

Estimated blood pressure trajectories and hypertension patterns among pregnant women living with HIV, Haiti, 2007–2017

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Abstract

Hypertension in pregnancy is a key driver of mortality and morbidity among Haitian women. HIV infection and treatment may worsen hypertension and increase cardiovascular disease risk. The authors examined blood pressure and hypertension patterns among 1965 women (2306 pregnancies ending in live births) in a prevention of maternal-to-child transmission (PMTCT) program in Port-au-Prince, Haiti, between 2007 and 2017. Hypertension was defined as blood pressure $\geq 140/90$ mm Hg on two consecutive visits. Latent class analysis assessed trajectories of mean arterial pressure (MAP) and multinomial ordinal logistic regression examined factors associated with higher trajectories. Between 2007–2009 and 2013–2016, hypertension at PMTCT entry increased from 1.3% to 3.8% ($p = .005$), while incidence at any time during PMTCT follow-up increased from 5.0 to 16.1 per 100 person-years ($p < .001$). Hypertension detected ≤ 20 weeks and > 20 weeks of gestation (possible gestational hypertension) increased from 1.1% to 3.5% ($p = .003$) and from 2.3% to 6.9% ($p < .001$), respectively. Five MAP trajectories ranged from low-stable to high-increasing. In multivariable analysis controlling for history of antiretroviral therapy, age, parity, and weight, program entry in more recent years was associated with greater odds of higher MAP trajectory (adjusted odds ratio for 2013–2016 vs. 2007–2009 = 3.1, 95% confidence interval: 1.7–5.6). The increasing prevalence and incidence of hypertension highlight a need for screening and management prior to PMTCT entry and during follow-up. In a population with limited access to chronic disease care, and where many deliveries occur outside of a clinical setting, the period of PMTCT follow-up represents an opportunity to diagnose and initiate management of preexisting and pregnancy-related hypertension.

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KEYWORDS

blood pressure, Caribbean region, global health, Haiti, HIV, hypertension, pregnancy

1 | INTRODUCTION

Hypertension in pregnancy is a major cause of maternal and perinatal morbidity and mortality, affecting about 10% of pregnancies worldwide.¹ In the Caribbean, the condition is estimated to be responsible for over a quarter of maternal deaths² and has been documented at substantial rates among pregnant women living with HIV (WLWH).³ In Haiti, high rates of hypertensive disorders of pregnancy such as eclampsia, pre-eclampsia,⁴⁻⁶ and postpartum eclampsia^{4,7} have been reported, and are associated with adverse outcomes such as low birth weight, stillbirth, and maternal death.⁶ Haiti's maternal mortality rate is the highest in the Western Hemisphere with an estimated 480 deaths for every 100 000 live births, five times as high as in the neighboring Dominican Republic.⁸ Although 91% of Haitian women report receiving some form of prenatal care for their most recent pregnancy, fewer than four in 10 births take place in a healthcare facility, and two thirds of women receive no postnatal care at all.⁹

Overweight, obesity, chronic hypertension, and HIV positivity, are risk factors for pre-eclampsia, and are common among Haitian women of reproductive age.^{9,10} HIV and antiretroviral (ARV) medications, including those used for the prevention of mother-to-child transmission (PMTCT) of HIV, may promote hypertension via multiple factors including: chronic HIV-associated inflammation, immune suppression and reconstitution, impairment in endothelial function and imbalance in the renin-angiotensin system, impaired kidney function, metabolic effects, dyslipidemia, lipodystrophy, and body weight changes.^{11,12} Hypertension is more prevalent among adults with HIV than those without the infection,¹³⁻¹⁵ and HIV infection is associated with more frequent complications, even at similar blood pressure (BP) levels.¹⁶ Although among pregnant women specifically, findings on the association between HIV infection and ARV history, and hypertension in pregnancy, have been mixed,^{3,17-23} this vulnerable population merits targeted study, as the HIV care system may potentially be leveraged to screen for and provide hypertension care in pregnancy.

This study sought to describe BP and hypertension patterns among pregnant WLWH in a PMTCT program in Port-au-Prince, Haiti.

