgh

<sup>4</sup> Department of Non-communicable Disease Epidemiology, London School of Hygiene and Tropical Medicine, London, UK

<sup>5</sup> Emory University, Atlanta, Georgia, USA

<sup>6</sup> Coptic Hospital, Nairobi, Kenya

<sup>7</sup> Imperial College Hospital NHS Trust, London, UK

**Correspondence and requests for reprints:**

Dr Anoop Shah,  
Room 249,  
Department of Non-communicable Disease Epidemiology,  
London School of Hygiene and Tropical Medicine,  
Keppel Street,  
London,  
UK  
WC1E 7HT

Mobile: +(44) 7766 544 156

E-mail: [Anoop.Shah@lshtm.ac.uk](mailto:Anoop.Shah@lshtm.ac.uk)

**Abstract:** 299 (300)

**Word count:** 2,712

**Table and Figures:** 4

Figure S1: Study flow diagram

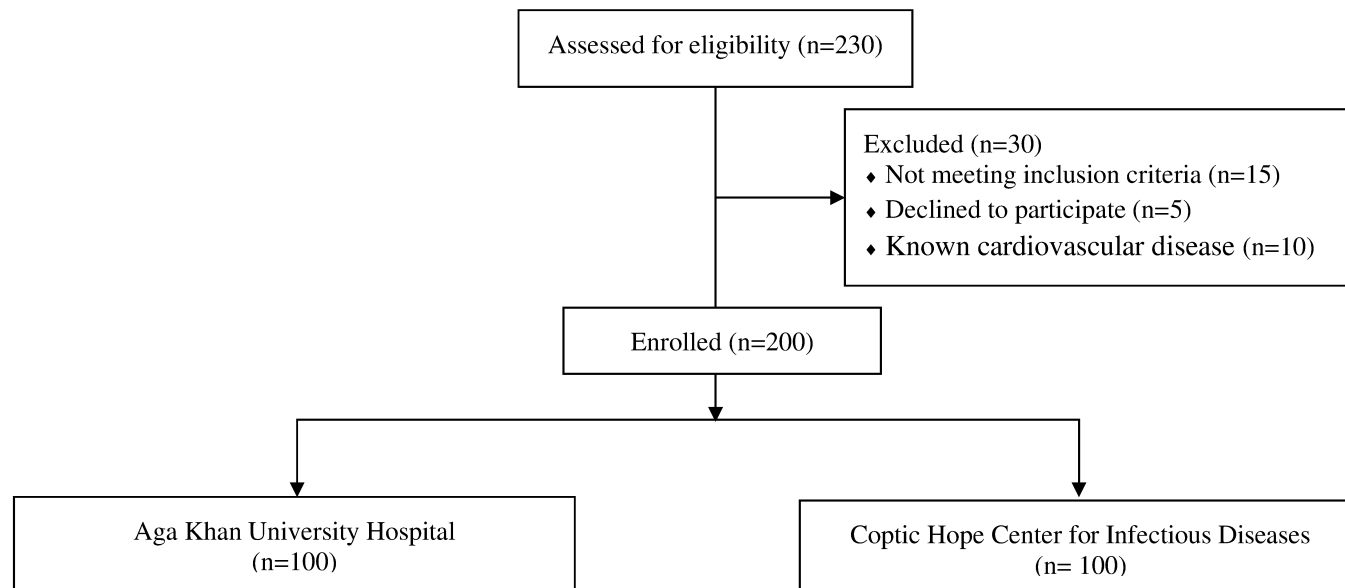




Table S1: Baseline demographics and clinical characteristics by clinical site<sup>1</sup>

