

Spectrum of prevalent cardiovascular diseases in urban Port-au-Prince, Haiti: a population-based cross-sectional study



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Summary

Background Eighty percent of global cardiovascular disease (CVD) is projected to occur in low- and middle-income countries (LMICs), yet local epidemiological data are scarce. We provide the first population-based, adjudicated CVD prevalence estimates in Port-au-Prince, Haiti to describe the spectrum of heart disease and investigate associated risk factors.

Methods Demographic, medical history, clinical, imaging and laboratory data were collected among adults recruited using multistage random sampling from 2019 to 2021. Prevalent CVD (heart failure, stroke, ischemic disease) were adjudicated using epidemiological criteria similar to international cohorts. Multivariable Poisson regressions assessed relationships between risk factors and prevalent CVD.

Findings Among 3003 participants, median age was 40 years, 58.1% were female, 70.2% reported income <1 USD/day, and all identified as Black Haitian. CVD age-adjusted prevalence was 14.7% (95% CI 13.3%, 16.5%), including heart failure (11.9% [95% CI 10.5%, 13.5%]), stroke (2.4% [95% CI 1.9%, 3.3%]), angina (2.1% [95% CI 1.6%, 2.9%]), myocardial infarction (1.0% [95% CI 0.6%, 1.8%]), and transient ischemic attack (0.4% [95% CI 0.2%, 1.0%]). Among participants with heart failure, median age was 57 years and 68.5% of cases were among women. The most common subtype was heart failure with preserved ejection fraction (80.4%). Heart failure was associated with hypertension, obesity, chronic kidney disease, depression, and stress.

Interpretation Early-onset heart failure prevalence is alarmingly high in urban Haiti and challenge modelling assumptions that ischemic heart disease and stroke dominate CVDs in LMICs. These data underscore the importance of local population-based epidemiologic data within LMICs to expedite the selection and implementation of evidence-based cardiovascular health policies targeting each country's spectrum of heart disease.

Funding This study was funded by NIH grants R01HL143788, D43TW011972, and K24HL163393, [clinicaltrials.gov NCT03892265](https://clinicaltrials.gov/NCT03892265).

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Keywords: Cardiovascular disease; Hypertension; Heart failure; Stroke; Myocardial infarction; Cohort; Haiti; Global health

Research in context

Evidence before this study

Cardiovascular diseases are the leading cause of global mortality, with the largest burden in low- and middle-income countries. However, local population-representative data from these countries like Haiti are scarce given lack of robust health systems and research infrastructure, resulting in a knowledge gap around the clinical epidemiology of cardiovascular risk factors and diseases. Prior to this study, there were no regional or national population-based cardiovascular disease cohorts in low- and middle-income countries reporting adjudicated outcomes including heart failure, stroke, angina, myocardial infarction, and associated risk factors. We searched from January 2023 to July 2023 PubMed and Web of Science for relevant articles published since 1990 using search terms including “cardiovascular disease”, “cardiovascular”, “cohort”, “low-middle income country”, with and without “Haiti”.

Added value of this study

We describe the age-adjusted prevalence of cardiovascular diseases among a population-based urban cohort in Haiti,

including heart failure, stroke, transient ischemic attack, myocardial infarction, and angina using adjudicated epidemiologic criteria. The most prevalent cardiovascular disease was heart failure, especially heart failure with preserved ejection fraction, and was associated with hypertension, obesity, chronic kidney disease, depression, and stress.

Implications of all the available evidence

The burden of prevalent heart disease in Haiti is over two-fold greater than global estimates, with early-onset heart failure over 15-fold higher than previously estimated in Haiti (11.9% vs 0.7%). These data suggest the cardiovascular disease burden in LMICs may be higher than anticipated and differ from the spectrum seen in higher income countries that is driven by ischemic heart disease. Future policy and research in LMICs should include local, accurate epidemiological data on cardiovascular disease to investigate the aetiology and drivers of endemic cardiovascular disease.

Introduction

Cardiovascular diseases (CVD) are the leading cause of mortality and morbidity worldwide with 19.7 million deaths and 417 million disability adjusted life years in 2019.¹ Over 80% of the CVD burden is projected to occur in low- and middle-income countries (LMICs), yet many of the poorest countries lack primary epidemiological data resulting in modelling estimates based on case series or extrapolation from neighbouring countries.¹ As such, the CVD epidemic in LMICs is considered an extension of the pattern seen in high-income countries, with ischemic heart disease being the dominant type.¹ Without local and accurate data from LMICs, it is unclear if low-income countries have unique drivers and distributions of endemic CVD, and how the spectrum of CVD varies across low-income settings.² Understanding the CVD burden within and across low-income countries is essential to expedite the selection and implementation of evidence-based health policies and interventions to achieve the United Nations Sustainable Development goal of a 30% reduction in premature CVD mortality.

Haiti is the poorest country in the Western Hemisphere and is actively undergoing the epidemiologic transition from predominantly infectious to chronic diseases. Modelling estimates suggest CVD accounts for 36.0% of all deaths among Haitian adults >20 years old, far outpacing deaths from infectious disease like HIV

(7.3%).¹ However, to date there have been no large population-based cohorts to characterize the CVD epidemic in Haiti, or that of similar countries within the larger Latin American-Caribbean region.

To fill this knowledge gap, we established the population-based Haiti Cardiovascular Disease Cohort (clinicaltrials.gov NCT03892265) to systematically estimate the prevalence, incidence, and severity of CVD outcomes and risk factors in an urban Black population living in severe poverty, as a model for similar low-income settings.³ In this analysis, we describe the prevalence of CVD and investigate associated risk factors among a vulnerable population-based urban cohort of adults enrolled from 2019 to 2021 including heart failure, stroke, transient ischemic attack, myocardial infarction, and angina using adjudicated outcomes comparable to US and international cohorts.