2 | METHODS

2.1 | Study population and setting

Participants were pregnant WLWH in the PMTCT program at the GHESKIO clinic, a nongovernmental organization and the largest provider of HIV and PMTCT services in Haiti. Upon entry, women received a physical examination, World Health Organization (WHO) staging, a CD4 count test, tetanus vaccination, and antenatal assessment, including collection of sociodemographics.²⁴ Follow-up appoint-

ments were scheduled every 4 weeks until 8 months of gestation, and weekly thereafter. During these visits, BP was measured by the auscultation method using a manual sphygmomanometer with a stethoscope, and medication refills were dispensed (ferrous sulphate, folic acid, and ARV medications, if indicated). The policies guiding HIV treatment of pregnant women followed WHO and national guidelines.

Retrospective electronic medical record data for pregnancies of women who entered the PMTCT program between January 1, 2007 and December 28, 2016, were used, with follow-up through pregnancy end dates until August 2017.

2.2 | Eligibility

To be included, a pregnancy had to be confirmed by laboratory tests and ultrasound, have a known confirmed or estimated delivery date, ≥ 12 weeks PMTCT follow-up between entry (first PMTCT visit) and delivery date, and ≥ 3 BP measurements on separate days during PMTCT follow-up. Excluded were pregnancies known to have ended in an abortion, stillbirth, or maternal death (Figure 1).

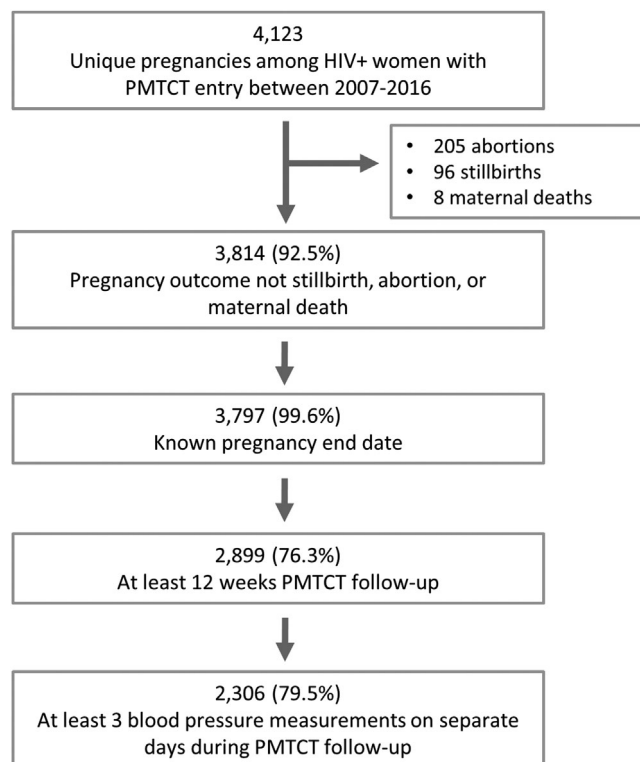


FIGURE 1 Cohort selection diagram

2.3 | Definitions

2.3.1 | Hypertension

Per local practice, most BP measurements were abbreviated and recorded in cm Hg, for example, 12/8. For analysis, a "5" was added to such readings (with 12/8 cm Hg becoming 125/85 mm Hg, eg).

Hypertension was defined as systolic BP (SBP) ≥ 14 cm Hg (140 mm Hg) or diastolic BP (DBP) ≥ 9 cm Hg (90 mm Hg) at two consecutive measurements on separate days.^{25,26} Prescription of antihypertensive drugs by a medical professional was not included due to the lack of prescription data.

Patients were considered to have hypertension at entry if their first two measurements following PMTCT entry met the definition. Among patients without hypertension at entry, hypertension was considered incident if any two consecutive measurements met the definition. Date of hypertension onset was set to the date of the first of the two measurements meeting the definition. Additionally, severe hypertension was defined as SBP ≥ 160 mm Hg or DBP ≥ 110 mm Hg at any single measurement.²⁵

All cases of hypertension were also categorized as detected ≤ 20 weeks gestation (a proxy for chronic hypertension) or > 20 weeks gestation (a proxy for possible gestational hypertension).²⁵ No data were available on pre-pregnancy BP, urine protein, or laboratory measures such as platelet count or transaminase, which would help differentiate between chronic hypertension, gestational hypertension, and likely pre-eclampsia.

