Lifetime Cardiovascular Disease Risk Prediction and Social Determinants of Cardiovascular Health in Women with a History of Gestational Hypertension and Preeclampsia in Kenya

Floria Nyandaya

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Committee:

Sarah Masyuko

Chris Longenecker

Alfred Osoti

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Abstract

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Floria Nyandaya

Chair of the Supervisory Committee:

Sarah Masyuko

Department of Global Health

The global cardiovascular disease (CVD) burden among women is on an upward trend, adversely affecting women in low and middle-income settings (LMIC). Gestational hypertension and preeclampsia, a subset of hypertensive disorders of pregnancy, have a 2 to 6-fold increase in future cardiovascular events based on data from high-income countries. While gestational hypertension or preeclampsia may resolve post-delivery, the lingering impact of cardiovascular stress during pregnancy, vascular inflammation, endothelial dysfunction, and prevailing CVD risk factors including elevated blood pressure, dyslipidemia, hyperglycemia and increased body mass index, pose a high likelihood of experiencing future CVD events such as fatal and non-fatal coronary heart disease, stroke, peripheral vascular disease, and heart failure.

While the postpartum period is an opportune window for CVD risk reduction, postpartum cardiovascular assessment, especially in LMIC like Kenya, is underutilized. Sociodemographic hardship, an adverse score of social determinants of health (SDOH), includes social, economic and environmental factors that impact

cardiovascular health. While SDOH's impact on CVD risk and development is established, its influence on blood pressure changes in postpartum women with gestational hypertension or preeclampsia in Kenya is unknown. This thesis compares the lifetime CVD risk among postpartum Kenyan women with and without gestational hypertension or preeclampsia and examines the influence of SDOH on blood pressure changes.

In the first aim, we evaluated the 6-month postpartum CVD risk using pooled cohort equations (PCE), comparing women with a history of gestational hypertension or preeclampsia in their most recent pregnancy versus those who had a normotensive pregnancy. We hypothesized that women with a history of gestational hypertension or preeclampsia would have a higher lifetime CVD risk. In the second aim, we explored the correlation between SDOH, blood pressure (BP) and other CVD risk factors among those with gestational hypertension or preeclampsia from 6 months to 24 months postpartum. We hypothesized that a high SDOH burden would be associated with high CVD risk factors.

In the first aim, women with a history of gestational hypertension or preeclampsia had significantly higher mean predicted lifetime CVD risk scores and were twice as likely to have a high predicted lifetime CVD risk of ≥ 39% ($p < 0.001$) compared to normotensive women. In the second aim, we observed that at 6 months postpartum, women with gestational hypertension or preeclampsia exhibited elevated cardiometabolic risk factors that included elevated BP, hypercholesterolemia and obesity. A high SDOH burden was positively correlated with non-significant high BP ($p = 0.171$). Linear mixed models showed non-significant trends between SDOH and BP but significant effects of age, diet and physical activity factors on systolic BP ($p < 0.05$). Secondary cardiometabolic risk factors had non-significant varying trends by SDOH burden.

Together, these findings highlight the heightened CVD risk during the postpartum period following a pregnancy complicated by gestational hypertension or preeclampsia. Integrating cardiovascular risk assessment and stratification using PCE and SDOH in routine postpartum care in resource-limited settings,

regardless of gestational hypertension or preeclampsia status, can facilitate timely interventions, enhancing the overall cardiovascular health of postpartum women.

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CHAPTER 1: Introduction

Cardiovascular disease burden among women

Cardiovascular diseases (CVD) are a leading cause of morbidity and mortality worldwide, imposing a substantial burden on healthcare systems and individual well-being. While high-income countries (HIC) have experienced a decline in CVD deaths due to public health interventions, Africa's CVD burden has doubled,[1(p25),2,3] due to demographic and epidemiologic changes and an increase in CVD risk factors.[4,5] The impact of CVD is pronounced in women, accounting for 35% of deaths globally, with over 80% of CVD-related fatalities occurring in low and middle-income countries (LMICs).[6] In Kenya, the situation reflects the broader trend in LMIC. CVD-associated disability-adjusted life years (DALYs), a measure that quantifies the overall burden of CVD accounting for premature mortality and duration in years lived with CVD among women of reproductive age (15-49 years), is steadily increasing with advancing age.[4]

The high CVD burden in women is partly attributed to adverse pregnancy outcomes that include hypertensive disorders of pregnancy (HDP), gestational diabetes mellitus (GDM), preterm delivery, small-for-gestational-age delivery, and placental abruption, which the American Heart Association recognizes as emerging non-traditional CVD risk-enhancing factors that impact women disparately.[7,8] In HIC, HDP, primarily gestational hypertension and preeclampsia, has been associated with a two to six-fold higher risk of future CVD events when compared to women with a normotensive pregnancy when followed up long term.[7–9] While there is compelling evidence of heightened CVD risk following HDP, much of the data originates from HIC, with a paucity of data from sub-Saharan Africa (SSA).

Pathophysiology of CVD in HDP

HDP is a spectrum of conditions that include gestational hypertension, preeclampsia with or without severe features, eclampsia, and chronic hypertension that significantly impact maternal and neonatal

outcomes.[10,11] Pregnancy stresses the cardiovascular system due to physiological adaptations that increase cardiac output, induce a hypercoagulable state, elicit an inflammatory response, and cause changes in lipid metabolism and insulin sensitivity.[12] For some women, pregnancy increases susceptibility to hypertensive disorders. While HDP can typically resolve after delivery, there is growing evidence that underlying cardiovascular stress during pregnancy, vascular inflammation, endothelial dysfunction, and prevailing CVD risk factors inactivity augments the likelihood of future CVD events.[13,14]

Pre-pregnancy and pregnancy common risk factors for CVD development include elevated body mass index, diabetes mellitus, insulin resistance with high blood sugar levels, abnormal lipid levels, high blood pressure, lack of physical activity, smoking and secondhand smoke exposure, and a family history of CVD and metabolic syndrome.[7,8,14–16] In a prospective cohort study by Osoti et al. at Kenyatta National Hospital (KNH), women with gestational hypertension and preeclampsia had a three-fold higher risk of developing metabolic syndrome, a known independent risk factor for CVD at 6 months postpartum compared to normotensive women.[17]

Postpartum cardiovascular evaluation and social determinants of cardiovascular health after HDP

Continued follow-up and good linkage with primary or specialist care are essential for women with a history of HDP to receive appropriate interventions and timely treatment even beyond the postpartum period. The American College of Obstetricians and Gynecologists recommends women with high-risk pregnancies, including a history of HDP, should have an obstetric review in 3 weeks postpartum, followed by a comprehensive review no later than 12 weeks postpartum and subsequent annual cardiovascular assessments of blood pressure, lipids, fasting plasma glucose and body mass index for early CVD risk stratification and treatment.[18] Postpartum clinical follow-up in specialized clinics is underutilized even in HIC. In a retrospective nationwide cohort study in the US spanning nine years, assessing continuity care post-delivery among women with and without HDP, clinical follow-up was low at 58% for women with

HDP and 47% for normotensive women at 6 months postpartum.[19] In LMIC, the CVD risk following HDP remains undetermined, and the timing and frequency of visits for cardiovascular risk assessments are not yet established.

Social determinants of health (SDOH) are social, economic, and environmental factors that influence overall health outcomes and well-being and add complexity to the postpartum CVD continuum of care. Barriers to optimal cardiovascular health include socioeconomic hardship, low literacy levels, low levels of social support and loneliness, unsafe or insecure housing, neighborhood violence, and limited healthcare.[20,21] The impact of sociodemographic hardship on overall cardiovascular health during the pregnancy period has been established; however, their influence during the postpartum period and beyond for women with gestational hypertension or preeclampsia remains uncertain.[22] While SDOH play a pivotal role in the onset and development of CVD, their specific impact on CVD risk among postpartum women with a history of HDP remains unclear. Understanding the SDOH is crucial for tailoring effective interventions and addressing this vulnerable population's multifaceted challenges in postpartum cardiovascular care.

Impact on policy

As nations pursue Sustainable Development Goal 3 by reducing premature mortality from non-communicable diseases including CVD,[23] it is crucial to comprehend the CVD burden and risks among postpartum women and the social determinants of cardiovascular health. This thesis contributes essential insights into the CVD risk among postpartum women with and without HDP and delves into the social determinants influencing cardiovascular health, specifically among women with HDP.

CHAPTER 2: Lifetime cardiovascular risk prediction

Abstract

Objective: We evaluated the 6-month postpartum cardiovascular (CVD) risk using pooled cohort equations (PCE), comparing women with a history of gestational hypertension or preeclampsia in their most recent pregnancy versus those who had a normotensive pregnancy.

Methods: We conducted a longitudinal analysis using de-identified data from a prior prospective cohort of postpartum women aged 26 - 45 years at Kenyatta National Hospital. Women with complete clinical records from enrollment at 12 weeks post-delivery to the 6-month follow-up visit were included. Baseline characteristics were descriptively summarized. We computed predicted lifetime CVD risk scores using PCE for women with and without gestational hypertension or preeclampsia. Cardiovascular risk factors and lifetime CVD risk scores were compared at 6 months postpartum between these two groups using independent t-tests, Wilcoxon rank sum tests and chi-square tests.

Results: Among 243 women, 104 (42.8%) had gestational hypertension or preeclampsia. Women with a history of gestational hypertension or preeclampsia had significantly higher mean predicted lifetime CVD risk scores (34.7% ± 10.4 vs. 23.7% ± 12.9, $p < 0.001$) and were twice as likely to have a high CVD predicted risk of ≥ 39% (65% vs. 30.9%, $p < 0.001$) compared to normotensive women.

Conclusion: A history of gestational hypertension or preeclampsia was associated with high predicted CVD lifetime risk. Integrating cardiovascular risk assessment and stratification using PCE into routine postpartum care in resource-limited settings, regardless of gestational hypertension or preeclampsia status, can facilitate timely interventions, enhancing the overall cardiovascular health of postpartum women.