Methods

Study setting and population

The Haiti Cardiovascular Disease Cohort is a longitudinal, population-based urban cohort of 3005 Port-au-Prince residents aged ≥ 18 years. The cohort was designed with a fixed sample size of 3000 adults based on feasibility, with power calculations based on the association between hypertension—the most prevalent CVD risk factor—and sociodemographic and clinical

variables.⁴ Assuming 20% hypertension prevalence, 80% power, and two-tail alpha of 0.01 to adjust for multiple comparisons, we determined a minimum detectable odds ratios of 1.3–2.0 between variables (e.g. age, sex, health behaviours etc.) and hypertension.³ Participants were recruited using multistage random sampling of national census blocks, enumerated by the Institut Haitien de Statistique et d'Informatique.⁵ Using Geographic Information System software, waypoints were randomly assigned across census blocks, with the number of waypoints per block proportional to its estimated population. Study staff then used standardized procedures to select the closest residential building to each waypoint to approach households for study participation and screening. Additional details on cohort enrolment have been previously described.³

Inclusion criteria for enrolment were age ≥ 18 years, primary residence in Port-au-Prince, and absence of any serious medical condition with less than 1 year life expectancy or cognitive impairment that would prevent participation.³ We also included young adults given prior data suggested high rates of hypertension and chronic diseases in this age group in Haiti.⁴ Enrolment occurred from March 2019 to August 2021, with ongoing follow-up. For this primary data analysis, we excluded 2 (0.07%) participants missing all of the following data: vital signs, reported CVD symptoms, physical exam, laboratory data, and imaging ([Supplementary Figure S1](#)).

The Haiti Cardiovascular Disease Cohort is conducted by the Groupe Haitien d'Etude du Sarcome de Kaposi et des Infections Opportunistes Centers (GHESKIO) in Haiti. GHESKIO is a medical non-profit organization that has operated continuously over four decades in Haiti to provide clinical care and conduct research on infectious and chronic diseases.

Study procedures and informed consent were approved by the institutional review boards at GHESKIO and Weill Cornell.

Measurements

Data were collected at study enrolment over two study visits to GHESKIO. Sociodemographic information included age, sex, education level, income, employment, and marital status. Anthropometrics included height, weight, and blood pressure (BP) measurements following American Heart Association (AHA) and World Health Organization (WHO) guidelines^{6,7} using semi-automated oscillometric research-grade BP machines (Omron HEM 907). Participants sat in a quiet room for 5 min with both feet flat on the floor, and then had three BPs measured, separated by 1-min intervals. The average of the last two BPs was used as the study BP.

A study physician performed a clinical exam including past medical history; family history of heart disease; screening for angina, heart failure and stroke

symptoms; medication use; and a physical exam. The physician screened for angina symptoms using the validated Rose angina questionnaire,⁸ heart failure using a symptom checklist adapted from the American Heart Association (AHA) guidelines for CVD endpoint events,⁹ and stroke symptoms using the Questionnaire for Verifying Stroke-Free Status (QVSFS).¹⁰ Electrocardiography (Nasiff CardioCard PC) was performed on all participants, and echocardiography (Sonosite M-turbo ultrasound machine using a P21x (5–1 MHz) probe) was performed for participants with either systolic BP ≥ 140 mmHg, diastolic BP ≥ 90 mmHg, abnormal ECG, or clinical concern for ischemic heart disease, heart failure, stroke or other heart disease. Study staff were credentialed in echocardiography, with examinations and measurements based on the American Society of Echocardiography (ASE) guidelines.¹¹ Laboratory measurements included serum haematology (Abbott CELLDYN 3200), creatinine, glucose, total cholesterol, high density lipoprotein (HDL), low density lipoprotein (LDL) (Vitros 250/350), and HIV-1 (Alere Determine HIV-1/2, Colloidal Gold HIV-1/2 Antibody).

We used the WHO STEPwise Approach to Non-communicable Disease Risk Factor Surveillance instrument to ascertain smoking status, alcohol intake, physical activity, fruit/vegetable intake, and dietary salt intake.⁶ Stress was measured using the Cohen's Perceived Stress Scale 4 (PSS-4). Answer choices range from 0 = Never to 4 = Very Often, with total score ranging from 0 to 16.¹² Depressive symptoms were measured using the Patient Health Questionnaire 9 (PHQ-9),¹² with a total score ranging from 0 to 27. Food insecurity was measured at the household level using an adapted version of the six-item short form of the Household Food Security Scale.¹³

Definitions of cardiovascular risk factors and diseases

Cardiovascular disease risk factors include prehypertension, stage 1 and 2 hypertension, diabetes, hypercholesterolemia, chronic kidney disease, smoking, physical activity, low fruit and vegetable intake, salt intake, food insecurity, stress, and depression. Hypertension was defined as systolic blood pressure (SBP) ≥ 140 mmHg, diastolic blood pressure (DBP) ≥ 90 mmHg or taking antihypertensive medications, based on 2021 WHO guidelines.¹⁴ Hypertension was further categorized into stage 1 (SBP 140–159 mmHg, or DBP 90–99 mmHg) or stage 2 (SBP ≥ 160 mmHg or DBP ≥ 100 mmHg) based on WHO definitions.¹⁵ Prehypertension was defined as SBP 120–139 mmHg, or DBP 80–89 mmHg.^{16,17} Elevated blood pressure was defined as having either prehypertension or hypertension. Detailed definitions for remaining risk factors can be found in the [Supplementary Material](#).

Prevalent CVD was defined as heart failure (HF), stroke, transient ischemic attack (TIA), myocardial

infarction (MI), and angina, defined using epidemiological criteria from the AHA, the WHO, and the European Society of Cardiology.^{9,18,19} Prevalent events were identified and adjudicated based on criteria similar to other CVD epidemiological cohorts including the Reasons for Geographic and Racial Differences in Stroke (REGARDS) and Coronary Artery Risk Development in Young Adults (CARDIA), which categorize cases into definite, probable, and possible events based on a combination of patient reported symptoms, past medical history, physical exam signs, imaging data, and laboratory data.^{20,21} For example, for a diagnosis of HF, participants had to have signs or symptoms on clinical exam in addition to echocardiography findings or treatment for HF. Adjudication criteria and reference sources are outlined in detail in [Supplementary Table S1](#). Consistent with prior studies, we only report definite and probable events in this analysis. Of note, US based cohorts rarely adjudicate the presence of a history of CVD at baseline, or CVD prevalence. Due to lack of access to medical care in Haiti, the study often detected CVD for the first time in many participants during the study enrolment visit, warranting an adjudication process to standardize the presence of baseline CVD.