2.4 | Other clinical variables

For each pregnancy, multiple gestational status, pregnancy's sequence at GHESKIO, woman's weight, and gestational age at PMTCT entry were recorded. Gestational age was calculated from the date of the last reported menstrual period. To represent the woman's HIV exposure and clinical status, time between the first known HIV diagnosis and PMTCT entry, WHO stage, and CD4 count at entry (within ± 30 days) were described. ARV exposure was coded as none until delivery, mono- or bi-regimen during pregnancy, and four levels of triple-ARV antiretroviral therapy (ART), based on the timing of its initiation: at PMTCT entry, up to a year before entry, 1–3 years before entry, or more than 3 years before entry.

3 | STATISTICAL ANALYSIS

3.1 | Characteristics of pregnancies and hypertension measures

Descriptive statistics were used to describe the frequency and timing of BP measurements, pregnancy characteristics, and the proportion of pregnancies with hypertension known at entry, incident, detected \leq or > 20 weeks gestation, or severe, overall and by program

period. Among patients free of hypertension at entry, the incidence rate of hypertension during the pregnancy was calculated per 100 person-years of follow-up. Time trend across the three entry periods was tested using logistic regression (for hypertension at entry) and Cox proportional hazards models (for incident hypertension), all of which accounted for the clustering due to repeat pregnancies within women.

3.1.1 | Trajectories of mean arterial pressure (MAP)

To describe BP patterns and identify pregnancies at potentially increased risk of pre-eclampsia, previously linked to MAP,^{27–29} trajectory of MAP ($[\text{SBP} + 2 \times \text{DBP}] / 3$) was modeled. Latent class models identified subgroups of pregnancies sharing similar underlying MAP trajectories. The approach uses a semiparametric, group-based modeling strategy which takes advantage of traditional methods for analyzing developmental trajectories—hierarchical modeling and latent growth curve modeling. Longitudinal MAP values were modeled as a discrete mixture of multiple trajectories via maximum likelihood.^{30–32}

Models with different numbers and forms of potential trajectories were tested, with model fit assessment via the Bayesian Information Criterion (BIC). A censored normal model for continuous outcomes was used, with weeks remaining until delivery, in weeks, as the timescale. The final model had two trajectory classes with up to quadratic order terms and 3 classes with up to cubic order terms. Each pregnancy was assigned to the trajectory group for which it had the greatest posterior predictive probability. The resulting trajectories were qualitatively examined and assigned names representing the observed visual patterns (from "low-stable" to "high-increasing").

3.2 | Factors associated with higher MAP trajectories

To assess characteristics associated with higher MAP trajectories, a multinomial ordinal logistic regression model accounting for clustering of pregnancies within women was developed.³³ The bottom three trajectories, roughly corresponding to normal MAP, were grouped together for analysis.

Variables considered for inclusion in the model were known risk factors for gestational hypertension and pre-eclampsia such as age group (with a category for advanced maternal age defined as over 40 years old) and pregnancy sequence at GHESKIO (as a proxy for parity),^{34,35} as well as factors related to pregnant woman's HIV disease status (CD4 count and WHO stage at PMTCT entry, ART exposure), and education (as a proxy for socioeconomic status). Multiple pregnancy status was not included in the analysis because there were no multiple pregnancies in the highest MAP trajectory.

Variables were included in multivariable analysis if they were potential risk factors for gestational hypertension and pre-eclampsia or if they had p -values $< .2$ in bivariate analysis, and were not collinear with other variables.

3.3 | Ethics

This analysis of routinely collected de-identified data was approved by the Ethics Board at GHESKIO and the institutional review boards at Weill Cornell Medicine and City University of New York, Graduate School of Public Health and Health Policy.