Introduction

The global cardiovascular disease (CVD) burden among women is on an upward trend. CVD accounts for 35% of female deaths and adversely impacts women in low and middle-income settings (LMIC) who bear 80% of CVD-related fatalities.[6] In Kenya, the mortality rate from CVD in women is alarmingly high at 15% at 1 year, surpassing that in men.[24] The high CVD burden among women is attributed to a combination of non-traditional sex-specific risk factors such as hypertensive disorders of pregnancy (HDP) and established CVD risk factors that impact women disparately.[7,8] In high-income countries (HIC), women with a history of HDP face a two to six-fold higher risk of developing ischaemic heart disease, stroke and venous thromboembolism 5-15 years following delivery.[7–9,25]

HDP affects 5.5-10% of all pregnancies in Kenya,[26] and includes gestational hypertension and preeclampsia as key components. While gestational hypertension or preeclampsia may resolve post-delivery, the lingering impact of cardiovascular stress during pregnancy, vascular inflammation, endothelial dysfunction, and prevailing CVD risk factors including elevated blood pressure, dyslipidemia, hyperglycemia and increased body mass index, pose a high likelihood of experiencing future CVD events such as fatal and non-fatal coronary heart disease, stroke, peripheral vascular disease, and heart failure.[7,8,27] The 2011 American Heart Association effectiveness-based guidelines for CVD prevention among women recognize the unique cardiometabolic stress of gestational hypertension and preeclampsia and their critical role in estimating and enhancing women's CVD lifetime risk.[28] The postpartum period provides an opportune window for early cardiovascular risk assessment using CVD risk scores and targeted interventions to mitigate long-term risks.[18] Despite concerns of heightened CVD risk following gestational hypertension or preeclampsia, cardiovascular assessment using risk scores in the postpartum period and beyond is underutilized in LMIC.

Most existing cardiovascular risk prediction tools lack validation in younger postpartum cohorts of

postpartum women and limited lifetime CVD risk prediction, particularly in LMIC. While tools like the Framingham risk score, systematic coronary risk evaluation (SCORE), QRISK, and ASSIGN scores demonstrate a synergistic effect of risk factors in CVD development, they may not address the unique characteristics of postpartum women in LMIC.[29–32] The 2013 American College of Cardiology/American Heart Association Pooled Cohort Equations (PCE), leveraging a multiethnic sample pool, provides a valuable tool for assessing lifetime CVD in individuals aged 20-79 years, proving particularly relevant for evaluating CVD risk among postpartum women.[33,34] PCE utilizes a multivariable race and sex-specific risk factor algorithm considering age, total and high-density lipoprotein cholesterol (HDL-C), systolic blood pressure, current smoking status and a history of diabetes and antihypertensive treatment to predict lifetime CVD risk.[33,34]

In this study, we utilized pooled cohort equations (PCE) to determine the lifetime predicted CVD risk among postpartum women, comparing those with and without a history of gestational hypertension and preeclampsia at 6 months postpartum. Our hypothesis posited that women with gestational hypertension or preeclampsia would exhibit higher lifetime CVD predicted estimates than women with normotensive pregnancies.

Methods

Study setting and design

This analytic study abstracted de-identified data from a completed 3-year prospective cohort study (K43 TW010363, PI: Alfred Osoti) conducted in Kenyatta National Hospital (KNH), Kenya's largest national and referral hospital.[17] This study evaluated the risk and correlates of Metabolic Syndrome in postpartum women aged 26 years to 45 years with and without a history of gestational hypertension, preeclampsia and gestational diabetes mellitus (GDM) from 6 months to 36 months postpartum. Appropriate institutional and ethical review boards approved the parent study protocol and informed consent was

obtained from all study participants. The University of Washington's Institutional Review Board determined this secondary analysis as non-human subject research. However, the University of Nairobi/KNH Ethical Review Committee approved this analytical study. For the present analysis, we conducted longitudinal analyses using enrollment and follow-up data at 6 months postpartum.

Study population

Our inclusion criteria included women with and without a history of gestational hypertension or preeclampsia, aged 26 years and older who had complete medical and laboratory records at 6 months postpartum. We excluded individuals with missing responses and GDM as a standalone diagnosis.

Study measures

Exposure of interest

The primary exposure of interest was the presence or absence of gestational hypertension or preeclampsia at enrollment. Participants were classified as exposed if they had gestational hypertension or preeclampsia and unexposed if they were normotensive based on medical records that included blood pressure (BP) measurements. Based on the International Society for the Study of Hypertension in Pregnancy (ISSHP) 2018 classification guidelines, we defined gestational hypertension as new onset BP elevation ≥ 140/90mmHg pressure obtained by an automated oscillometric blood pressure cuff at least 2 hours apart at rest after 20 weeks gestation but preceding 12 weeks postpartum without target organ dysfunction.[10,11] Preeclampsia was characterized by gestational hypertension with target organ damage such as proteinuria, renal, liver, cardiac, neurological or uteroplacental dysfunction, [10,11] and classified as early onset if it occurred before 34 weeks of gestation and late onset if it developed at ≥ 34 weeks of gestation.[11,35] For this study we focused on women with early-onset preeclampsia.

Outcome of interest

The primary outcome of interest was the lifetime predicted CVD risk score calculated using the 2013

American College of Cardiology/American Heart Association PCE.[33,34] PCE incorporated self-reported participants' age in years, sex (female), race (categorized as "other" for participants in our study), and smoking status(yes versus no), whereas antihypertensive treatment use (yes versus no) and diabetes history (yes versus no) were self-reported and validated by medication use. Total cholesterol (TC), high-density lipoprotein cholesterol (HDL-C), and systolic BP were measured using standard protocols. The lifetime predicted CVD risk scores were defined as high if ≥ 39% and low if < 39%.[36,37]

Sample size and statistical analysis

We assumed a sample size of 200 women (100 per group) would achieve 80% power to detect a mean difference of 10% in lifetime CVD risk score at a two-sided alpha level of 0.05. This estimation assumes a 25% lifetime CVD risk score rate in the control group of women with a normotensive pregnancy outcome. Descriptive statistics summarized the baseline population characteristics. Continuous and categorical variables were presented as counts using mean ± standard deviation (SD) for normally distributed data and by the median and interquartile range (IQR) for non-normally distributed variables. We calculated predicted lifetime CVD risk scores using PCE for women with and without gestational hypertension or preeclampsia. Out-of-range laboratory values were adjusted to the nearest upper or lower limit by winsorizing in the PCE.[38] Cardiovascular risk factors and lifetime CVD risk scores were compared at 6 months postpartum between women with and without gestational hypertension or preeclampsia using independent t-tests and nonparametric Wilcoxon rank sum tests for continuous variables and Pearson's chi-square tests or Fisher's exact tests for categorical variables. P-values <0.05 were deemed statistically significant. All statistical analyses were performed using R 4.3.2 (R Foundation for Statistical Computing, Vienna, Austria, 2023).

Results

Baseline sociodemographic and clinical characteristics

Of the 351 eligible women followed up from enrollment until 6 months postpartum, 243 (69.2%) had complete medical and laboratory records (Figure 2.1). In a cohort of 243 participants, 104 (42.8%) women had a history of gestational hypertension or preeclampsia in their most recent pregnancy and 139 (57.2%) were normotensive (Table 2.1). All baseline variables had less than 5% missingness except for BMI, which was 23%. Baseline sociodemographic characteristics were similar across the two groups. The median age was 32 years. Most of the women were married (91.8%), had a college education or higher (29.6%) and were self-employed (47.7%). For baseline obstetrics and gynecological characteristics, women with and without gestational hypertension or preeclampsia had a similar parity of 3 and majority (>66.7%) underwent a cesarean section. However, women with a history of gestational hypertension or preeclampsia had a lower mean gestational age (35.6 weeks versus 38.5 weeks), a higher prevalence of previous HDP (94.2% versus 2.9%), elevated mean systolic and diastolic BP (139 versus 117 and 93.3 versus 78.8mmHg, respectively), increased BMI (31.0 kg/m^2 versus 29.6 kg/m^2) and a larger waist circumference (96.1cm versus 94.1cm).

Physical and biochemical characteristics at 6 months postpartum

At 6 months postpartum, women with a history of gestational hypertension or preeclampsia had significantly higher mean systolic and diastolic BP (137 versus 121, $p < 0.001$ and 90.6 versus 78.7mmHg, $p < 0.001$ respectively). Women with gestational hypertension or preeclampsia had significantly higher rates of elevated blood pressure compared to normotensive women: 39.4%(41/104) versus 12.2% (17/139) for systolic BP (>140 mmHg) and 47.1% (49/104) versus 12.9% (18/139) for diastolic BP (>90 mmHg). Among women with a history of gestational hypertension or preeclampsia, only 35/104 (33.7%) were on regular antihypertensive medication at 6 months postpartum and 2/104 (0.8%) had diabetes. A history of gestational hypertension or preeclampsia was associated with significantly higher mean

triglyceride levels (104 versus 75.4 mg/dl, p-value < 0.001). There were no significant mean differences in fasting plasma glucose (FPG), total cholesterol (TC), high-density lipoprotein cholesterol (HDL-C), low-density lipoprotein (LDL-C), body mass index (BMI) or waist circumference among women with and without gestational hypertension or preeclampsia (Table 2). BMI increased by 1.7kg/m^2 for women with a history of gestational hypertension or preeclampsia and 2.3kg/m^2 for normotensive women 6 months postpartum compared to enrollment levels 3 months prior.

Lifetime CVD risk prediction

The overall computed mean lifetime CVD risk was 28.4% (Table 3). Women with a history of gestational hypertension or preeclampsia had significantly higher mean predicted lifetime CVD risk scores (34.7% ± 10.4 versus 23.7% ± 12.9, p < 0.001). Computed lifetime CVD risk ranged from 8 - 50% for women with gestational hypertension or preeclampsia and 8 - 39% for women with normotensive pregnancies. A lifetime risk of 8% indicated optimal CVD risk factors while a higher risk corresponded with elevated or major CVD risk factors. For women with a history of gestational hypertension or preeclampsia, only 7.7% (8/104) had a lifetime CVD risk of 8% and more than half (53.8%, 39/104) had a lifetime CVD risk of 39%. Among normotensive women, the majority (36.7%, 51/139) had a lifetime CVD risk of 8%, while the least proportion of women (30.9%, 43/139) had a lifetime CVD risk of 39%. Women with gestational hypertension or preeclampsia were twice as likely to have a high lifetime CVD predicted risk of ≥39% (65% (68/104) versus 30.9% (43/139), p-value <0.001) when compared to normotensive women. Recommended measures based on PCE results included lifestyle modification of diet, regular exercise, weight management and tobacco cessation for women with a low predicted CVD lifetime risk of <39%, while those with a high lifetime risk of ≥ 39% would require lifestyle modification and additional statin therapy commenced after 6 months postpartum with lactation consideration.

Discussion

In this longitudinal analysis, we observed an overall mean predicted lifetime CVD risk estimate of 28.4%. Women with a history of gestational hypertension or preeclampsia had significantly higher mean predicted lifetime CVD risk estimates at 34.7% compared to 23.7% in women who had normal blood pressure in their most recent pregnancy in this Kenyan setting. We found a two-fold increased likelihood of a high predicted lifetime risk of ≥ 39% and the lowest proportion of women with optimal predicted CVD lifetime risk in those with a history of gestational hypertension or preeclampsia compared to women with a normotensive pregnancy.