Characteristics	All patients (n=200)	Site		p-value <sup>2</sup>
		Aga Khan University Hospital (n= 100)	Coptic Hope Center for Infectious Diseases (n = 100)	
Age, median (Q1, Q3), years	45.5 (37.7, 52.6)	41.9 (35.3, 49.4)	48.0 (40.5, 54.3)	<0.001
<b>Gender</b>				
Male, %	79/200 (39.5)	46/100 (46.0)	33/100 (33.0)	0.083
Female, %	121/200 (60.5)	54/100 (54.0)	67/100 (67.0)	
Years of education, median (Q1, Q3)	14.0 (12.0, 16.0)	16.0 (13.0, 16.0)	13.5 (10.8, 16.0)	<0.001
<b>Highest level of education attained</b>				
Primary/none/don't know, %	30/200 (15.0)	5/100 (5.0)	25/100 (25.0)	<0.001
Secondary, %	45/200 (22.5)	21/100 (21.0)	24/100 (24.0)	
Higher Education/University, %	125/200 (62.5)	74/100 (74.0)	51/100 (51.0)	
<b>Marital status</b>				
Married (monogamous/polygamous), %	128/200 (64.0)	70/100 (70.0)	58/100 (58.0)	0.119
Single	26/200 (13.0)	13/100 (13.0)	13/100 (13.0)	
Separated/widowed/divorced/refused/cohabiting/others, %	46/200 (23.0)	17/100 (17.0)	29/100 (29.0)	
<b>Employment status</b>				
Salaried Job or self-employed, %	180/200 (90.0)	91/100 (91.0)	89/100 (89.0)	0.117
Unemployed/housewife/retiree, %	13/200 (6.5)	8/100 (8.0)	5/100 (5.0)	
Casual labourer, %	7/200 (3.5)	1/100 (1.0)	6/100 (6.0)	
<b>Household income per month</b>				
< 15,001 KES <sup>3</sup> , %	34/198 (17.2)	6/100 (6.0)	28/98 (28.6)	<0.001
> 15,001 KES, %	164/198 (82.8)	94/100 (94.0)	70/98 (71.4)	
<b>Cardiovascular risk factors</b>				
<b>Smoking</b>				
Current smoker, %	5/200 (2.5)	3/100 (3.0)	2/100 (2.0)	1.000
Ex-smoker, %	44/200 (22.0)	22/100 (22.0)	22/100 (22.0)	
Never smoker, %	151/200 (75.5)	75/100 (75.0)	76/100 (76.0)	
Diabetes, %	7/200 (3.5)	5/100 (5.0)	2/100 (2.0)	0.444
Self-reported hypertension <sup>4</sup> , %	44/200 (22.0)	22/100 (22.0)	22/100 (22.0)	1.000
Cumulative hypertension <sup>5</sup> , %	60/200 (30.0)	25/100 (25.0)	35/100 (35.0)	0.165
Dyslipidemia, %	1/197 (0.5)	0/100 (0.0)	1/97 (1.0)	0.288
Chronic kidney disease, %	2/200 (1.0)	2/100 (2.0)	0/100 (0.0)	<b>0.036</b>
<b>HIV</b>				
Time since (months) HIV <sup>6</sup> infection, Median (Q1, Q3)	143.0 (59.0, 191.0)	106.0 (47.0, 191.0)	159.0 (95.0, 191.0)	<b>0.037</b>
Currently on ART <sup>7</sup> , %	195/200 (97.5)	95/100 (95.0)	100/100 (100.0)	0.059
<b>Past medical history</b>				
Malaria, %	21/200 (10.5)	0/100 (0.0)	21/100 (21.0)	<0.001
Tuberculosis, %	12/200 (6.0)	4/100 (4.0)	8/100 (8.0)	0.373
<b>Clinical characteristics</b>				

<sup>1</sup> Number of patients may not sum to the corresponding column totals where there are missing data for the variable.

<sup>2</sup> p-value from Chi-square test or Fisher's exact test for categorical variables and unpaired two-sample Wilcoxon test or Student's t-test for continuous variables, two-sided; bold p-values indicate statistical significance (p<0.05).

<sup>3</sup> KES, Kenya shillings currency code

<sup>4</sup> Self-reported physician-diagnosed hypertension.

<sup>5</sup> Self-reported hypertension or measured systolic blood pressure (SBP)  $\geq$  140 mmHg or diastolic blood pressure (DBP)  $\geq$  90 mmHg, or physician-prescribed blood pressure-lowering medications.

<sup>6</sup> HIV, human immunodeficiency virus,

<sup>7</sup> ART, antiretroviral therapy.