Statistical analyses

Continuous variables were summarized with median and interquartile ranges (IQR, 25th–75th percentile) given non-normal distributions. CVD prevalence was age-adjusted using direct standardization with the WHO 2000–2025 standard population.²² We also calculated crude CVD prevalence stratified by sex and age <40 years vs ≥40 years. We a priori identified relevant health behaviours and risk factors for CVD events based on published literature and clinical relevance. All covariates were included in a multivariable regression model, and multicollinearity was assessed with generalized variance inflation factors. Covariates included sociodemographic factors (age, sex, education, income, marital status), health behaviours (smoking, alcohol, fruit/vegetable intake, physical activity), clinical characteristics (BMI, diabetes mellitus, hypercholesterolemia, chronic kidney disease, systolic BP, diastolic BP), and psychosocial risk factors (food insecurity, stress, depression). However, due to low counts of certain outcomes (MI, stroke), and unbalanced data for some covariates (e.g. none of MI cases had active smoking), the final multivariable regression models for stroke do not include fruit/vegetable intake, and for MI do not include smoking status, alcohol intake, or fruit/vegetable intake as the models could not converge with inclusion of these covariates. Variables without variation across MI included smoking, alcohol, fruit/vegetable intake, while variables without variation across stroke included fruit/vegetable intake. We used multivariable Poisson regressions with robust standard errors with each CVD event type as an

outcome to assess the association of CVD risk factors and prevalent CVD. Given the data was cross-sectional, the exponent of the coefficients from the Poisson regression were interpreted as prevalence ratios. We used Poisson regression as an alternative to logistic regression because the CVD outcomes were not all rare, with robust standard errors to account for violation of the assumption of a Poisson distribution.²³

For the main analyses, we used participants without any missing data in the Poisson regressions (n = 2904, 96.6%). In a sensitivity analysis, we used multiple imputation by chained equations with 10 imputations using all covariates listed above including outcomes, using the random forest method to impute missing data under the assumption that data were missing at random.^{24,25}

All analyses were conducted in R 4.3.

Role of funding sources

Study sponsors had no role in study design, data collection, data analysis, interpretation, writing, or decision to submit paper for publication.

Results

Among 3005 adults, 3003 (99.9%) had complete clinical data for inclusion in analyses. Median age was 40 years (IQR: 27–55 years), with 58.1% female ([Table 1](#)). All participants identified their race as Black Haitian. The majority (70.2%) lived in extreme poverty with daily income of <1 USD/day and 35.8% reported no schooling or only a primary education. Just over half of participants (53.5%) had elevated blood pressure: 30.4% with hypertension and 23.0% with prehypertension. A total of 17.2% participants had obesity. Other risk factors were less frequent among participants: 3.6% had current smoking, 12.4% had hypercholesterolemia, 8.8% had CKD, and 5.3% had diabetes. Almost all (99.3%) ate less than the WHO recommended 5 servings a day of fruits and vegetables, 87.1% reported high salt intake. Most people reported at least moderate levels of stress (80.8%) and 12.5% reported moderate to severe symptoms of depression.

Prevalence of cardiovascular diseases

The age-adjusted prevalence of total CVD was 14.7% (95% CI 13.3%, 16.5%) ([Fig. 1](#)).

HF was the predominant CVD with an age-adjusted prevalence of 11.9% (95% CI 10.5%, 13.5%). The age-adjusted prevalence of stroke was 2.4% (95% CI 1.9%, 3.3%), TIA 0.4% (95% CI 0.2%, 1.0%), MI 1.0% (95% CI 0.6%, 1.8%) and angina 2.1% (95% CI 1.6%, 2.9%).

Women had a higher prevalence of HF (13.9%, 95% CI 12.3%, 15.5%) than men (8.9%, 95% CI 7.3%, 10.6%) ([Supplementary Table S2](#), [Supplementary Figure S2](#)). The prevalence of stroke, TIA, MI, and angina between sexes was similar. The prevalence of CVD stratified by

	Overall N = 3003	Male N = 1259	Female N = 1744
Demographics			
Age: median (IQR, Range)	40 (27–55, 18–93)	38 (26–54, 18–87)	42 (29–55, 18–93)
Age, years			
18–29	889 (29.6%)	439 (34.9%)	450 (25.8%)
30–39	568 (18.9%)	215 (17.1%)	353 (20.2%)
40–49	533 (17.7%)	198 (15.7%)	335 (19.2%)
50–59	499 (16.6%)	184 (14.6%)	315 (18.1%)
60+	514 (17.1%)	223 (17.7%)	291 (16.7%)
Black Haitian	3003 (100%)	1259 (100%)	1744 (100%)
Education			
Primary or lower	1073 (35.8%)	330 (26.2%)	743 (42.8%)
Secondary or higher	1921 (64.2%)	928 (73.8%)	993 (57.2%)
(Missing)	9 (0.3%)	1 (0.8%)	8 (0.5%)
Income (daily)			
< 1 USD/day	2103 (70.2%)	895 (71.1%)	1208 (69.6%)
1–10 USD/day	360 (12.0%)	153 (12.2%)	207 (11.9%)
> 10 USD/day	531 (17.7%)	210 (16.7%)	321 (18.5%)
(Missing)	9 (0.3%)	1 (0.8%)	8 (0.5%)
Employment			
Employed	946 (31.6%)	410 (32.6%)	536 (30.9%)
Unemployed/Student/Retired/Disabled	2048 (68.4%)	848 (67.4%)	1200 (69.1%)
(Missing)	9 (0.3%)	1 (0.8%)	8 (0.5%)
Marital status			
Married/Living together	1171 (39.1%)	510 (40.5%)	661 (38.1%)
Single	1654 (55.2%)	697 (55.4%)	957 (55.1%)
Widowed/Divorced/Separated	169 (5.6%)	51 (4.1%)	118 (6.8%)
(Missing)	9 (0.3%)	1 (0.8%)	8 (0.5%)
CVD risk factors			
Hypertension	914 (30.4%)	349 (27.7%)	565 (32.4%)
Prehypertension	692 (23.0%)	349 (27.7%)	343 (19.7%)
SBP: median (IQR)	120 (108, 139)	121 (111, 139)	118 (106, 140)
DBP: median (IQR)	73 (64, 84)	71 (62, 83)	74 (65, 86)
BMI, kg/m ² : median (IQR)	24.0 (20.9, 28.1)	22.0 (20.1, 24.9)	26.1 (22.2, 30.3)
BMI category			
Obese ≥30.0	515 (17.2%)	55 (4.4%)	460 (26.4%)
Overweight 25.0–29.9	784 (26.1%)	252 (20.0%)	532 (30.5%)
Underweight/Normal <24.9	1702 (56.7%)	951 (75.6%)	751 (43.1%)
(Missing)	2 (0.07%)	1 (0.8%)	1 (0.06%)
Diabetes mellitus	159 (5.3%)	56 (4.5%)	103 (5.9%)
(Missing)	2 (0.07%)	1 (0.8%)	1 (0.06%)
Hypercholesterolemia	371 (12.4%)	115 (9.2%)	256 (14.7%)
(Missing)	6 (0.3%)	3 (0.2%)	3 (0.2%)
Total cholesterol: Median (IQR)	173 (148, 202)	161 (139, 188)	181 (156, 209)
(Missing)	90 (3.0%)	43 (3.4%)	47 (2.7%)
HDL: Median (IQR)	48 (41, 57)	47 (40, 55)	49 (43, 58)
(Missing)	88 (2.9%)	42 (3.3%)	46 (2.6%)
LDL: Median (IQR)	103 (81, 128)	92 (73, 116)	110 (88, 135)
(Missing)	90 (3.0%)	43 (3.3%)	47 (2.7%)
Chronic kidney disease	256 (8.8%)	95 (7.8%)	161 (9.5%)
(Missing)	81 (2.7%)	38 (3.0%)	43 (2.5%)
Health behaviors			
Smoking status			
Never/Formal	2872 (96.4%)	1193 (95.5%)	1679 (97.1%)