To the best of our knowledge, our study is the first to evaluate PCE among postpartum women of African descent for lifetime CVD risk prediction in an LMIC setting. Studies conducted in LMIC computed the 10-year CVD risk in middle-aged and elderly female and male individuals, with or without prior CVD events.[39–41] The elevated CVD risk for women with gestational hypertension or preeclampsia is consistent with previous meta-analyses and prospective studies in HIC that have demonstrated a long-term heightened risk of CVD events among women with a history of gestational hypertension or preeclampsia.[7,8,42] Similar to our study, a prospective study in Canada evaluating CVD risk following gestational hypertension and preeclampsia, among other pregnancy complications, found women with these conditions 3 times more likely to have a high lifetime CVD risk of ≥ 39% than normotensive women at 6 months postpartum using CVD risk factor burden.[43] A high predicted lifetime CVD risk among postpartum women with a history of gestational hypertension or preeclampsia underscores the potential long-term consequences of HDP as a cardiometabolic stressor and risk enhancer of CVD.[6,7,28]

A study by Lloyd et al. showed a higher mean predicted lifetime CVD risk at 39.2% using risk factor burden among non-pregnant women 50 years or older free of any CVD event. In this study, elevated BP, total cholesterol, diabetes and current smoking history were associated with a higher lifetime risk.[36] This

partially aligns with our study when examining specific CVD risk factors where significantly higher systolic BP, elevated triglycerides and diabetes history among women with a history of gestational hypertension or preeclampsia were associated with higher lifetime risk estimates. A possible explanation for our findings could be due to using PCE instead of the risk factor burden approach in a younger postpartum cohort in an LMIC setting. However, our analyses revealed comparable trends, wherein the winsorizing of outliers beyond model specifications did not affect the overall prediction estimations. This observation is consistent with the findings of a community-cohort PCE validation study conducted by Medina-Inojasa et al. in Minnesota.[38]

A third of postpartum women who were normotensive during their most recent pregnancy had a high lifetime CVD risk. Our study focused on women with early onset gestational hypertension and preeclampsia who are known to have a higher CVD risk compared to those with late-onset cases.[25] It is possible that some women in the normotensive group could have developed late-onset preeclampsia or gestational hypertension by 6 months postpartum, potentially contributing to a higher lifetime risk. However, this highlights the role of physiological cardiovascular pregnancy changes and the need for increased awareness and proactive cardiovascular risk management strategies in the postpartum period, even among women with a history of normotensive pregnancies.[13,44]

The implications of predicted lifetime CVD risks hold significant public health importance, indicating that interventions initiated during the postpartum period could reduce the long-term effects of CVD. For women with a high predicted lifetime CVD risk (≥39%), implementing lifestyle interventions such as heart-healthy diets, moderate-intensity physical activities, weight management and tobacco avoidance and potential statin therapy with lactation considerations may be appropriate to reduce CVD risk. For women with low predicted lifetime risk (<39%), lifestyle interventions remain crucial to maintaining and lowering long-term CVD risk.[7,34,45,46]

The clinical significance of our study lies in its potential to yield a comprehensive understanding of lifetime cardiovascular risk among postpartum women with and without gestational hypertension or preeclampsia and inform postpartum care practices in Kenya. However, our study was limited by PCE's relatively limited validation in cohorts of African descent for predicting lifetime CVD) risk. Moreover, the equation's performance outside the United States may be influenced by variations in CVD risk factors, such as smoking risk, which was absent in our study. Our study assessed women with early-onset gestational hypertension or preeclampsia, limiting the generalizability of our findings to this specific subgroup and not extending to those with late-onset cases. Nevertheless, our study contributes valuable insights into the assessment of lifetime CVD risk among postpartum women of African descent in a region where its utility is constrained. Additionally, our findings pave the way for more extensive validation studies that consider including female-specific CVD risk factors and traditional CVD risk factors used in the equation.

Conclusion

A history of gestational hypertension or preeclampsia is linked to a heightened mean predicted lifetime CVD risk and a two-fold increased likelihood of a high lifetime CVD predicted risk of ≥ 39% at 6 months postpartum. These findings emphasize the need for early CVD risk assessment and stratification among postpartum women with and without gestational hypertension or preeclampsia to guide timely lifestyle interventions and targeted pharmacotherapy for women with high CVD risk. Our study advocates for integrating comprehensive CVD screening and management within postpartum care frameworks, particularly in resource-limited settings, regardless of HDP status.

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FN, SM, CL and AO contributed to the conception and design of the work. FN analyzed the data and drafted the manuscript. All authors contributed to the editing of the manuscript and approved the submission of the final draft publication.

We declare no conflicts of interest.

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Disclaimer Statement:

The content is solely the authors' responsibility and does not represent the official views of the National Institutes of Health.

Figure 2.1: Sampling framework of study participants

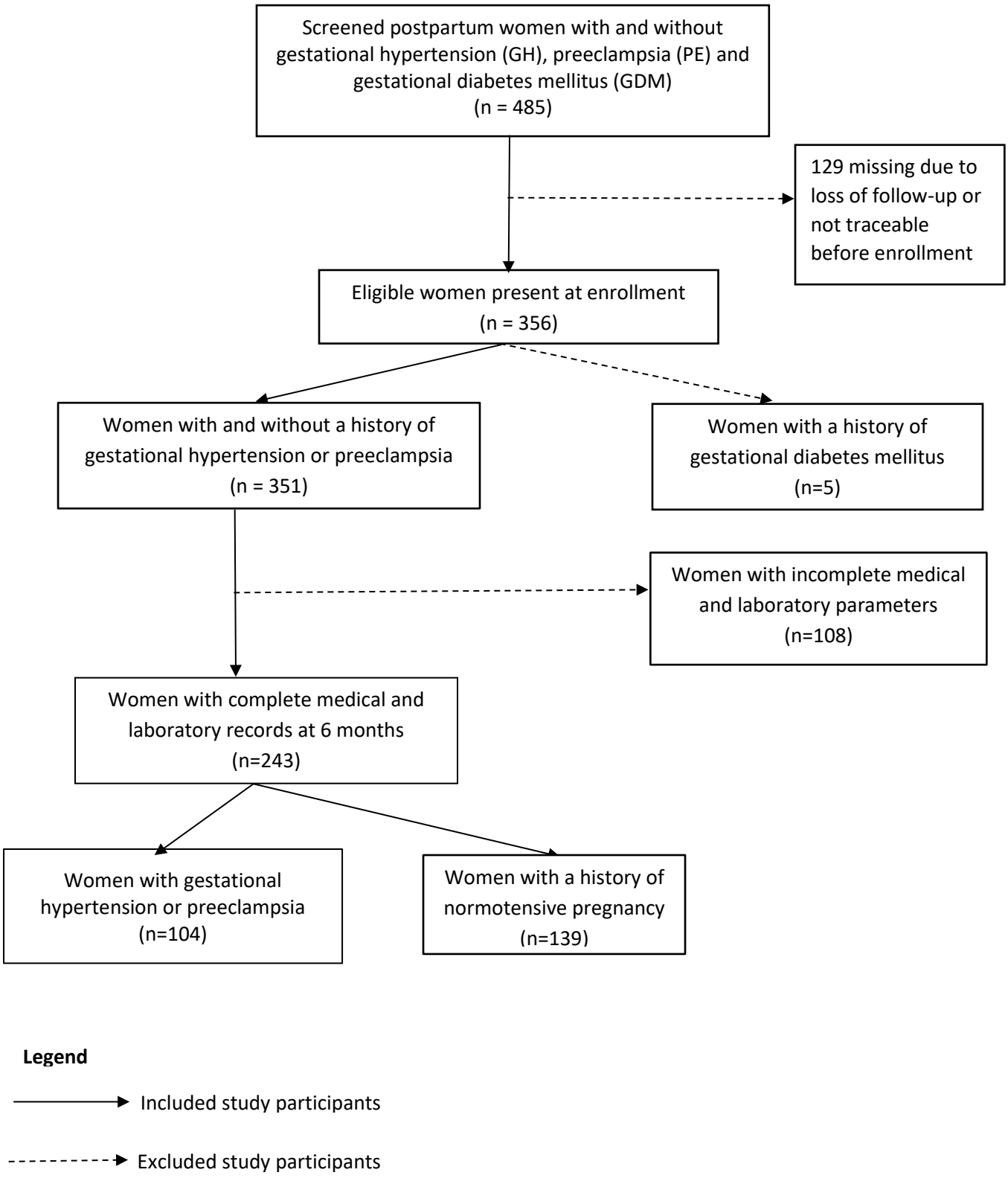

Table 2.1: Baseline sociodemographic and clinical characteristics of women with and without a history of gestational hypertension and preeclampsia

	Overall (n=243)		With GH or PE (n=104)		Without GH or PE (n=139)	
	n	%	n	%	n	%
Age (years), median (IQR)	32 [26, 45]		32 [26, 45)		32 [27, 45]	
Marital Status						
Currently married	223	(91.8)	96	(92.3)	127	(91.4)
Separated/Divorced	7	(2.9)	3	(2.9)	4	(2.9)
Widowed	1	(0.4)	0	(0)	1	(0.7)
Never married	11	(4.5)	4	(3.8)	7	(5.0)
Cohabiting	1	(0.4)	1	(1.0)	0	(0)
Highest education attainment						
Completed primary school	69	(28.4)	31	(29.8)	38	(27.3)
Did not complete high school	36	(14.8)	14	(13.5)	22	(15.8)
Completed high school	66	(27.2)	33	(31.7)	33	(23.7)
College or higher	72	(29.6)	26	(25.0)	46	(33.1)
Occupation						
Formally employed	61	(25.1)	24	(23.1)	37	(26.6)
Self-employed	116	(47.7)	44	(42.3)	72	(51.8)
Homemaker	61	(25.1)	32	(30.8)	29	(20.9)
Student	1	(0.4)	1	(1.0)	0	(0)
Unemployed	3	(1.2)	2	(1.9)	1	(0.7)
Parity, mean (SD)	3 ± 1		3 ± 1		3 ± 2	
Gestation at delivery (weeks), mean (SD)	37.2 ± 3.5		35.6 ± 5.0		38.5 ± 1.4	
Mode of delivery						
Cesarean section	162	(66.7)	62	(59.6)	100	(71.9)
Vaginal delivery	81	(33.3)	42	(40.4)	39	(28.1)
Previous pregnancy complications						
Gestational diabetes mellitus	1	(0.4)	0	(0)	1	(0.7)
Hypertensive disorders of pregnancy	102	(42.0)	98	(94.2)	4	(2.9)
Both GDM and HDP	2	(0.8)	2	(1.9)	0	(0)
Others	1	(0.4)	0	(0)	1	(0.7)
None	137	(56.4)	4	(3.8)	133	(95.7)
Prepregnancy hormonal contraception	144	(59.3)	62	(59.6)	82	(59.0)
Systolic blood pressure (mmHg), mean (SD)	126 ± 20.0		139 ± 21.1		117 ± 12.8	
Diastolic blood pressure (mmHg), mean (SD)	85.0 ± 14.3		93.3 ± 14.9		78.8 ± 10.0	
Body mass index (kg/m^2), mean (SD)	30.2 ± 5.0		31.0 ± 5.2		29.6 ± 4.8	
18.5 - 24.9	25	(10.3)	9	(8.7)	16	(11.5)
25 - 29.9	74	(30.5)	26	(25.0)	48	(34.5)
≥ 30	88	(36.2)	46	(44.2)	42	(30.2)
Missing	33	(23.7)	56	(23.0)	23	(22.1)
Waist circumference, mean (SD)	95.0 ± 10.6		96.1 ± 12.1		94.1 ± 9.16	
Waist-hip ratio (cm), mean (SD)	0.89 ± 0.06		0.89 ± 0.06		0.89 ± 0.05	
>0.85	170	(70.0)	69	(66.3)	101	(72.7)