4 | RESULTS

4.1 | Cohort characteristics

Altogether, 2306 pregnancies among 1965 women met the inclusion criteria. Pregnancies were excluded from the analysis mainly due to lack of sufficient follow-up. (Figure 1) The median age at PMTCT entry was 29 years (IQR: 25–34), with no appreciable change in age distribution over time. Over half (55%) of pregnancies were to women who reported no income (Table 1).

Median gestational age at PMTCT entry was 15 weeks (IQR: 10–20), 2% of pregnancies were multiple, and 71% were the woman's first pregnancy at GHESKIO. Between 2007–2009 and 2013–2016, the proportion of pregnancies with prior ART exposure increased from 11% to 58% and duration of prior exposure increased from a median of 15.0 months (IQR: 5.8–40) to 26.1 months (IQR: 12.3–51.9). There was also an increase in the median CD4 count at PMTCT entry, from 425 cells/ μ l (IQR: 289–575) in 2007–2009 to 463 cells/ μ l (IQR: 309–656) in 2013–2016. At least 28% of the pregnancies were delivered outside of a clinical setting.

Compared to pregnancies included in the analysis, excluded pregnancies were more likely to have been the woman's first at GHESKIO (81% vs. 71%) and have had no prior ARV exposure (30% vs. 9%) (Data not shown).

4.2 | Blood pressure measurements

Blood Pressure measurement patterns were similar over the three periods, with the median number per pregnancy ranging from 5 to 6, and almost all pregnancies having a measurement recorded on the day of PMTCT entry (96–98%). Median time between measurements was 4 weeks and most were taken within > 2 to 6 weeks apart. (Table S1) In each period, there were relatively fewer measurements early in the pregnancy than later in the pregnancy (Figure S1).

4.3 | Hypertension measures

Overall, 2.5% of pregnancies had hypertension detected \leq 20 weeks gestation and 4.8% - > 20 weeks. Among pregnancies without hypertension at entry, the incidence rate was 11.2 per 100 person-years of follow-up (Table 2).

There was a marked temporal trend in all of the measures. Hypertension detected \leq 20 weeks and > 20 weeks gestation increased from 1.1% to 3.5% and from 2.3% to 6.9%, respectively, between

2007–2009 and 2013–2016 (*p*-values .003 and < .001, respectively). Hypertension at entry increased from 1.3% to 3.8%, while the incidence rate increased from 5.0 to 16.1 per 100 person-years (*p*-values .005 and < .001, respectively). The proportion of pregnancies with at least one severely hypertensive measurement was 3.2% across the study period, without appreciable change over time.

4.4 | MAP trajectories and factors associated with higher trajectories

Five MAP trajectories were identified: (1) low-stable (458 or 19.8% of pregnancies, with final estimated MAP of 72.4 mm Hg), (2) low-increasing (1,037 or 45.0% of pregnancies, with final estimated MAP of 81.9 mm Hg), (3) moderate-increasing (585 or 25.4% of pregnancies, with final estimated MAP of 93.2 mm Hg), (4) elevated-increasing (200 or 8.7% of pregnancies, with final estimated MAP of 109.9 mm Hg), and (5) high-increasing (26 or 1.1% of pregnancies, with final estimated MAP of 131.6 mm Hg). (Figure 2) Pregnancies were classified into trajectory groups with good discrimination; the mean probability of group membership was 0.86 (range 0.85–0.98 across the five trajectory groups). The number of BP measurements across categories was similar (median 6, IQR 4–7 or 4–8). Median final recorded blood pressure values were in group 1: SBP 95 (IQR: 85–95) / DBP 65 (IQR: 55–65) mm Hg, group 2: 105 (IQR: 95–105) / 65 (IQR: 65–75) mm Hg, group 3: 115 (IQR: 105–125) / 85 (IQR: 75–85) mm Hg, group 4: 135 (IQR: 125–145) / 95 (IQR: 85–105) mm Hg, group 5: 175 (IQR: 145–195) / 115 (IQR: 105–125) mm Hg.