(Table 1 continues on next page)

	Overall N = 3003	Male N = 1259	Female N = 1744
(Continued from previous page)			
Current	107 (3.6%)	56 (4.5%)	51 (2.9%)
(Missing)	24 (0.8%)	10 (0.8%)	14 (0.8%)
Alcohol intake			
< 1 drink a day (low)	2875 (96.3%)	1172 (93.4%)	1703 (98.4%)
≥ 1+ drinks a day (moderate or higher)	111 (3.7%)	83 (6.6%)	28 (1.6%)
(Missing)	17 (0.6%)	4 (0.3%)	13 (0.7%)
Physical activity			
≤ 150 min/week (low)	1515 (50.7%)	637 (50.7%)	878 (50.7%)
> 150 min/week (moderate-high)	1474 (49.3%)	619 (49.3%)	855 (49.3%)
(Missing)	14 (0.5%)	3 (0.2%)	11 (0.6%)
Fruit/vegetable intake			
< 5 servings a day	2972 (99.3%)	1252 (99.6%)	1720 (99.1%)
≥ 5 servings a day	20 (0.7%)	5 (0.4%)	15 (0.9%)
(Missing)	11 (0.4%)	2 (0.2%)	9 (0.5%)
Salt intake			
Moderate-low	386 (12.9%)	117 (9.3%)	269 (15.5%)
High	2608 (87.1%)	1141 (90.7%)	1467 (84.5%)
(Missing)	9 (0.3%)	1 (0.8%)	8 (0.5%)
Food insecurity scale (FIS)			
No/Low FIS	55 (1.9%)	21 (1.7%)	34 (2.0%)
Moderate FIS	462 (15.7%)	187 (15.2%)	275 (16.1%)
High FIS	2422 (82.4%)	1022 (83.1%)	1400 (81.9%)
(Missing)	64 (2.1%)	29 (2.3%)	35 (2.0%)
Psycho-social factors			
Stress (PSS4)			
Low (<6)	574 (19.2%)	324 (25.8%)	250 (14.4%)
Moderate (6–10)	2013 (67.2%)	812 (64.5%)	1201 (69.2%)
High (≥11)	407 (13.6%)	122 (9.7%)	285 (16.4%)
(Missing)	9 (0.3%)	1 (0.8%)	8 (0.5%)
Depression (PHQ-9)			
None to mild (0–10)	2618 (87.5%)	1179 (93.8%)	1439 (82.9%)
Moderate to severe (≥11)	375 (12.5%)	78 (6.2%)	297 (17.1%)
(Missing)	10 (0.3%)	2 (0.2%)	8 (0.5%)
Legend: Statistics presented are median (Interquartile range [IQR]); n (%), percentages are calculated with denominator as those who responded. FIS, Food Insecurity Scale; CVD, cardiovascular disease; SBP, systolic blood pressure; DBP, diastolic blood pressure; BMI, body mass index; HDL, high density lipoprotein; LDL, low density lipoprotein; PSS, Perceived Stress Scale, PHQ-9, Patient Health Questionnaire 9.			
Table 1: Demographic and clinical characteristics of Haiti cardiovascular disease cohort, n = 3003.			

age (<40 years vs ≥40 years) is shown in [Supplementary Table S2](#) and [Supplementary Figure S3](#).

The prevalence of total CVD was higher in our Haiti Cardiovascular Disease cohort, compared to 2019 global estimates for Haiti ([Supplementary Figure S4](#)).^{26–28} Total CVD is over 2-fold greater than global estimates, and driven by high prevalence of heart failure. Our prevalence of HF 11.9% (95% CI 10.5%, 13.5%) is much higher than estimates for either Haiti (0.7% [95% CI 0.6%, 0.8%]) or LMICs (0.8% [95% CI 0.7%, 0.9%]). Our prevalence for stroke (2.4% [95% CI 1.9%, 3.3%]) is higher than global estimates for Haiti (1.1% [95% CI 1.0%, 1.2%]), while our prevalence for MI (1.0% [95% CI 0.6%, 1.8%]) is lower than global estimates (2.0% [95% CI 1.9%, 2.1%]).