<0.85	70	(28.8)	34	(32.7)	36	(25.9)

GH: Gestational hypertension, PE: Preeclampsia, GDM: Gestational diabetes mellitus, HDP: Hypertensive disorder of pregnancy

Column percent totals will not sum to 100% due to missingness or may be >100% due to the inclusion of missing values >5%

Table 2.2: Physical and biochemical characteristics at 6 months postpartum

	Overall (n=243)		With GH or PE (n=104)		Without GH or PE (n=139)		
	n	%	n	%	n	%	p-value
Systolic blood pressure (mmHg), mean (SD)	128 ± 18.6		137 ± 19.2		121 + 14.7		<0.001*
<120	90	(37.0)	15	(14.4)	75	(54.0)	<0.001*
≥120 - 139	95	(39.1)	48	(46.2)	47	(33.8)	
≥140 - 159	43	(17.7)	29	(27.9)	14	(10.1)	
≥160	15	(6.2)	12	(11.5)	3	(2.2)	
Diastolic blood pressure (mmHg), mean (SD)	83.8 ± 12.9		90.6 ± 13.6		78.7 + 9.58		<0.001*
<80	101	(41.6)	20	(19.2)	81	(58.3)	<0.001*
≥80 - 89	75	(30.9)	35	(33.7)	40	(28.8)	
≥90 - 99	43	(17.7)	28	(26.9)	15	(10.8)	
≥100	24	(9.9)	21	(20.2)	3	(2.2)	
Antihypertensive medication use	35	(14.4)	35	(33.7)	0	(0)	<0.001*
Diabetes	2	(0.8)	2	(1.9)	0	(0)	0.355
Fasting plasma glucose (mg/dl), mean (SD)	74.7 ± 16.7		75.9 ± 18.5		70.5 ± 6.62		0.295
Nonsmoker[+]	243	(100)	104	(100)	139	(100)	NA
Total cholesterol (mg/dl), mean (SD)	174 ± 37.0		174 ± 41.8		175 ± 37.0		0.814
<180	141	(58.0)	58	(55.8)	83	(59.7)	0.630
≥180 - 199	43	(17.7)	17	(16.3)	26	(18.7)	
≥200 - 239	49	(20.2)	25	(24.0)	24	(17.3)	
≥240	10	(4.1)	4	(3.8)	6	(4.3)	
LDL cholesterol (mg/dl), mean (SD)	107 ± 29.9		109 ± 27.9		105 ± 32.4		0.300
<100	104	(42.8)	47	(45.2)	57	(41.0)	0.925
100 – 129	89	(36.6)	37	(35.6)	52	(37.4)	
130 – 159	38	(15.6)	14	(13.5)	24	(17.3)	
160 – 189	9	(3.7)	4	(3.8)	5	(3.6)	
≥190	2	(0.8)	1	(1.0)	1	(0.7)	
HDL cholesterol (mg/dl), mean (SD)	49.8 ± 12.1		50.4 ± 10.0		49.8 ± 12.1		0.313
<50	127	(52.3)	58	(55.8)	69	(49.6)	0.414
≥50	116	(47.7)	46	(44.2)	70	(50.4)	
Triglycerides (mg/dl), mean (SD)	87.7 ± 62.1		104 ± 83.2		75.4 ± 35.3		<0.001*
<150	220	(90.5)	88	(84.6)	132	(95.0)	0.015
≥150 - 199	17	(7.0)	10	(9.6)	7	(5.0)	
≥200 - 499	4	(1.6)	4	(3.8)	0	(0)	
≥500	2	(0.8)	2	(1.9)	0	(0)	
Body mass index[¶](kg/m^2), mean (SD)	32.3 ± 5.9		32.7 ± 6.3		31.9 ± 5.6		0.306
<18.5	1	(0.4)	1	(1.0)	0	(0)	0.141
18.5 – 24.9	23	(9.5)	12	(11.5)	11	(7.9)	
25 – 29.9	53	(21.8)	17	(16.3)	36	(25.9)	
≥30	147	(60.5)	69	(66.3)	78	(56.1)	

*p value <0.05

GH: Gestational hypertension, PE: Preeclampsia, GDM: Gestational diabetes mellitus, HDP: Hypertensive disorder of pregnancy

Column percent totals will not sum to 100% due to missingness

[+] Non-smoker includes both a history of current and past smoker

[¶]Body mass index has missingness of up to 10.1%

Table 2.3: Lifetime CVD risk prediction at 6 months postpartum

	Overall (n=243)		With GH or PE (n=104)		Without GH or PE (n=139)		p-value
	n	%	n	%	n	%	
Lifetime CVD risk prediction, mean (SD) %	28.4 ± 13.1		34.7 ± 10.4		23.7 ± 12.9		<0.001*
8	59	(24.3)	8	(7.7)	51	(36.7)	<0.001*
27	73	(30.0)	28	(26.9)	45	(32.4)	
39	99	(40.7)	56	(53.8)	43	(30.9)	
50	12	(4.9)	12	(11.5)	0	(0)	
Lifetime CVD risk prediction stratum							
High risk (≥39%)	111	(45.7)	68	(65.4)	43	(30.9)	<0.001*
Low risk (<39%)	132	(54.3)	36	(34.6)	96	(69.1)	

CVD: Cardiovascular disease; GH: Gestational hypertension, PE: Preeclampsia,
*p-value <0.05

Lifetime CVD risk of 8% indicates optimal levels characterized by untreated total cholesterol <180 mg/dL, untreated blood pressure <120/<80 mm Hg, no history of diabetes, and non-smoking status.

Lifetime CVD risk of 27% signifies nonoptimal levels defined by 1 or more of the following: untreated total cholesterol of 180 to 199 mg/dL, untreated systolic blood pressure of 120 to 139 mm Hg or diastolic blood pressure of 80 to 89 mm Hg, and no history of diabetes or current smoking.

Lifetime CVD risk of 39% indicates elevated levels represented by 1 or more of the following: untreated total cholesterol of 200 to 239 mg/dL, untreated systolic blood pressure of 140 to 159 mm Hg or diastolic blood pressure of 90 to 99 mm Hg, and no history of diabetes or current smoking.

Lifetime CVD risk of 50% is classified as major risk levels, signifying any of the following: total cholesterol ≥240 mg/dL (or treated), systolic blood pressure ≥160 mm Hg or diastolic blood pressure ≥100 mm Hg (or treated), diabetes, or current smoking.

CHAPTER 3: Social determinants of cardiovascular health

Abstract

Introduction

Gestational hypertension and preeclampsia have been associated with a heightened risk of cardiovascular disease (CVD). Social determinants of health (SDOH) encompass social, economic and environmental factors that impact overall health and life satisfaction. SDOH's impact on CVD risk and development is established, but its influence on blood pressure changes in postpartum women with gestational hypertension or preeclampsia in Kenya is unknown. We examined the association between SDOH and CVD risk factors, primarily from 6 to 24 months postpartum. We hypothesized that sociodemographic burden severity would be associated with elevated CVD risk factors

Methods

This longitudinal analysis used de-identified data from a 3-year prospective cohort study in Kenyatta National Hospital for women with a history of gestational hypertension or preeclampsia aged 26 years and older, followed from 6 to 24 months postpartum. The primary predictor, SDOH burden, was calculated as a composite score based on six components across four domains (education, economic stability, neighborhood and physical environment, and community and social context), ranging from 0 to 3, where 3 represented severe SDOH burden. Time was a secondary predictor. The primary outcomes were systolic and diastolic blood pressure changes; secondary outcomes included fasting plasma glucose, total cholesterol, HDL and LDL cholesterol, triglycerides and body mass index. We used linear mixed models to model associations between SDOH burden and CVD risk factors adjusting for age and lifestyle factors.

Results

We had 291 observations from repeated measures in 97 women with gestational hypertension or

preeclampsia taken over 3 occurrences. At 6 months postpartum, women with gestational hypertension or preeclampsia exhibited elevated cardiometabolic risk factors of borderline hypertension, hypercholesterolemia and obese body mass index. Though non-significant, a higher SDOH burden was positively correlated with higher blood pressure ($p = 0.171$). Linear mixed models showed non-significant trends between SDOH and BP but significant effects of age and lifestyle dietary and physical activity factors($p < 0.05$). Secondary cardiometabolic risk factors had non-significant varying trends by SDOH burden.

Conclusion

SDOH burden severity correlates with increased BP, offering nuanced insights into context-specific postpartum care. Integrating SDOH evaluation in routine CVD assessment ensures timely interventions, mitigating CVD risk and events. Future research should explore long-term impacts, incorporating diverse SDOH components for comprehensive postpartum care guidelines.