In multivariable analysis adjusted for ART exposure, there was a trend of increasing odds of higher MAP trajectory with more recent PMTCT entry. Pregnancies with PMTCT entry between 2010–2012 or 2013–2016 had 2.2 and 3.1 times the adjusted odds of higher map trajectory (95% CI: 1.3–3.8 and 1.7–5.6, respectively) as those with entry in 2007–2009. Older age was also associated with greater odds of higher MAP trajectory (aOR for age > 40 vs. 20–40 years = 2.5, 95% CI: 1.3–4.9), as were pregnancies which were the women's first at GHESKIO (aOR first vs. second pregnancy = 1.5, 95% CI: 1.03–2.2), and higher weight at entry (aOR for each additional kilogram = 1.03, 95% CI: 1.02–1.04). A strong trend between duration of ART exposure prior to PMTCT entry and higher MAP trajectory was observed in unadjusted analysis; however, the associations were not statistically significant and point estimates were lower in magnitude after adjusting for entry year (Table 3).

5 | DISCUSSION

The rates of hypertension have increased in pregnancies which ended in live births among WLWH receiving PMTCT care in Port-au-Prince between 2007 and 2017. A tenth of pregnancies had an elevated-increasing or high-increasing MAP trajectory, suggesting increased risk of hypertension-related complications such as strokes, pre-eclampsia,

TABLE 1 Characteristics of analyzed pregnancies in the PMTCT program (N = 2306)

Characteristic		Included pregnancies, by period of entry		
		2007–2009: N (%) or Median (IQR)	2010–2012: N (%) or Median (IQR)	2013–2016: N (%) or Median (IQR)
N pregnancies (% of total)		617 (27%)	730 (32%)	959 (42%)
N women with pregnancy in period		596	703	906
Age at PMTCT entry, years		28 (24,33)	29 (25,34)	29 (24,34)
Age category	< 20 years	42 (7%)	28 (4%)	54 (6%)
	20–40 years	564 (91%)	680 (93%)	880 (92%)
	> 40 years	11 (2%)	22 (3%)	25 (3%)
Education level	None	100 (16%)	100 (14%)	123 (13%)
	Primary	242 (39%)	292 (40%)	360 (38%)
	Secondary	260 (42%)	327 (45%)	450 (47%)
	University or professional	11 (2%)	10 (1%)	13 (1%)
	Unknown	4 (1%)	1 (0%)	13 (1%)
Multiple gestation pregnancy	Yes	11 (2%)	16 (2%)	30 (3%)
Sequence at GHESKIO	1	494 (80%)	516 (71%)	624 (65%)
	2	104 (17%)	158 (22%)	231 (24%)
	3+	19 (3%)	56 (8%)	104 (11%)
Gestational age at PMTCT entry, weeks		15 (10,21)	15 (10,20)	14 (10,20)
Weight at PMTCT entry (+/- 30 days), kg		57.6 (52.2, 65.3)	57.6 (51.3, 65.3)	56.4 (50.2, 63.5)
BMI at PMTCT entry (+/- 30 days) available		115 (19%)	241 (33%)	941 (98%)
BMI at PMTCT entry (+/- 30 days), kg/m ²		22.9 (20.5, 25.5)	22.0 (20.2, 24.2)	22.1 (20.0, 24.8)
Time from HIV diagnosis to PMTCT entry available		521 (84%)	593 (81%)	773 (81%)
Time from HIV diagnosis to PMTCT entry, months		13 (0.2,44)	34 (11,60)	39 (15,77)
ARV exposure relative to PMTCT entry	None ever until delivery	106 (17%)	87 (12%)	16 (2%)
	ARV mono- or bi- at or after entry	382 (62%)	90 (12%)	0 (0%)
	ART initiated at entry	62 (10%)	340 (47%)	391 (41%)
	ART for up to 1 year before entry	30 (5%)	88 (12%)	134 (14%)
	ART for > 1–3 years before entry	17 (3%)	88 (12%)	211 (22%)
	ART for > 3 years before entry	20 (3%)	37 (5%)	207 (22%)
If received ART prior to PMTCT entry, duration of prior ART (months)		15 (6,40)	17 (6,31)	26 (12,52)
CD4 count at PMTCT entry (+/- 30 days), cells/ μ l		425 (289, 575)	439 (308, 588)	463 (309, 656)