Descriptive clinical characteristics of cardiovascular diseases

Prevalent HF cases were young (median age 57 years, IQR 43, 64) with high prevalence among adults <40 years (4.6%, 95% CI 3.6%, 5.8%) ([Supplementary Table S3](#)). The majority (68.5%) were female. Out of all cases, only 12.8% reported awareness or a past medical history of having HF. The most common HF symptoms were dyspnoea on exertion (79.5%), oedema (33.5%) and fatigue interfering with usual activities (24.4%). There were high rates of diastolic dysfunction, with the most common criteria being large left ventricular mass index (69.6%). Detailed description of the diastolic dysfunction can be found in [Supplementary Table S2](#). Heart failure with preserved ejection fraction

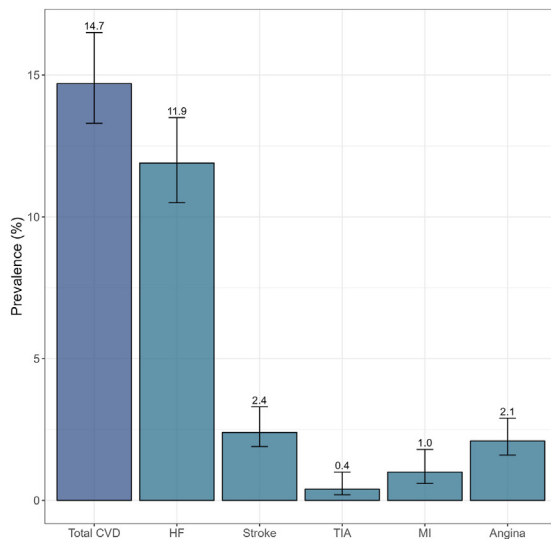


Fig. 1: Age-adjusted prevalence of cardiovascular diseases in the Haiti cardiovascular disease cohort. 95% confidence intervals are represented using error bars. CVD, cardiovascular disease; HF, heart failure; TIA, transient ischemic attack; MI, myocardial infarction.

(HFpEF) was the most common subtype (80.4%). Only 31.2% of individuals with HF were on evidence-based treatment defined as a beta blocker, angiotensin converting enzyme inhibitor, angiotensin receptor blocker, loop diuretic, or mineralocorticoid receptor antagonist.

Prevalent stroke cases had a median age of 60 years, with 7.8% cases among those <40 years (Supplementary Table S3), and 64.9% were female. Almost all (96.1%) were aware of their diagnosis. The most commonly reported stroke symptom was hemiparesis (28.6%), although 48.1% of all strokes had a motor deficit on clinical exam. Only 20.8% of participants with stroke were on evidence-based treatment, defined as aspirin or statin.

Participants with MI were similarly young (median age 54 years, IQR 42, 64) (Supplementary Table S3). Half were female. All cases <40 years were based on self-reported past medical history alone, without evidence of infarct on ECGs. The most common symptom among participants was pain or discomfort in the chest (83.3%), with pain walking uphill in 56.0% of participants and pain walking on ground level in 40.0%. Only 16.7% of participants with MI were on any evidence-based treatment, defined as a beta blocker, aspirin, or statin.

Factors associated with prevalent cardiovascular diseases

Table 2 shows results from the multivariable Poisson regressions, adjusting for age, sex, education, marital status, income, smoking, alcohol, physical activity, fruit or vegetable intake, food insecurity, salt intake, BMI

category, diabetes mellitus, hypertension, hypercholesterolemia, chronic kidney disease, stress, and depression. Generalized variance inflation factors were <2, consistent with no multicollinearity.

For total CVD, associated factors included prehypertension (1.46 PR, 95% CI 1.11, 1.95), hypertension stage 1 (2.23 PR, 95% CI 1.65, 3.00), hypertension stage 2 (3.00 PR, 95% CI 2.29, 4.06), obesity (1.75 PR, 95% CI 1.40, 2.18), CKD (1.40 PR, 95% CI 1.13, 1.75), stress (+1 unit 1.05 PR, 95% CI 1.02, 1.08), depression (1.52 PR, 95% CI 1.22, 1.90), and age (+10 years: 1.30 PR, 95% CI 1.20, 1.40). Lower income and low physical activity were associated with lower PR of total CVD (Table 2, Fig. 2).

For HF, there was a step-wise increase in prevalence ratios (PR) with increasing blood pressure from prehypertension (1.39 PR, 95% CI 1.00, 1.93) to hypertension stage 1 (2.05 PR, 95% CI 1.46, 3.00) to hypertension stage 2 (3.00 PR, 95% CI 2.23, 4.48) compared to participants with normal BP. Other factors associated with higher HF included obesity (1.97 PR, 95% CI 1.54, 2.56), depression (1.54 PR, 95% CI 1.19, 1.99), age (+10 years: 1.31 PR, 95% CI 1.19, 1.45) and stress (1.04 PR, 95% CI 1.00, 1.08) (Table 2, Fig. 2).

For MI, both CKD (PR 2.72, 95% CI 1.23, 5.47) and hypercholesterolemia (2.56 PR, 95% CI 1.21, 5.47) were associated with higher prevalence (Table 2, Fig. 2). Age, obesity, diabetes, and elevated BP were not significantly associated with MI.

Hypertension stage 2 (4.95 PR, 2.08, 13.5), CKD (2.16 PR, 1.26, 3.67), age (+10 years: 1.48 PR, 95% CI 1.20, 1.82) and stress (1.11 PR, 95% CI 1.02, 1.21) were significantly associated with stroke (Table 2, Fig. 2).

The sensitivity analysis using multiple imputation for missing covariate data are shown in Supplementary Table S4. For total CVD, HF and MI, there was no difference in results with multiple imputation. For stroke, in addition to the associations listed above, hypertension stage 1 (PR 2.63, 95% CI 1.04, 6.67) and hypercholesterolemia (PR 1.68, 95% CI 1.04, 2.71) were also associated with higher prevalence. Given low counts for MI, if missingness was not at random then MI results may be biased. However given low percentage of missingness and the similarity between the main analysis (complete cases) and sensitivity analyses (multiple imputation), the bias is likely negligible.²⁴

Discussion

This study found the dominant type of prevalent cardiovascular disease in Haiti is untreated, early-onset HF, largely HFpEF, with a much lower prevalence of ischemic heart disease and stroke. These data represent the first urban population-based estimates of CVD prevalence and associated risk factors from a young Black cohort living in extreme poverty, using adjudicated outcomes that incorporate comprehensive clinical exams, and cardiac imaging. Our cohort data