Table S2 Biochemistry and haematology by clinical site<sup>1</sup>

Characteristics	All patients (n=200)	Site <sup>2</sup>		p-value <sup>3</sup>
		Aga Khan University Hospital (n=100)	Coptic Hope Center for Infectious Diseases (n=100)	
Creatinine, median (Q1, Q3), n=197	85.0 (73.0, 101.0)	89.0 (74.0, 106.0)	83.0 (71.8, 98.2)	0.102
Urea, median (Q1, Q3), n=196	3.7 (3.1, 4.6)	3.8 (3.1, 5.0)	3.5 (3.0, 4.2)	<b>0.011</b>
Hemoglobin, mean (SD), n=98*	–	14.01 (2.06)	–	–
Glucose, median (Q1, Q3), n=197	4.8 (4.4, 5.3)	5.2 (4.9, 5.6)	4.5 (4.1, 4.6)	<b>&lt;0.001</b>
HbA1c, median (Q1, Q3), n=98*	5.6 (5.4, 5.9)	5.6 (5.4, 5.9)	–	–
HbA1c <5.7, %	–	50/98 (51.0)	–	–
HbA1c 5.7 – 6.4, %	–	45/98 (45.9)	–	–
HbA1c ≥ 6.5, %	–	3/98 (3.1)	–	–
<b>Lipid profiles</b>				
Total cholesterol, median (Q1, Q3), n=196	4.6 (3.9, 5.1)	4.6 (3.8, 5.3)	4.4 (4.0, 5.1)	0.665
TC < 4.7, %	107/196 (54.6)	52 (53.1)	55 (56.1)	0.955
TC 4.8 – 5.1, %	22/196 (11.2)	11 (11.2)	11 (11.2)	
TC 5.2 – 6.1, %	30/196 (15.3)	15 (15.3)	15 (15.3)	
TC ≥ 6.2, %	37/196 (18.9)	20 (20.4)	17 (17.3)	
LDL, median (Q1, Q3), n=196	3.0 (2.3, 3.6)	3.1 (2.3, 3.6)	3.0 (2.4, 3.5)	0.858
LDL < 2.6, %	75/196 (38.3)	36 (36.7)	39 (39.8)	0.978
LDL 2.6 – 3.3, %	53/196 (27.0)	27 (27.6)	26 (26.5)	
LDL 3.4 – 4.1, %	41/196 (20.9)	21 (21.4)	20 (20.4)	
LDL ≥ 4.2, %	27/196 (13.8)	14 (14.3)	13 (13.3)	
HDL, median (Q1, Q3), n=196	1.2 (1.0, 1.5)	1.2 (1.0, 1.4)	1.2 (1.0, 1.5)	0.457
Triglycerides, median (Q1, Q3), n=196	1.4 (0.9, 2.0)	1.5 (1.0, 2.2)	1.3 (0.9, 1.9)	0.196
Trig < 1.7, %	123/196 (62.8)	56 (57.1)	67 (68.4)	0.257
Trig 1.7 – 2.2, %	32/196 (16.3)	19 (19.4)	13 (13.3)	
Trig >2.3, %	41/196 (20.9)	23 (23.5)	18 (18.4)	
<b>Cardiac and inflammatory biomarkers</b>				
High sensitivity troponin I, median (Q1, Q3), n=169	2.5 (2.5, 3.0)	2.5 (2.5, 3.0)	2.5 (2.5, 3.2)	0.654
hscTnI < 2.5 ng/L, %	109/169 (64.5)	46 (66.7)	63 (63.0)	0.848
hscTnI 2.5 – 45 ng/L, %	59/169 (34.9)	23 (33.3)	36 (36.0)	
hscTnI ≥ 45 ng/L, %	1/169 (0.6)	0 (0.0)	1 (1.0)	
High-sensitivity CRP, median (Q1, Q3), n=198	2.0 (0.8, 4.2)	2.4 (1.1, 4.4)	1.6 (0.7, 4.2)	0.112
hsCRP < 1mg/L, %	58/198 (29.3)	23 (23.5)	35 (35.0)	0.197
hsCRP 1 - 3 mg/L, %	65/198 (32.8)	41 (41.8)	34 (34.0)	
hsCRP >3 mg/L, %	75/198 (37.9)	34 (34.7)	31 (31.0)	

<sup>1</sup> Number of patients may not sum to the corresponding column totals where there are missing data for the laboratory marker.

<sup>2</sup> \*Data for Hemoglobin and hemoglobin A1c (HbA1c) was available for Aga Khan University Hospital only.

<sup>3</sup> p-value from Chi-square test or Fisher's exact test for categorical variables and unpaired two-sample Wilcoxon test for continuous variables, two-sided; bold p-values indicate statistical significance (p<0.05).