*As of September 2021, 5000 gourdes equals 51 USD.

preterm delivery, or fetal growth restriction. The population under study has high background prevalence of high BP and hypertension risk factors, such as overweight and obesity,¹⁰ highlighting an urgent need to leverage HIV testing, PMTCT care and prior HIV care for hypertension screening and management for women, so that measures may be taken to reduce the risk of severe hypertension-related outcomes.

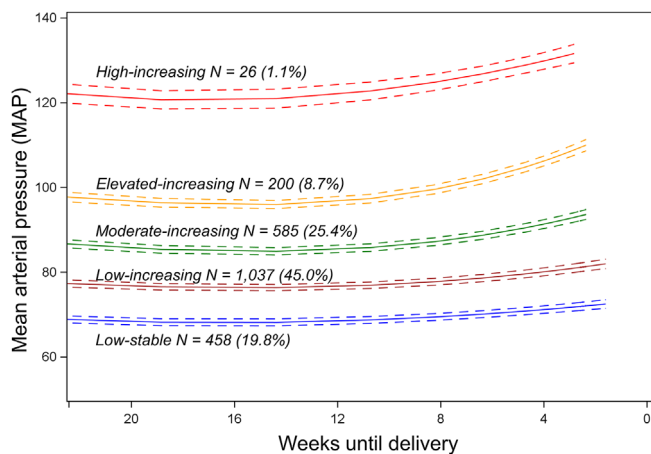
Over the study period, at least 2.5% of pregnancies were affected by hypertension detected \leq 20 weeks and another 4.8% by hypertension detected > 20 weeks, or potentially gestational hypertension which increases the risk of pre-eclampsia. In 2013–2016, the former was identified among 3.5% of pregnancies and the latter—among 6.9%, higher than the estimates of hypertensive disorders from four rural

TABLE 2 Hypertension during PMTCT follow-up (N = 2306 pregnancies)

	Overall	2007–2009	2010–2012	2013–2016	p-value*
Hypertension detection timing ^a					
≤20 weeks gestation	2.5% (1.9–3.2%)	1.1% (0.5–2.3%)	2.3% (1.4–3.7%)	3.5% (2.5–4.9%)	.003
>20 weeks gestation	4.8% (3.9–5.7%)	2.3% (1.2–3.8%)	4.1% (2.8–5.8%)	6.9% (5.4–8.7%)	<.001
Hypertension at entry					
	2.6% (2.0–3.3%)	1.3% (0.6–2.6%)	2.2% (1.3–3.6%)	3.8% (2.7–5.2%)	.005
Incidence rate among those free of hypertension at entry, per 100 person-years					
	11.2 (9.3–13.4)	5.0 (2.7–8.4)	10.0 (6.9–14.0)	16.1 (12.6–20.0)	<.001
Severe hypertension at any one measurement					
	3.2% (2.5–4.0%)	2.8% (1.6–4.4%)	2.9% (1.8–4.4%)	3.6% (2.6–5%)	.473

^aHypertension type combines hypertension at entry and incident hypertension cases.

*p-values are model-based (logistic for prevalence, Cox for incidence) and account for clustering of pregnancies within women.

**FIGURE 2** Trajectories of mean arterial blood pressure (N = 2306 pregnancies)

referral hospitals across Haiti in 2012–2014, which also included pregnancies which ended in stillbirth or maternal death.⁶