Characteristic	HF			Stroke			MI			Total CVD		
	aPR	95% CI	p-value	aPR	95% CI	p-value	aPR	95% CI	p-value	aPR	95% CI	p-value
Age (10 years)	1.31	1.19–1.45	<0.001	1.48	1.20–1.82	<0.001	1.28	0.90–1.84	0.2	1.3	1.20–1.40	<0.001
Sex												
Male	ref	–	–	ref	–	–	ref	–	–	ref	–	–
Female	1.14	0.90–1.43	0.3	1.22	0.71–2.08	0.5	0.71	0.30–1.73	0.5	1.13	0.92–1.38	0.2
Education												
Secondary or higher	ref	–	–	ref	–	–	ref	–	–	ref	–	–
Primary or lower	1.08	0.84–1.38	0.5	0.68	0.38–1.23	0.2	0.95	0.41–2.20	>0.9	0.98	0.79–1.21	0.9
Marital status												
Married/Living together	ref	–	–	ref	–	–	ref	–	–	ref	–	–
Single	0.88	0.72–1.07	0.2	0.84	0.51–1.36	0.5	0.86	0.33–2.16	0.7	0.9	0.76–1.07	0.2
Widowed/Divorced/Separated	0.81	0.59–1.12	0.2	0.58	0.27–1.27	0.2	1	0.27–3.67	>0.9	0.81	0.61–1.08	0.2
Income (daily)												
> 10 USD/day	ref	–	–	ref	–	–	ref	–	–	ref	–	–
1–10 USD/day	0.61	0.38–0.98	0.039	0.83	0.27–2.59	0.7	1.9	0.27–12.18	0.5	0.64	0.43–0.96	0.033
< 1 USD/day	1.16	0.88–1.54	0.3	1.58	0.74–3.32	0.2	2.14	0.46–9.97	0.3	1.2	0.94–1.54	0.15
Smoking status												
Never/Former	ref	–	–	ref	–	–	N/A	–	–	ref	–	–
Current	1.4	0.90–2.16	0.13	0.39	0.05–3.00	0.4	N/A	N/A	N/A	1.25	0.84–1.86	0.3
Alcohol intake												
Less than 1 drink a day (low)	ref	–	–	ref	–	–	N/A	–	–	ref	–	–
1 or more drinks a day (moderate or higher)	1.27	0.70–2.29	0.4	2.46	0.76–8.17	0.13	N/A	N/A	N/A	1.06	0.62–1.80	0.8
Physical activity												
> 150 min/week (moderate-high)	ref	–	–	ref	–	–	ref	–	–	ref	–	–
Less or equal 150 min/week (low)	0.73	0.60–0.88	0.001	1.2	0.74–1.93	0.5	0.5	0.25–1.02	0.057	0.73	0.63–0.87	<0.001
Fruit/vegetable intake												
5 or more servings a day	ref	–	–	N/A	–	–	N/A	–	–	ref	–	–
Less than 5 servings a day	1.06	0.33–3.67	>0.9	N/A	N/A	N/A	N/A	N/A	N/A	0.86	0.30–2.41	0.8
Food insecurity												
Moderate-low	ref	–	–	ref	–	–	ref	–	–	ref	–	–
High	1.23	0.92–1.63	0.2	0.65	0.38–1.12	0.12	0.45	0.20–1.07	0.072	1.09	0.86–1.38	0.5
Salt intake												
Moderate-low	ref	–	–	ref	–	–	ref	–	–	ref	–	–
High	0.88	0.68–1.14	0.3	0.79	0.44–1.39	0.4	0.79	0.27–2.34	0.7	0.86	0.69–1.08	0.2
BMI category												
Underweight/Normal <24.9	ref	–	–	ref	–	–	ref	–	–	ref	–	–
Overweight 25.0–29.9	1.26	0.99–1.62	0.063	1.27	0.76–2.16	0.4	0.57	0.22–1.43	0.2	1.27	1.03–1.55	0.024
Obese ≥30.0	1.97	1.54–2.56	<0.001	1.43	0.79–2.59	0.2	0.88	0.30–2.69	0.8	1.75	1.40–2.18	<0.001
Diabetes mellitus												
No	ref	–	–	ref	–	–	ref	–	–	ref	–	–
Yes	1.31	0.97–1.77	0.076	1.11	0.58–2.12	0.8	1.31	0.44–4.06	0.6	1.27	0.99–1.65	0.06
Hypertension												
Normotension (SBP <120 and DBP <80)	ref	–	–	ref	–	–	ref	–	–	ref	–	–
Pre-HTN (SBP 120–139 or DBP 80–89)	1.39	1.00–1.93	0.047	1.36	0.55–3.32	0.5	1.36	0.45–4.06	0.6	1.46	1.11–1.95	0.008
Hypertension stage 1 (SBP ≥140 or DBP ≥90)	2.05	1.46–3.00	<0.001	2.44	0.95–6.05	0.064	1.22	0.37–4.06	0.7	2.23	1.65–3.00	<0.001
Hypertension stage 2 (SBP ≥160 or DBP ≥100)	3.00	2.23–4.48	<0.001	4.95	2.08–13.46	<0.001	1.01	0.30–3.67	>0.9	3.00	2.29–4.06	<0.001
Hypercholesterolemia												
No	ref	–	–	ref	–	–	ref	–	–	ref	–	–
Yes	1.01	0.81–1.27	>0.9	1.58	0.98–2.59	0.059	2.56	1.21–5.47	0.014	1.09	0.90–1.32	0.3
Chronic kidney disease												
No	ref	–	–	ref	–	–	ref	–	–	ref	–	–
Yes	1.42	1.09–1.82	0.008	2.18	1.26–3.67	0.006	2.72	1.23–6.69	0.014	1.4	1.13–1.75	0.003
Stress score	1.04	1.00–1.08	0.03	1.11	1.02–1.21	0.016	1.01	0.87–1.17	0.9	1.05	1.02–1.08	0.004
Depression												

(Table 2 continues on next page)

Characteristic	HF			Stroke			MI			Total CVD		
	aPR	95% CI	p-value	aPR	95% CI	p-value	aPR	95% CI	p-value	aPR	95% CI	p-value
(Continued from previous page)												
None/Mild (<11)	ref	-	-	ref	-	-	ref	-	-	ref	-	-
Moderate/Severe (≥11)	1.54	1.19–1.99	<0.001	1.12	0.60–2.08	0.7	1.92	0.81–4.48	0.14	1.52	1.22–1.90	<0.001

Legend: HF, heart failure; MI, myocardial infarction; CVD, cardiovascular disease; aPR, adjusted prevalence ratios; CI, confidence interval; USD, US dollar; BMI, body mass index; HTN, hypertension; SBP, systolic blood pressure; DBP, diastolic blood pressure; Ref, reference group.