Introduction

Gestational hypertension and preeclampsia integral components of hypertensive disorders of pregnancy (HDP), pose a two-to-six-fold elevated risk for cardiovascular disease (CVD).[8–10] Beyond the immediate pregnancy-related implications, emerging evidence from various studies suggests that a history of gestational hypertension and preeclampsia may act as a harbinger of long-term CVD outcomes later in life.[13,47,48] The longitudinal trajectory following gestational hypertension or preeclampsia shows a significant increase in chronic hypertension after pregnancy, exceeding 4-fold, 2-fold, and 1.5-fold at 1 year, 10 years, and 20 years postpartum, respectively, compared to normotensive women. [49,50]

Social determinants of health (SDOH) as defined by the Centers for Disease Control and Prevention and the World Health Organization, are the circumstances in the surroundings where individuals are born, reside, acquire knowledge, labor, engage in leisure activities, practice religion, and grow old and impact their overall health, welfare, and life satisfaction.[51,52] SDOH encompass economic stability, educational opportunities and standards, local and environmental surroundings, healthcare availability and standards, and the community's social fabric influencing CVD risk and outcomes.[20,22] Sociodemographic hardship, an adverse SDOH, has been linked with poor maternal health and pregnancy outcomes with increased CVD morbidity, mortality, and health disparities in high-income countries (HIC).[22]

While the pivotal impact of SDOH on CVD is well-established, their precise influence on CVD risk among postpartum women with a history of gestational hypertension or preeclampsia in Kenya remains uncertain, given the limited availability of data that comprehensively evaluates the aggregate social determinants of cardiovascular health in this population. We therefore sought to determine the association between SDOH and CVD risk factor changes, primarily blood pressure (BP) from a baseline of 6 months to 12 months and 24 months postpartum. We included secondary outcomes of fasting plasma glucose (FPG), total cholesterol (TC), low-density lipoprotein cholesterol (LDL-C), high-density lipoprotein

cholesterol (HDL-C), triglycerides (TG) and body mass index (BMI). We hypothesized that the severity of the sociodemographic burden would be associated with elevated CVD risk factors.

Methods

Study setting and design

This longitudinal analytic study abstracted de-identified data from a completed 3-year prospective cohort study (K43 TW010363, PI: Alfred Osoti) conducted in Kenyatta National Hospital (KNH), Kenya's largest national and referral hospital.[17] This study evaluated the risk and correlates of Metabolic Syndrome in postpartum women aged 26 years to 45 years with and without a history of gestational hypertension, preeclampsia and gestational diabetes mellitus (GDM) from 6 months to 36 months postpartum. Appropriate institutional and ethical review boards approved the parent study protocol and informed consent was obtained from all study participants. The University of Washington's Institutional Review Board determined this secondary analysis as non-human subject research. However, the University of Nairobi/KNH Ethical Review Committee approved this analytical study. For the present analysis, we conducted longitudinal analyses using baseline data from 6 months postpartum, at 12 months and 24 months postpartum among women with gestational hypertension or preeclampsia.

Study population

We included women with a history of gestational hypertension or preeclampsia. We defined gestational hypertension and preeclampsia using the International Society for the Study of Hypertension in Pregnancy (ISSHP) 2018 classification guidelines as new onset BP elevation ≥ 140/90mmHg pressure obtained by an automated oscillometric blood pressure cuff at least 2 hours apart at rest after 20 weeks gestation but preceding 12 weeks postpartum without target organ dysfunction.[10] Preeclampsia was gestational hypertension with target organ damage that includes proteinuria, renal, liver, cardiac, neurological or uteroplacental dysfunction.[10] Our inclusion criteria was women aged 26 years and older with complete

SDOH variables, medical and laboratory records at a baseline of 6 months postpartum and were followed up to 24 months postpartum. We excluded women with normotensive pregnancies, GDM only and missing responses at baseline of 6 months postpartum.

Study measures

Exposures of interest

SDOH burden, a composite score derived from self-reported sociodemographic variables representing education, economic stability, neighborhood and built environment and community and social context domains was the main predictor. We did not include healthcare access and quality domain as they were not part of the collected data. All variables were classified as either adverse (scored 1) or otherwise (scored 0). Education included the highest formal education attained and was dichotomized as above high school or lower. Economic stability was determined based on self and partner's occupation, categorized as favorable (formally employed or self-employed) or unfavorable (student, homemaker or unemployed) due to >95% income data missingness. Urban or rural residence defined the neighborhood and built environment, while household size (>2 adults or ≤2 adults) and marital status (married versus separated, divorced or cohabiting) were proxies for community and social context. The scores in each domain were aggregated and ranged from 0 to 3, with higher scores denoting a higher SDOH burden. A secondary exposure was the time point in months at which CVD risk factors were repeatedly measured.

Outcomes of interest

The primary outcome included a change in systolic and diastolic BP from a baseline of 6 months to 12 months and at 24 months postpartum. Secondary outcomes evaluated were FPG, TC, LDL-C, HDL-C and BMI all measured using standard protocols from 6 months to 24 months postpartum.

Covariates

We included self-reported age, physical activity, dietary intake and cooking oil use as potential covariates

selected a priori based on published studies.[45,46] Physical activity included work, travel, and leisure and was defined as adequate if it included at least 150 minutes of moderate-intensity activity or 75 minutes of vigorous-intensity activity per week and inadequate if it was less than the recommended duration. Dietary intake of fruits and vegetables was defined as healthy if it included ≥ 5 daily servings and unhealthy if <5. Cooking oil use was defined as healthy if using unsaturated fats and unhealthy cooking oil use if using saturated fats and trans-fats.

Statistical analysis

Descriptive statistics summarized the baseline population characteristics. Continuous and categorical variables were presented as counts using mean ± standard deviation (SD) for normally distributed data and by the median and interquartile range (IQR) for non-normally distributed variables. Cardiovascular risk factors were compared by SDOH burden using independent t-tests and nonparametric Wilcoxon rank sum tests for continuous variables and Pearson's chi-square tests or Fisher's exact tests for categorical variables. We performed linear mixed model analysis using the lme4 package[53] in R with systolic and diastolic BP as the main dependent variables. Fixed effects included SDOH burden as the main predictor, time, an interaction term between SDOH burden and time, and covariates. Time and participant identification (ID) were included as random effects. Statistical significance was determined using the lmerTest package,[54] applying Satterthwaite's method to estimate degrees of freedom and generate coefficients, 95% confidence intervals and p-values for mixed models. The model specifications included:

Systolic / Diastolic BP ~ β_0 + β_1SDOH + $\beta_2$time + β_3SDOH*time + β_4Age + β_5Diet + β_6Cooking oil use + β_7Physical activity + (1 + time | participant ID) + ε

Where,

- **β_0** was the intercept, representing the expected systolic or diastolic BP for 0 SDOH at 6 months postpartum after adjusting for age, diet, cooking oil use, and physical activity

- $\mathbf{B_1}$ represented the fixed effects of SDOH burden
- $\boldsymbol{\beta_2}$ represented the fixed effects of time
- $\boldsymbol{\beta_3}$ represented the interaction between SDOH burden and time
- $\boldsymbol{\beta_4 - B_7}$ represented the fixed effects of age, diet, cooking oil use, and physical activity, respectively.
- **(1 + time | participant ID)** represented the random slope for time and a random intercept for each participant, capturing individual-specific variability not explained by the fixed effects.
- $\boldsymbol{\varepsilon}$, the error term, accounts for unobserved or unmeasured influences on systolic or diastolic BP.

Exploratory analyses using FPG, TC, LDL-C, HDL-C, and BMI as secondary dependent variables were modeled to examine the impact of SDOH burden, time, and covariates on these cardiometabolic risk factors. P-values <0.05 were deemed statistically significant. In our study, covariates – dietary habits and cooking oil use and primary and secondary dependent variables had missingness ranging from 25.3 – 28%. To avoid biased and inefficient model estimates, we deliberately chose not to exclude participants with missing follow-up data at 12 and 24 months in a complete case analysis to avoid biased and inefficient model estimates. We assumed the variables to be missing at random and linear mixed models were robust to handle the missingness.[55]

We ran sensitivity analyses using mixed models for repeated measures with an unstructured time and covariance structure to evaluate the robustness of our study findings. The model incorporated fixed effects for SDOH burden, time (modeled as categorical), and their interaction and covariates. A random intercept and slope were specified for the time within each participant ID. All statistical analyses were performed using R 4.3.2 (R Foundation for Statistical Computing, Vienna, Austria, 2023).

Results

Baseline sociodemographic and clinical characteristics

In this study, we analyzed data from 97 women with a history of gestational hypertension or preeclampsia

at 6 months postpartum, 76 women at 12 months postpartum, and 38 women at 24 months postpartum with a total of 291 observations due to repeated measurements at the 3 time points.

The median age was 32 years (IQR 26 - 45), 98% were married and more than half (56.7%) had a high school education or higher (Table 3.1). Self-employment was common in 42.3% of women and 48.5% of their partners. The median parity was 3 (IQR 1, 8), indicative of varied reproductive experiences within the group. Women with gestational hypertension or preeclampsia had a low mean gestational age of 35.6 weeks and a high prevalence of previous HDP (93.8%). At 6 months postpartum, these women displayed elevated cardiometabolic risk factors, including borderline elevated mean systolic and diastolic BP (137 and 90.9mmHg, respectively), high mean TC of 172 mg/dl, an obese BMI of 32.9kg/m^2, and a larger waist circumference at 96.9cm. Only 35% (34/97) of women were on regular antihypertensive medication at 6 months postpartum and 2.1% (1/97) were diabetic. Dietary habits, including daily fruit and vegetable servings, oil use and physical activity, were adequate in > 69% of participants.

Prevalence of SDOH burden

The SDOH burden was stratified into four levels (0 to 3), with higher scores representing increasing sociodemographic challenges among 291 observations which accounted for repeated measurements in 97 women at 6, 12, and 24 months postpartum. The group with optimal SDOH (0 SDOH) had the least observations, (9/291, 0.03%), while the minimal SDOH burden group (representing 1 adverse SDOH) had 78/291 observations (26.8%, Table 3.2). The moderate SDOH burden group (2 SDOH burden) represented the largest sample size of 132/291 observations (45.4%) and the severe SDOH burden group (3 SDOH) consisted of 72/291 observations (24.7%).

The median age of participants varied across SDOH burden, ranging from 26 to 45 years ($p = 0.022$). A high school education and lower was significantly associated with a higher SDOH burden ($p < 0.001$). The prevalence of self-unemployment significantly increased with higher SDOH burden levels ($p < 0.001$) and

no instances of partner unemployment were observed. All participants, regardless of SDOH burden, resided in urban areas. Participants with higher SDOH burden were likely to have a smaller household size of 2 people or fewer, reaching 100% in the severe SDOH burden group ($p < 0.001$).