Prevalence and incidence of hypertension increased over time, alongside increases in ART exposure and its duration. In rural Haiti, two analyses a decade apart did not indicate an increase in the prevalence of eclampsia or pre-eclampsia among women delivering in a hospital^{4,5}; however, no other trend data from Haiti are available for comparison. There was no evidence of increase in other measured risk factors such as maternal age or weight at entry. In unadjusted analyses, duration of ART exposure was strongly associated with higher MAP trajectories; however, there was no association in the model including time period. While some studies have reported higher rates of hypertension in pregnancy²⁰ or pre-eclampsia specifically³⁶ among women with HIV overall and ones with ART exposure in particular,^{3,37} possibly due to immune reconstitution, evidence is mixed.^{17–19,21–23} In the general HIV-positive population, low-magnitude associations between cumulative exposure to specific ARVs and hypertension onset or BP

change on anti-hypertensive therapy have been reported.^{38–40} While this study lacked adequate data to assess ARV exposure in detail, it is possible that increases in hypertension and the odds of higher MAP trajectory over time are driven in part by ARV history, and associated changes in body composition and biological markers, which should be explored in more detail in future work.

In addition to calendar time, advanced maternal age (40 years or older), pregnancies that were the women's first in the PMTCT program, a proxy for primiparity, and higher maternal weight at entry were associated with greater odds of a higher MAP trajectory, consistent with previously documented risk factors for hypertension in pregnancy.^{3,34,41,42} Analyses exploring blood pressure among women with repeat pregnancies, leveraging longitudinal data on body weight, laboratories, and presence or type of clinical intervention on blood pressure, can shed more light on the interplay of these factors with cumulative ART exposure.

The findings highlight the importance of screening and ongoing monitoring for hypertension in and prior to pregnancy among WLWH in Haiti. In addition to monitoring for sustained elevated BP, establishing the diagnosis of pre-eclampsia also involves evaluation for proteinuria,¹ thrombocytopenia, renal insufficiency, impaired liver function, pulmonary edema, and visual or cerebral symptoms.³⁴ Since screening for these conditions is not readily available in resource-constrained settings, properly measured BP remains the key diagnostic tool for hypertension in pregnancy. Consistent measurement at every visit and recording of BP in medical records is critical, in addition to low-cost tests for proteinuria for low-income settings.^{43,44} Mobile health approaches are also increasingly examined as tools for patient and provider education, and screening for and management of hypertension in pregnancy in low-resource settings,⁴⁵ but may face challenges in integration into health systems and limited internet connectivity.

Importantly, attention to the background prevalence and risk of chronic hypertension is critical. As women increasingly enter PMTCT

TABLE 3 Factors associated with higher MAP trajectories (N = 2306 pregnancies)

Variable	OR (95% CI)	p-value	aOR (95% CI)	p-value
Period				
2007–2009	ref	<.001	ref	<.001
2010–2012	2.3 (1.4–3.5)		2.22 (1.31–3.76)	
2013–2016	3.2 (2.1–4.9)		3.12 (1.74–5.59)	
Woman's sociodemographic characteristics				
Age at PMTCT entry				
< 20 years	0.47 (0.20–1.1)	.004	0.56 (0.24–1.3)	.031
20–40 years	ref		ref	
> 40 years	2.8 (1.5–5.4)		2.5 (1.3–4.9)	
Education level				
None	ref	.112		
Primary	0.69 (0.44–1.1)			
Secondary, university, or professional	0.94 (0.61–1.4)			
Clinical HIV & pregnancy characteristics				
Pregnancy sequence at GHESKIO				
1	1.2 (0.83–1.6)	.280	1.5 (1.03–2.2)	.065
2	ref		ref	
3+	1.6 (0.92–2.7)		1.4 (0.81–2.5)	
Weight at PMTCT entry				
One kg increase	1.03 (1.02–1.04)	<.001	1.03 (1.02–1.04)	<.001
CD4 count at PMTCT entry				
≤ 200 cells/μl	1.1 (0.65–1.9)	.756		
201–350 cells/μl	0.80 (0.51–1.3)			
351–500 cells/μl	0.92 (0.60–1.4)			
> 500 cells/μl	ref			
Unknown	0.85 (0.60–1.2)			
ART status respective to PMTCT entry				
None ever until delivery ^a	ref	<.001	ref	.311
ART initiated at PMTCT entry	1.7 (1.1–2.6)		0.9 (0.53–1.5)	
ART for up to a year before PMTCT entry	2.0 (1.2–2.2)		1.0 (0.54–1.8)	
ART for > 1–3 years before PMTCT entry	2.6 (1.6–4.0)		1.4 (0.75–2.5)	
ART for > 3 years before PMTCT entry	2.6 (1.6–4.2)		1.3 (0.69–2.5)	
WHO stage at PMTCT entry				
1	ref	.501		
2	0.86 (0.54–1.3)			
3	0.94 (0.55–1.6)			
4	1.4 (0.88–2.2)			