Table S3: Cardiovascular risk factors, markers of myocardial injury and inflammation by Framingham cardiovascular risk category

Variable	Framingham risk score classification (FRS lipid)			<i>p</i> -value for trend <sup>1</sup>
	Low	Intermediate	High	
<b>Overall</b>				
All patients (%)	166 (83.0)	23 (11.5)	11 (5.5)	–
Male	58 (34.9)	14 (60.9)	7 (63.6)	<b>0.006</b>
Female	108 (65.1)	9 (39.1)	4 (36.4)	
<b>Smoking</b>				
Current smoker, %	5/166 (3.0%)	0/23 (0.0)	0/11 (0.0)	0.306
Ex-smoker, %	33/166 (19.9)	6/23 (26.1)	5/11 (45.5)	
Never smoker, %	128/166 (77.1)	17/23 (73.9)	6/11 (54.5)	
Diabetes, %	3/166 (1.8)	2/23 (8.7)	2/11 (18.2)	0.999
Hypertension <sup>2</sup> , %	36/166 (21.7)	14/23 (60.9)	10/11 (90.9)	<b>&lt;0.001</b>
Hyperlipidemia, %	0/164 (0.0)	1/22 (4.5)	0/11 (0.0)	0.145
<b>Lipid profiles</b>				
Total cholesterol, median (Q1, Q3)	4.5 (3.8, 5.0)	4.9 (4.3, 5.4)	5.1 (4.4, 6.4)	<b>0.001</b>
TC < 4.7, %	93/162 (57.4)	10/23 (43.5)	4/11 (36.4)	<b>0.007</b>
TC 4.8 – 5.1, %	20/162 (12.3)	2/23 (8.7)	0/11 (0.0)	
TC 5.2 – 6.1, %	23/162 (14.2)	6/23 (26.1)	1/11 (9.1)	
TC ≥ 6.2, %	26/162 (16.0)	5/23 (21.7)	6/23 (54.5)	
LDL, median (Q1, Q3)	3.0 (2.3, 3.5)	3.3 (2.4, 3.8)	3.6 (2.9, 4.5)	<b>0.017</b>
LDL < 2.6, %	65/162 (40.1)	8/23 (34.8)	2/11 (18.2)	<b>0.016</b>
LDL 2.6 – 3.3, %	47/162 (29.0)	4/23 (17.4)	2/11 (18.2)	
LDL 3.4 – 4.1, %	30/162 (18.5)	8/23 (34.8)	3/11 (27.3)	
LDL ≥ 4.2, %	12/162 (12.3)	3/23 (13.0)	4/11 (36.4)	
HDL, median (Q1, Q3)	1.2 (1.0, 1.5)	1.1 (0.9, 1.3)	1.0 (0.9, 1.2)	<b>0.043</b>
Triglycerides, median (Q1, Q3)	1.3 (0.9, 1.9)	1.9 (1.2, 3.1)	2.9 (1.8, 3.4)	<b>&lt;0.001</b>
Trig < 1.7	110/162 (67.9)	11s/23 (47.8)	2/11 (18.2)	<b>&lt;0.001</b>
Trig 1.7 – 2.2	26/162 (16.0)	3/23 (13.0)	3/11 (27.3)	
Trig >2.3	26/162 (16.0)	9/23 (39.1)	6/11 (54.5)	
<b>Cardiac and inflammatory biomarkers</b>				
High sensitivity troponin I, median (Q1, Q3)	2.5 (2.5, 2.7)	3.3 (2.5, 4.7)	3.3 (2.5, 7.1)	<b>&lt;0.001</b>
hscTnI < 2.5 ng/L, %	100/140 (71.4)	6/18 (33.3)	3/11 (27.3)	<b>&lt;0.001</b>
hscTnI 2.5 – 45 ng/L	39/140 (27.9)	12/18 (66.7)	8/11 (72.7)	
hscTnI ≥ 45 ng/L	1/140 (0.7)	0/18 (0.0)	0/11 (0.0)	
High-sensitivity CRP, median (Q1, Q3)	1.9 (0.8, 4.1)	2.9 (1.1, 5.3)	2.4 (0.9, 4.2)	0.283
hsCRP < 1mg/L	49/164 (29.9)	6/23 (26.1)	3/11 (27.3)	0.854
hsCRP 1 - 3 mg/L	54/164 (32.9)	6/23 (26.1)	5/11 (45.5)	
hsCRP >3 mg/L	61/164 (37.2)	11/23 (47.8)	3/11 (27.3)	
Creatinine, median (Q1, Q3)	83.0 (72.0, 100.5)	97.0 (87.0, 106.5)	91.0 (79.0, 104.5)	<b>0.009</b>

<sup>1</sup> *p*-values for trend were calculated using Jonckheere-Terpstra for continuous variables and Cochran-Armitage, or Cochran-Mantel-Haenszel tests, as appropriate, for categorical variables.

<sup>2</sup> Self-reported hypertension or measured systolic blood pressure (SBP) ≥ 140 mmHg or diastolic blood pressure (DBP) ≥ 90 mmHg, or physician-prescribed blood pressure-lowering medications.