Distribution of blood pressure and other cardiometabolic risk factors by SDOH burden

Blood pressure distribution varied across SDOH burden. Women in the no SDOH group exhibited the lowest mean systolic and diastolic BP (129.2 and 86mmHg respectively), while those with minimal SDOH burden had the highest mean systolic and diastolic BP (138.4 and 91.38mmHg respectively), (Table 3.3). The mean systolic and diastolic BP were not significantly different across the SDOH groups ($p = 0.171$ versus 0.339). An increase in SDOH severity was associated with elevated systolic and diastolic BP at 6 months postpartum (Figures 3.1 and 3.2). The temporal changes in systolic and diastolic BP from baseline at 6 months to 24 months postpartum were consistent but variable among distinct SDOH groups. Women with modest and severe SDOH burdens showed the most substantial decline over time with systolic BP decreasing by 14 and 20 mmHg, and diastolic BP declining by 7.1 and 11.5 mmHg, respectively. At 24 months postpartum their mean BP levels were lower than those with no SDOH burden. In contrast, women with minimal SDOH burden had elevated baseline BP with a modest 3mmHg decline in systolic BP and a marginal 0.4mmHg rise in diastolic BP by 24 months postpartum.

Secondary cardiometabolic outcomes showed a non-significant variability by SDOH burden (Table 3.2). For lipids, mean TC was elevated in all SDOH burden categories, exhibiting a crescendo-decrescendo pattern with increasing SDOH burden, a trend similarly observed in TG. BMI tended to be higher among those with higher SDOH burden, although not statistically significant ($p = 0.580$).

Effect of SDOH burden on blood pressure and other cardiometabolic risk factors

Table 3.4 presents the linear mixed model results, demonstrating that a high SDOH burden was associated with higher systolic and diastolic BP, though not statistically significant. We did not have statistically

significant evidence that, adjusted for age differences, time, dietary or lifestyle factors, the mean systolic BP in a higher SDOH burden differed from a lower SDOH burden among women with gestational hypertension or preeclampsia. The mean expected change in systolic BP for every one-unit increase in SDOH burden among observations with the same time, age, dietary habits and physical activity was 1.77mmHg (95% CI: -3.57 – 7,11, p-value = 0.517) higher. An increase in age by 1 year among women with the same SDOH burden, time post-delivery and lifestyle factors was significantly associated with a higher mean change in systolic BP of 1.15mmHg (95% CI: 0.40 – 1.90, p-value 0.005). Engaging in adequate physical activity was positively associated with a higher mean systolic BP by 4.52mmHg (95% CI: 0.38 – 8.66, p-value 0.034), whereas a healthy diet was inversely associated with a lower mean systolic BP of 5.59mmHg ((95% CI: -10.71, -0.47, p-value 0.034).

The mean expected change in diastolic BP for every one-unit increase in SDOH burden among observations with the same time, age, dietary habits and physical activity was 0.78mmHg (95% CI: -3.07, 4.62, p-value = 0.692) higher. An increase in age by 1 year for women with the same SDOH burden, diet, cooking oil and physical activity was associated with a significantly higher mean change in diastolic BP by 0.73mmHg (95% CI: 0.19 – 1.26, p-value 0.009). Overall differences in mean systolic and diastolic BP by SDOH burden did not depend on time (p-value 0.338 and 0.620, respectively).

An exploratory analysis of cardiometabolic risk factors, TC, HDL-C, LDL-C, TG, BMI and FPG did not show significant associations between SDOH burden, time, dietary intake, cooking oil use or physical activity except for BMI (Table 3.5-3.7). Differences in BMI for women within the same SDOH burden, age, dietary habits, cooking oil use and physical activity showed a 0.07kg/m^2 (95% CI: -0.12, -0.02, p-value 0.015) decrease in BMI with a unit increase in the post-delivery interval by a month.

Additional sensitivity analyses were performed using mixed models for repeated measures to assess the robustness of our findings in the association between SDOH burden, time, and outcomes, including blood

pressure and secondary cardiometabolic factors. These analyses produced results that were consistent with the linear mixed models (Supplementary tables 3.1-3.4)

Discussion

In this longitudinal analysis, we observed that women with a history of gestational hypertension or preeclampsia had elevated cardiometabolic risk factors at 6 months postpartum, particularly borderline hypertension, hypercholesterolemia and obesity. A higher SDOH burden was positively correlated with an elevated BP at 6 months postpartum. Overall, there was a downward temporal trend in BP across all SDOH categories, with women with modest and severe SDOH burdens experiencing the most significant drop in BP by 24 months postpartum. While non-significant trends linked higher SDOH burden to higher BP, significant positive associations were observed for older age and adequate physical activity with higher systolic BP. In contrast, when all factors were constant, a healthy diet showed a significant negative correlation with lower systolic BP. Exploratory analyses of other cardiometabolic risk factors showed no significant associations between SDOH burden, time, age or lifestyle factors except for a decrease in BMI with increased time since delivery.

To the best of our knowledge, this is the first study that evaluated the correlation between SDOH and blood pressure among postpartum women with a history of gestational hypertension or preeclampsia in our setting. Our findings partially align with a longitudinal study utilizing cross-sectional and longitudinal Multi-Ethnic Study of Atherosclerosis data, which demonstrated an increased risk of hypertension and other CVD risk factors with severe sociodemographic hardship.[21] At the 6-month postpartum baseline, women with high SDOH burden had elevated BP, with the highest among women with minimal SDOH burden and slightly lower BP in the modest and severe SDOH group. This variance may stem from our study's utilization of a younger postpartum cohort and an aggregate SDOH score of 6 components in 4 SDOH domains, contrasting the mentioned study’s middle-aged to elderly participant cohort and

extensive SDOH components grouped into quartiles. However, the finding of the highest mean BP recordings at baseline for increased SDOH severity was consistent with previous studies that demonstrated cumulative effects of individual SDOH factors, such as low educational attainment, socioeconomic hardship, and low social cohesion, to be independently associated with elevated BP and heightened CVD risk.[56–58] Additionally, a longitudinal study in the Netherlands by Veerbeek et al that highlighted the greatest risk of post-pregnancy hypertension occurred less than a year after delivery for women with gestational hypertension and preeclampsia. [49]

The observed differences in baseline blood pressure and trends over time for women with distinct SDOH burdens provide insights into the impact of sociodemographic factors on cardiovascular outcomes. The consistency in temporal changes in BP among different SDOH groups emphasizes the need for nuanced approaches to postpartum cardiovascular care. Women with no or minimal SDOH burden had the least BP decline over time, although the latter group had persistent borderline hypertension across all the time points. Women with modest and severe SDOH burdens exhibited the greatest improvement in blood pressure decline, highlighting the potential reversibility of cardiovascular risk factors in individuals with sociodemographic challenges.

Our findings of non-significant trends between SDOH burden and blood pressure but a significant effect of age and lifestyle habits suggest that individual factors, behaviors and demographic factors may directly impact blood pressure outcomes alongside SDOH burden.[20,22] The lack of a significant association between SDOH burden and blood pressure contradicts previous studies that have modeled a significant

linear relationship between SDOH severity and hypertension, obesity, diabetes and atherosclerotic CVD.[21,59] A population-based cross-sectional study in the United States by Sharma et al. evaluated the impact of SDOH hardship on cardiovascular health in pregnant women.[60] The study showed that over 50% of women had subpar cardiovascular health and women with the highest SDOH quartile had adverse

cardiovascular health characterized by hyperlipidemia, smoking, obesity, and inadequate physical activity.[60] There is a paucity of studies evaluating cumulative SDOH burden and cardiovascular health in pregnancy and the postpartum period in LMIC. Further exploration is needed, considering the differences in cardiovascular health mechanisms between HIC and LMIC, namely metabolic versus inflammatory CVD effects.[61]

The exploratory analysis of secondary cardiometabolic risk factors showed variable temporal trends without any significant effect of SDOH on FPG, TC, HDL-C, LDL-C and TG. This partially aligns with previous studies showing a significant effect of aggregate SDOH burden on glycemic control and a non-significant effect on lipid control.[21,59] A possible explanation could be that our study utilized fasting glucose and lipid profiles as continuous variables, whereas these studies used glycated hemoglobin (HbA1C) as a marker for glycemic control and dichotomized dyslipidemia. There is a preponderance for fasting glucose in our setting, unlike in HIC, where fasting glucose and HbA1C are used to monitor glycemic control. Anemia, prevalent in postpartum women due to pregnancy effects or childbirth blood loss, can elevate HbA1C levels, potentially yielding falsely high readings that require caution when utilized.[62]

Our study's clinical relevance lies in the potential to comprehensively understand cardiovascular health in postpartum women with gestational hypertension or preeclampsia and inform postpartum care practices in Kenya. Routine assessment of SDOH burden could offer context-specific insights, guiding interventions to improve cardiovascular health among women facing social disadvantages. Integrating SDOH evaluation into postpartum care aligns with the ongoing shift toward non-communicable diseases, including CVD and facilitates targeted therapy, timely follow-up, and appropriate risk stratification.

Our study has noteworthy limitations that include a small sample size that lacked the power to detect a significant association of SDOH with BP and BP changes over time. Outcome missingness of 25-27.5% from loss to follow-up at 12 to 24 months postpartum also impacted the study’s power and precision, however

linear mixed models were robust to manage missingness. Additionally, the collection of SDOH burden relied on sociodemographic variables collected only at baseline which did not include healthcare access and quality domain and hence did not capture changes over time, although our findings remained partially consistent with previous studies. Future research should explore the long-term impact of other SDOH domains and components such as income and health care quality collected using a context specific and comprehensive SDOH burden questionnaire on blood pressure and metabolic outcomes in LMIC. Incorporating these factors into a composite score of SDOH burden would provide a more comprehensive understanding of the cardiovascular health in postpartum to inform policy, guidelines and targets for context-specific postpartum care and how to support women with sociodemographic disadvantage.

Conclusion

Severity in SDOH burden is linked with increased BP with temporal changes and variability in BP by SDOH burden. The nuanced evaluation of SDOH and blood pressure changes over time offers a foundation for context-specific care, emphasizing the importance of tailored interventions and support for women with varying sociodemographic challenges. Integrating CVD risk stratification using SDOH burden in routine CVD assessment will ensure the timely initiation of targeted therapy and lifestyle interventions that mitigate CVD risk and events.

Acknowledgment

FN, SM, CL and AO contributed to the conception and design of the work. FN analyzed the data and drafted the manuscript. All authors contributed to the editing of the manuscript and approved the submission of the final draft publication.

We declare no conflicts of interest.

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Disclaimer Statement

The content is solely the authors' responsibility and does not represent the official views of the National Institutes of Health.