^aIncludes ARV mono- and bi- exposure after PMTCT entry.

with a history of HIV care, many cases of pre-existing hypertension can be detected and managed prior to conception and PMTCT entry. As there are no hypertension screening or treatment guidelines specific to populations living with HIV,¹¹ general recommendations apply.^{46,47} Approaches such as home or ambulatory monitoring of BP are helpful in detecting masked hypertension and abnormalities in diurnal BP

patterns among individuals living with HIV,^{48–50} but may be infeasible in low-income countries. BP evaluation at each follow-up HIV clinic visit remains a critical screening tool to enable early intervention and distinction of gestational hypertension or pre-eclampsia from chronic hypertension.

Finally, frequent deliveries outside the clinical setting, even among women who accessed antenatal care, highlight the importance of addressing potential risks to the woman and fetus prior to or early in the pregnancy, given limited availability of specialized medical help at the time of many deliveries.

Study limitations include BP measurements mostly recorded in cm Hg, which did not affect the application of hypertension definitions, but constituted less granular data for trajectory modeling. Additionally, if any providers rounded, rather than abbreviated, BP readings, estimates would be biased upwards. Several factors, however, likely led to underestimation of hypertension: exclusion of pregnancies that ended in stillbirth or maternal death, the lack of prescription data for hypertension treatment, inclusion of pregnancies with as few as three BP measurements available, and the requirement of at least 3 months PMTCT follow-up, which may have excluded women with early preterm deliveries (and potentially early pre-eclampsia or other complications). Some instances of hypertension may have been misclassified as occurring after > 20 weeks gestation among women who entered care after that timepoint. Because of the lack of laboratory data, it was not possible to describe pre-eclampsia in women with incident hypertension > 20 weeks of gestation. There were also no data available for several risk factors, such as pre-pregnancy BMI, diet, smoking, diabetes, chronic kidney disease, family history, exposure to stress, and parity. Secular trends in other risk factors, such as BMI or diet, could be contributing to the observed increases in hypertension over time.

Findings cannot be generalized to pregnancies that ended in abortion, stillbirth, or maternal death; ones not supported by PMTCT and/or antenatal services, or which received such care only at late stages. Such pregnancies, likely among women with less access to healthcare, may be at even higher risk of poor outcomes, including hypertension.

This study documents a substantial and increasing prevalence and incidence of chronic and possible gestational hypertension in a large PMTCT program in Port-au-Prince, Haiti. The findings point to a need for hypertension treatment prior to PMTCT entry as well as during PMTCT follow-up, to minimize the risk of pregnancy complications and negative outcomes for the women and fetuses, and to protect the long-term health of the women. Since the population under study is largely low-income, with limited access to chronic disease care, and many deliveries occur outside of a clinical setting, the period of PMTCT follow-up represents an opportunity to diagnose and initiate management of chronic and gestational hypertension alike. Investigation of reasons driving increases in hypertension over time, including possible ARV exposure patterns, could inform potential differentiated hypertension screening and management for PMTCT clients.

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CONFLICTS OF INTEREST

None.

AUTHOR CONTRIBUTIONS

O.T., M.L.M., D.W.F., and D.N. conceived the study. M.M.D., V.R., Y.M., and J.W.P. led data collection and management. O.T. designed the study, conducted data cleaning and analysis, and wrote the manuscript. M.M.D., V.R., M.L.M., R.N.P., L.M., D.W.F., and D.N. contributed to the interpretation of findings. All authors contributed significantly to the revision and final approval of the manuscript.

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SUPPORTING INFORMATION

Additional supporting information may be found in the online version of the article at the publisher's website.

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