Table 2: Predictors of prevalent CVD events in the Haiti cardiovascular disease cohort, multivariable poisson regressions.

complement high-level summary statistics from modelling estimates by providing local and robust clinical data to more holistically convey the nuances of the CVD epidemic in a LMIC, and show the relative importance of different CVD events and risk factors.

The burden of heart failure is far greater than anticipated and requires further exploration of subtypes and aetiology to expedite targeted prevention, screening, and treatment to prevent deaths. Moreover, if similar data are found in other LMICs, larger poverty and

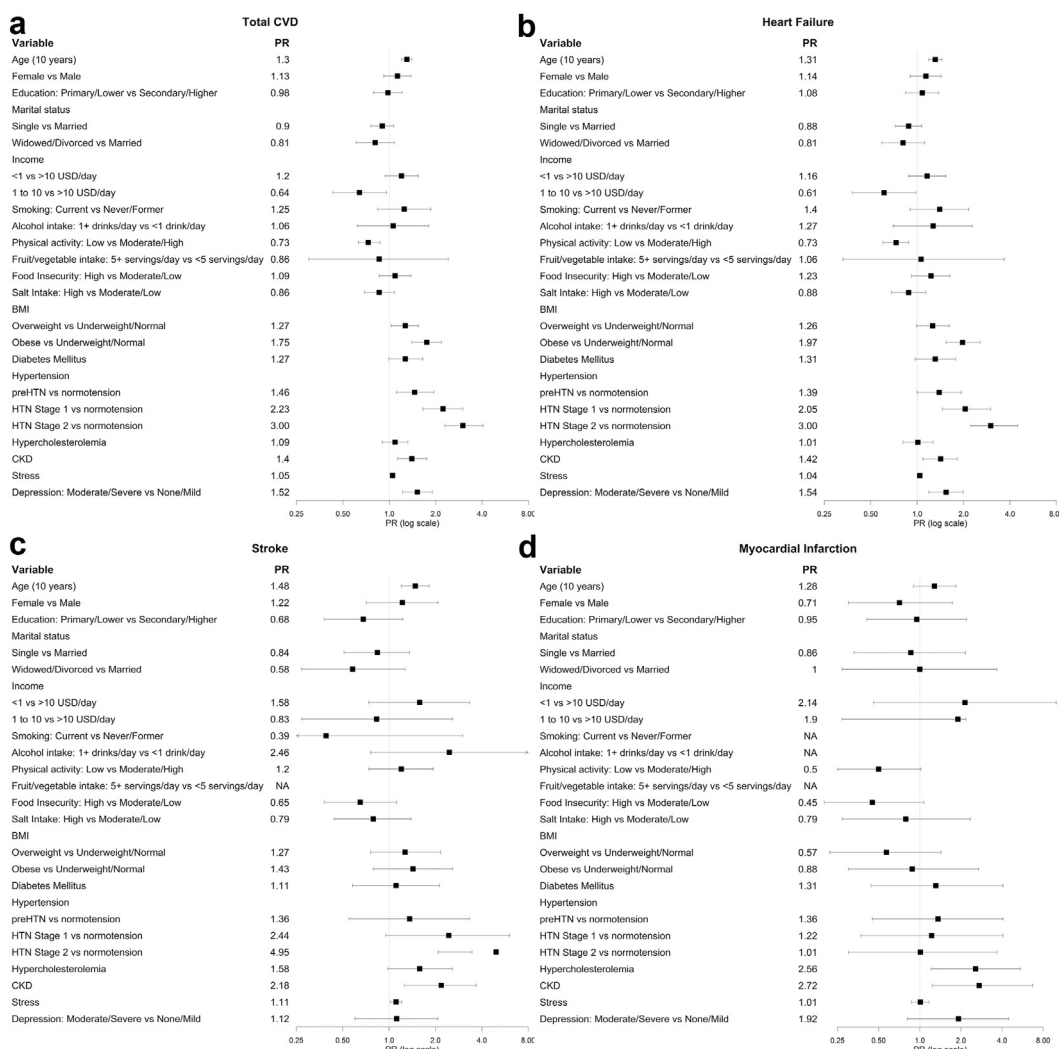


Fig. 2: Factors associated with prevalent CVD in the Haiti cardiovascular disease cohort, multivariable poisson regressions. CVD, cardiovascular disease; PR, prevalence ratio; BMI, body mass index; HTN, hypertension; CKD, chronic kidney disease.

environmental-related drivers of heart failure must be explored to explain the differences in heart disease across socioeconomic environments.

The age-adjusted prevalence estimate of 11.9% for HF is significantly higher than 2019 modelling estimates of 0.68% for Haiti and 0.83% for LMICs from the Global Burden of Disease (GBD) study.²⁶ Our estimates are also higher than estimates from other Latin-American cohorts,²⁹ and the US for non-Hispanic Black Americans (3.6%) as reported by the AHA incorporating data from national surveys, cohort studies, and disease registries.³⁰ We also found high rates of early-onset HF with 4.6% HF prevalence among Haitian adults <40 years, which is ten-fold higher than for Americans in the same age range (0.4%).³⁰ In contrast, the prevalence of MI and stroke in Haiti are similar to GBD modelling estimates and lower than those for non-Hispanic Black Americans.^{27,30} Notably, rates of current smoking were extremely low in this cohort at 3.6%.

There are a few potential reasons for the observed differences in HF prevalence between this study and prior literature. The first is that existing modelling estimates rely on small, unrepresentative clinic samples or extrapolation from neighbouring countries adjusted by Bayesian methods due to lack of systematic primary data from Haiti.³¹ In contrast, the Haiti Cardiovascular Disease Cohort systematically collects data including cardiac imaging, coupled with adjudication procedures similar to other established CVD cohorts, to focus on a vulnerable population which is more likely to be missed by vital statistics or clinic-based samples. Second, reported clinic or hospital case series may include individuals who both have access to health care and present with more severe, end-stage disease, while population-based cohorts show the extent of early, milder CVD that are also targets for treatment and prevention. Third, cohorts in LMICs often rely on local investigator judgement for CVD diagnoses, which may underestimate true prevalence given limited imaging or laboratory measures in routine clinical care.³² Fourth, Haiti is a country of extremes, and the extreme poverty experienced by our urban cohort may have unique and distinct drivers of early-onset HF, such as environmental pollution, prolonged food insecurity, and unrelenting stressors that collide to result in a different pattern of CVD than that seen in high-income countries.² For HFpEF cases specifically, the high prevalence of hypertension and diastolic dysfunction strengthen the basis that these are true cases of HFpEF. However, it is important to understand other processes that could lead to a HF syndrome accompanied by preserved ejection fraction, such as rheumatic heart disease, undiagnosed chronic lung disease, or infectious aetiologies. Participants are being followed longitudinally to delve deeper into the HFpEF aetiologies specific to urban Haiti as a model for similar global settings.