Figure 3.1: Temporal variation in systolic blood pressure by SDOH burden

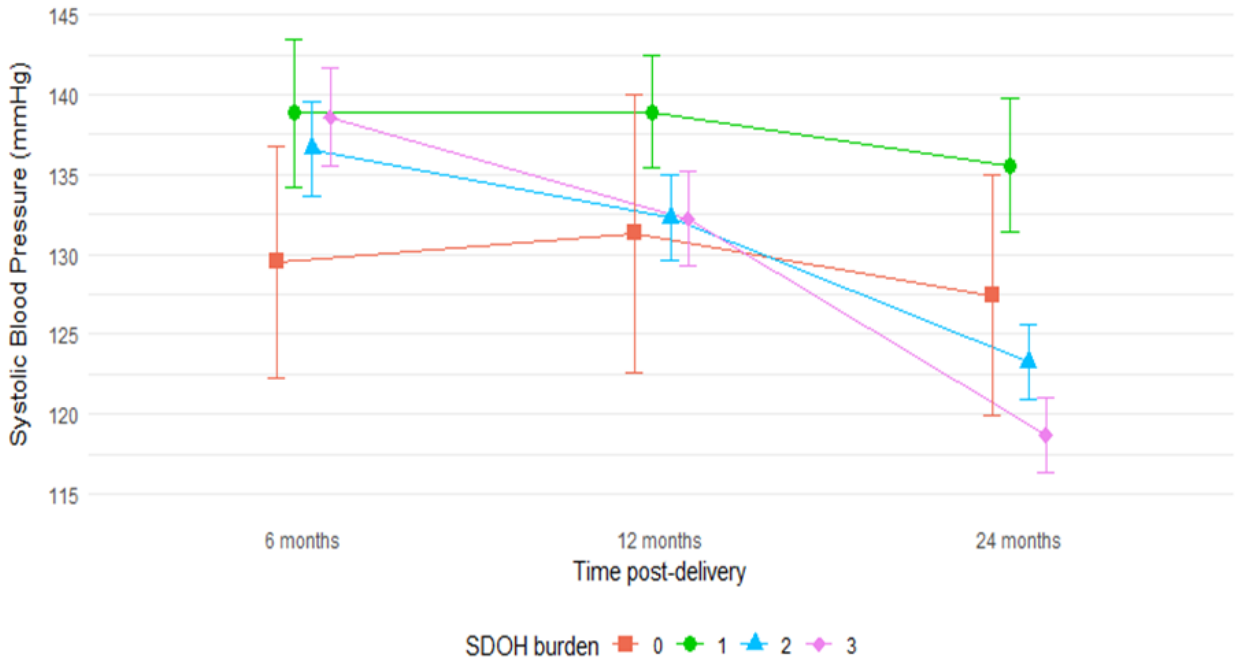

Figure 3.2: Temporal variation in diastolic blood pressure by SDOH burden

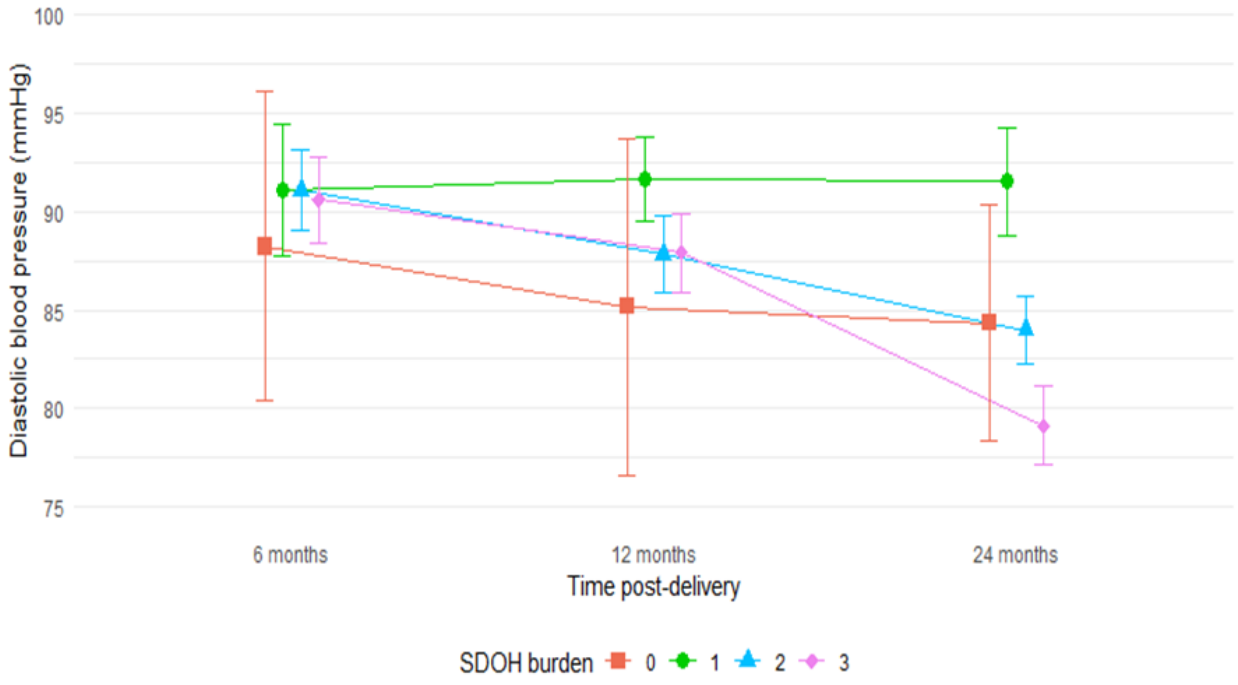

Table 3.1: Baseline sociodemographic and clinical characteristics of women with a history of gestational hypertension and preeclampsia at 6 months postpartum

	With gestational hypertension or preeclampsia (n=97)	
	n	%
Sociodemographic characteristics		
Age (years), median (IQR)	32.8 [26.0, 45.0].2	
Marital Status		
Currently married	95	(97.9)
Separated/Divorced	1	(1.0)
Cohabiting	1	(1.0)
Highest education attainment		
Completed primary school	31	(32.0)
Did not complete high school	12	(12.4)
Completed high school	29	(29.9)
College or higher	25	(25.8)
Occupation		
Formally employed	24	(24.7)
Self-employed	41	(42.3)
Homemaker	30	(30.9)
Student	1	(1.0)
Unemployed	1	(1.0)
Partner's occupation		
Formally employed	47	(48.5)
Self-employed	50	(51.5)
Household size, median (IQR)	2.00 [1.00, 4.00]	
Urban area of residence	104	(100)
Obstetrics and gynecological characteristics		
Parity, median (IQR)	3.00 [1, 6]	
Gestation at delivery (weeks), mean (SD)	35.6 ± 5.0	
Mode of delivery		
Cesarean section	58	(59.8)
Vaginal delivery	39	(40.2)
Previous pregnancy complications		
Hypertensive disorders of pregnancy	91	(93.8)
Both GDM and HDP	2	(2.1)
None	4	(4.1)
Cardiovascular risk factors		
Systolic blood pressure (mmHg), mean (SD)	137 ± 19.4	
Diastolic blood pressure (mmHg), mean (SD)	90.9 ± 13.8	
Fasting plasma glucose, (mg/dl), mean (SD)	74.9 ± 19.1	
Total cholesterol, mg/dl, mean (SD)	172 ± 40.6	
LDL cholesterol, mg/dl, mean (SD)	104 ± 31.2	
HDL cholesterol, mg/dl, mean (SD)	48.5 ± 14.5	
Triglycerides, mg/dl, mean (SD)	106 ± 85.6	
Body mass index (kg/m^2), mean (SD)	32.7 ± 6.3	

Waist circumference, mean (SD)	96.9 ± 13.3	
antihypertensive medication use	34	(35.1)
Diabetes	2	((2.1)
Current alcohol consumption	1	(1.0)
Nonsmoker[+]	97	(100)
Healthy diet[¶]	82	(84.5)
Healthy cooking oil use∞	94	(96.9)
Adequate physical activity*	767	(69.1)

GH: Gestational hypertension, PE: Preeclampsia, GDM: Gestational diabetes mellitus, HDP: Hypertensive disorder of pregnancy

Column percent totals will not sum to 100% due to missingness or may be >100% due to the inclusion of missing values >5%

[¶]Healthy diet defined by ≥ 5 daily servings of fruits and vegetables

∞Healthy cooking oil defined by use of unsaturated fats

*Adequate physical activity was defined as at least 150 minutes of moderate-intensity activity or 75 minutes of vigorous-intensity activity per week and included travel, work, and leisure activities

Table 3.2: Prevalence of social determinants of health in women with a history of gestational hypertension or preeclampsia

	SDOH Burden[+]										
	Overall (N=291)		0 (N=9)		1 (N=78)		2 (N=132)		3 (N=72)		
	n	%	n	%	n	%	n	%	n	%	p-value
Age, median (IQR)	32 (26, 45)		35 (29, 38)		32.5 (27, 42)		32 (26, 45)		31 (27, 37)		0.022
High school education or lower	213	(73.2)	0	(0)	27	(34.6)	117	(88.6)	69	(95.8)	**<0.001**
Self-unemployed	96	(33.0)	0	(0)	6	(7.7)	21	(15.9)	69	(95.8)	**<0.001**
Partner employed	291	(100)	9	(100)	78	(100)	132	(100)	72	(100)	NA
Urban area of residence	291	(100)	9	(100)	78	(100)	132	(100)	72	(100)	NA
Household size ≤ 2 adults	243	(83.5)	0	(0)	45	(57.7)	126	(95.5)	72	(100)	**<0.001**

N: Number of observations that account for repeated measures taken over 3 different timepoints
SDOH: Social determinants of health, GH: Gestational hypertension, PE: Preeclampsia
[+]SDOH burden based on aggregate individual unfavorable SDOH scores of high school education or lower, self and partner's occupation of student, homemaker or unemployed, rural residence and household size of ≤ 2 adults

Table 3.3: Cardiovascular risk factors by SDOH burden among women with a history of gestational hypertension or preeclampsia by SDOH burden