Our prevalence estimates may underestimate the CVD burden in Haiti due to survivor bias, or the exclusion of people with more severe and fatal CVD in the setting of a country where very few people with hypertension or CVD are treated, and where the average life expectancy is 63 years. Our cohort may represent those with milder or more recent onset CVD. Prospective data on outcomes and risk factors in this cohort are essential, and will result in less biased estimates of incidence, spectrum of disease, and risk factors in Haiti.

We found HF occurred at much younger ages than in US cohorts. In our cohort, 4.5% of adults 20–39 years old and 12.2% of those 40–59 years old had HF, compared to 0.3% and 1.4% respectively among Black Americans.³⁰ The median age of our HF cases was 57 years, compared to 72 years in the US registries.³³ This younger profile is similar to hospital-based cohorts of HF in rural Haiti, and in sub-Saharan Africa where the mean age at hospital admission for HF patients was 55 years.^{34,35} We also found there were more women than men among those with HF. This sex difference in our cohort was not statistically significant in our multivariable analyses, most notably with obesity which was associated with HF in Haiti. We have previously found the obesity prevalence in the Haiti Cardiovascular Disease Cohort is 17.1%, with women six times more likely to be obese than men (26.5% vs 4.3%).³⁶ In terms of other CVD risk factors, elevated blood pressure was the most common risk factor associated with HF, a finding reflected in other cohorts.³⁷ Hypertension prevalence in urban Haiti is 29%, yet only 45% of those with hypertension are on treatment and 13% achieve BP control,³⁸ representing a treatment gap in care that could have dramatic consequences for decreasing prevalent disease. Lastly, the vast majority of prevalent HF cases were HFpEF. In the US, there is increasing evidence that HFpEF incidence is rising in both community and hospital based cohorts, perhaps related again to rising rates of obesity.³⁰ Obesity and excess adiposity have been linked to left ventricular diastolic dysfunction and HFpEF through increased autonomic dysfunction, decreased peripheral vascular resistance, increased intrathoracic pressure, and obstructive sleep apnea.³⁹ Further research is needed to understand the aetiology of HFpEF in Haiti including valvular diseases, peripartum cardiomyopathy, and infectious causes in order to determine effective methods of prevention.

Strengths of this study include using a population-based urban cohort selected through multistage random sampling, use of validated CVD screening questionnaires, cardiac imaging data, and adjudication of CVD prevalence using standardized epidemiologic criteria. Additionally, data are from an understudied Black population living in extreme poverty within a country experiencing escalating humanitarian crises, providing previously unknown epidemiologic data about CVD in these settings. Limitations include cross-

sectional data with potential for unmeasured confounders, lack of laboratory data such as brain natriuretic peptide (mitigated by the availability of echocardiography), lack of catheterization data to evaluate elevated filling pressures with gold-standard pulmonary capillary wedge pressure, and lack of widely accessible CT scans for stroke imaging. Future analyses will examine incident CVD events after sufficient longitudinal follow-up. In addition, data from this study may not be generalizable to rural Haitian communities.

In conclusion, the prevalence of CVD in urban Haiti is primarily early-onset heart failure, with low prevalence of ischemic heart disease and stroke. This has profound implications for how national health policy and programming should prioritize potential targets of intervention including early treatment and prevention of hypertension and obesity. Local population-based CVD epidemiological data within LMICs are essential to understand the CVD landscape, regional trends, and modifiable risk factors on the individual and population level to inform clinical practice and research. These data are essential to expedite the selection and implementation of evidence-based health policies and interventions targeting each country's relevant risk factors and diseases. Future directions include prospectively examining and targeting the poverty-related drivers of HF including hypertension, obesity, and perceived stress.

Contributors

Conceptualisation: RM, MT, GP, JD, DN, MHL, MMS, LA, JPA, MD, PS, JWP, VR, MLM.

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Supervision: JWP, VR, MLM.

Validation: MHL.

Visualisation: LY, JL.

Writing: original draft: LY, MLM.

Writing: review & editing: all authors contributed equally.

LY and MLM have the final responsibility for the decision to submit the study for publication.

Data sharing statement

Researchers who provide a methodologically sound proposal may have access to a subset of deidentified participant data, with specific variables based on the proposal. Proposals should be directed to the principal investigator at mam9365@med.cornell.edu. To gain access, data requestors will need to sign a data access agreement. Data are available following publications through 3 years after publication and will be provided directly from the PI.

Declaration of interests

RS, RSS, MJP, YM, AA, JD, MHL, MMS, MD, PS, JWP, VR, MLM report a grant R01HL143788. RS, RSS, JWP, MLM report a grant

D43TW011972. MLM reports a grant K24HL163393. DWF reports grants K24AI098627, D43TW011826, U19AI162568, P30AI168433. JD reports grant R34MH133481. DN reports grants U01AI096299, R01MH125735, P30MH043520, R01MH117793, R34MH126809, R01AI179420, R21AI147933, RF1MH132360, R21AI177008, COVID research grant from Pfizer, and has received consulting fees from Gilead and Abbvie. GFK reports grants K23HL140133, and R21TW012165. MMS reports grant R01HL165452. JWP reports grants UM1AI069421 and D43TW011295.

Acknowledgements

We thank the participants of the Haiti Cardiovascular Disease Cohort, the GHESKIO community health workers and participating communities in Port-au-Prince. We thank Vanessa Rivera and Dr Eliezer Dade for their contributions in training and study operationalization. We also thank Dr David Zhang and Dr Sharan Yadev for assistance with ECG interpretation. Lastly, we thank the Haitian College of Cardiology and Haitian Ministry of Health for providing leadership in the design and interpretation of the study.

Funding: This study was funded by NIH grants R01HL143788, D43TW011972, and K24HL163393, clinicaltrials.gov NCT03892265.

Appendix A. Supplementary data

Supplementary data related to this article can be found at <https://doi.org/10.1016/j.lana.2024.100729>.

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