	SDOH Burden[+]				
	Overall (N=312)	**0 (N=9)**	**1 (N=78)**	**2 (N=150)**	**3 (N=69)**	**P - value**
Systolic blood pressure, mmHg, mean (SD)	134 ± 18.5	129 ± 11.4	138 ± 20.9	132 ± 18.6	133 ± 15.7	0.171
Diastolic blood pressure, mmHg, mean (SD)	88.9 ± 12.9	86.0 ± 10.9	91.4 ± 14.1	88.5 ± 13.1	87.5 ± 10.9	0.339
Fasting glucose, mg/dl, mean (SD)	79.1 ± 26.9	79.1 ± 8.32	80 ± 33.9	82.2 ± 27.9	87.5 ± 10.9	0.307
Total cholesterol, mg/dl, mean (SD)	169 ± 39.7	158 ± 41.0	166 ± 40.9	175 ± 37	163 ± 42.4	0.260
LDL cholesterol, mg/dl, mean (SD)	105 ± 29.4	105 ± 23.7	105 ± 28.9	107 ± 29.5	102 ± 31.0	0.821
HDL cholesterol, mg/dl, mean (SD)	47.9 ± 13.3	54.3 ± 11.2	45.8 ± 12.5	46.7 ± 11.7	51.2 ± 16.2	0.062
Triglycerides, mg/dl, mean (SD)	102 ± 73.8	69.4 ± 22.7	99.7 ± 51.4	111 ± 82.0	93.0 ± 82.5	0.291
Body mass index, kg/m^2, mean (SD)	32.9 ± 6.43	29.6 ± 2.42	33.9 ± 7.38	32.0 ± 5.83	33.8 ± 6.51	0.112
Healthy diet,[¶] n %	191 (65.6)	7 (77.8)	54 (69.2)	88 (66.7)	42 (58.3)	0.089
Healthy cooking oil use,∞ n %	212 (72.9)	8 (88.9)	59 (75.6)	93 (70.5)	52 (72.2)	0.430
Adequate physical activity,* n %	170 (58.4)	6 (66.7)	50 (64.1)	75 (56.8)	39 (54.2)	0.580

N: Number of observations that account for repeated measures taken over 3 different timepoints
SDOH: Social determinants of health, GH: Gestational hypertension, PE: Preeclampsia, HDL: High-density lipoprotein, LDL: Low-density lipoprotein
[+]SDOH burden based on aggregate individual unfavorable SDOH scores of high school education or lower, self and partner's occupation of student, homemaker or unemployed, rural residence and household size of ≤ 2 adults
[¶]Healthy diet defined by ≥ 5 daily servings of fruits and vegetables
∞Healthy cooking oil defined by use of unsaturated fats
*Adequate physical activity is defined as at least 150 minutes of moderate-intensity activity or 75 minutes of vigorous-intensity activity in a week and includes travel, work and leisure activities.

Table 3.4: Results of linear mixed models with fixed effects of SDOH burden, time and covariates on blood pressure among women with a history of gestational hypertension and preeclampsia

	Systolic blood pressure				Diastolic blood pressure			
	Estimate	95% Confidence intervals		P-value	Estimate	95% Confidence intervals		P-value
Fixed effects								
(Intercept)	105.66	74.78	136.53	**0.000**	71.43	49.09	93.81	0.000
SDOH	1.77	-3.57	7.11	0.517	0.78	-3.07	4.62	0.692
Time	-0.26	-0.79	0.27	0.338	-0.10	-0.50	0.30	0.620
Age	1.15	0.40	1.90	**0.003**	0.73	0.19	1.26	**0.009**
Healthy diet	-5.59	-10.71	-0.47	0.034	-3.10	-6.96	0.76	0.117
Healthy cooking oil	-4.32	-15.02	6.22	0.430	-2.79	-10.83	5.25	0.498
Adequate physical activity	4.52	0.38	8.66	**0.034**	1.12	-2.00	4.24	0.397
Interaction term								
SDOH * Time	-0.20	-0.46	0.06	0.127	-0.09	-0.29	0.11	0.397

Table 3.5: Results of linear mixed models with fixed effects of SDOH burden, time and covariates on total cholesterol and triglycerides among women with a history of gestational hypertension and preeclampsia

	Total Cholesterol				Triglycerides			
	Estimate	95% Confidence intervals		P-value	Estimate	95% Confidence intervals		P-value
Fixed effects								
(Intercept)	135.67	64.79	206.55	**0.000**	102.35	-26.39	231.10	0.121
SDOH	-4.03	-18.14	10.08	0.578	1.84	-20.55	24.23	0.872
Time	-1.54	-3.51	0.42	0.130	-0.31	-2.32	1.71	0.765
Age	1.00	-0.57	2.57	0.215	-0.47	-3.67	2.73	0.773
Healthy diet	6.91	-7.30	21.13	0.342	7.86	11.81	27.54	0.435
Healthy cooking oil	9.65	-18.65	37.96	0.505	9.80	-31.43	51.02	0.642
Adequate physical activity	1.00	-10.24	12.24	0.861	-3.43	-19.32	12.45	0.672
Interaction term								
SDOH * Time	0.43	-0.52	1.39	0.379	0.00	-0.99	0.99	0.995

Table 3.6: Results of linear mixed models with fixed effects of SDOH burden, time and covariates on HDL cholesterol and LDL cholesterol among women with a history of gestational hypertension and preeclampsia

	HDL Cholesterol				LDL Cholesterol			
	Estimate	95% Confidence intervals		P-value	Estimate	95% Confidence intervals		P-value
Fixed effects								
(Intercept)	55.09	31.35	78.82	**0.000**	68.28	14.70	121.82	**0.014**
SDOH	0.79	-3.56	5.14	0.723	-1.95	-11.73	7.83	0.696
Time	-0.08	-0.68	0.51	0.786	-0.34	-1.45	0.77	0.555
Age	-0.16	-0.67	0.35	0.547	0.74	-0.58	2.05	0.274
Healthy diet	-2.09	-7.25	3.08	0.430	0.29	-8.12	8.70	0.946
Healthy cooking oil	1.04	-9.49	11.58	0.846	13.00	-3.18	29.17	0.118
Adequate physical activity	-2.21	-6.37	1.95	0.300	4.56	-1.85	10.97	0.166
Interaction term								
SDOH * Time	0.01	-0.28	0.30	0.952	0.17	-0.37	0.72	0.536

HDL: High-density lipoprotein, LDL: Low-density lipoprotein

Table 3.7: Results of linear mixed models with fixed effects of SDOH burden, time and covariates on fasting plasma glucose and body mass index women with a history of gestational hypertension and preeclampsia

	Fasting plasma glucose				Body mass index			
	Estimate	95% Confidence intervals		P-value	Estimate	95% Confidence intervals		P-value
Fixed effects								
(Intercept)	84.09	18.47	149.71	**0.013**	25.84	14.64	37.04	**0.000**
SDOH	-3.19	-14.10	7.72	0.568	0.96	-0.71	2.62	0.262
Time	0.53	-0.68	1.74	0.394	0.10	0.00	0.21	0.060
Age	-0.11	-1.57	1.35	0.886	0.16	-0.15	0.47	0.322
Healthy diet	0.56	-11.58	12.70	0.928	-0.27	-1.04	0.50	0.493
Healthy cooking oil	-3.01	-37.43	31.41	0.864	0.30	-1.29	1.89	0.711
Adequate physical activity	1.72	-7.80	11.22	0.725	0.10	0.48	0.69	0.729
Interaction term								
SDOH * Time	-0.01	-062	0.43	0.969	-0.07	0.12	-0.02	**0.015**

Supplemental table 3.1: Results of mixed models for repeated measures with fixed effects of SDOH burden, time and covariates on blood pressure among women with a history of gestational hypertension and preeclampsia

	Systolic blood pressure				Diastolic blood pressure			
	Estimate	95% Confidence intervals		P-value	Estimate	95% Confidence intervals		P-value
Fixed effects								
(Intercept)	100.17	70.95	129.38	**0.000**	70.18	48.47	91.89	0.000
SDOH	1.30	-3.53	6.12	0.600	0.37	-3.07	3.80	0.835
Time (12 months)	1.70	-6.58	9.99	0.689	-0.73	-6.92	5.46	0.817
Time (24 months)	-5.26	-12.66	2.14	0.170	-2.05	-8.71	4.61	0.549
Age	1.21	0.49	1.93	**0.001**	0.71	0.19	1.24	**0.009**
Healthy diet	-4.49	-9.12	-0.13	0.059	-2.56	-6.35	1.23	0.118
Healthy cooking oil	-4.06	-13.49	5.38	0.402	-2.19	-9.85	5.48	0.577
Adequate physical activity	4.18	0.36	8.01	**0.034**	1.29	-1.84	4.41	0.421
Interaction term								
SDOH*Time (12 months)	-3.29	-7.29	0.72	0.111	-0.88	-3.87	2.12	0.568
SDOH*Time (24 months)	-2.96	-6.63	0.716	0.121	-1.33	-4.62	1.95	0.431

Supplemental table 3.2: Results of mixed model for repeated measures with fixed effects of SDOH burden, time and covariates on total cholesterol and triglycerides among women with a history of gestational hypertension and preeclampsia

	Total cholesterol				Triglycerides			
	Estimate	95% Confidence intervals		P-value	Estimate	95% Confidence intervals		P-value
Fixed effects								
(Intercept)	117.68	70.95	129.38	**0.001**	106.43	-1.02	213.89	0.054
SDOH	0.13	-3.53	6.12	0.980	2.16	-19.72	24.04	0.847
Time (12 months)	-0.40	-6.58	9.99	0.969	-9.24	-39.28	20.81	0.548
Time (24 months)	-28.35	-12.66	2.14	0.170	-6.36	-37.19	24.48	0.688
Age	1.08	0.49	1.93	0.110	-0.70	-3.27	1.87	0.595
Healthy diet	6.94	-9.12	-0.13	0.340	9.61	-6.19	25.40	0.236
Healthy cooking oil	12.93	-13.49	5.38	0.369	14.49	-15.56	44.54	0.347
Adequate physical activity	1.18	0.36	8.01	0.838	-5.68	-18.79	7.42	0.397
Interaction term								
SDOH*Time (12 months)	-1.91	-7.29	0.72	0.701	-1.11	15.63	13.41	0.881
SDOH*Time (24 months)	7.90	-6.63	0.716	0.356	-0.25	-14.91	15.42	0.974

Supplemental table 3.3: Results of mixed models for repeated measures with fixed effects of SDOH burden, time and covariates on HDL cholesterol and LDL cholesterol among women with a history of gestational hypertension and preeclampsia

	HDL cholesterol				LDL cholesterol			
	Estimate	95% Confidence intervals		P-value	Estimate	95% Confidence intervals		P-value
Fixed effects								
(Intercept)	57.34	35.19	79.49	**0.000**	63.64	11.15	116.13	0.019
SDOH	1.11	-2.62	4.83	0.561	-0.83	-8.96	7.30	0.842
Time (12 months)	1.94	-6.51	10.40	0.653	2.78	-8.33	13.88	0.626
Time (24 months)	-2.12	-11.86	7.61	0.671	-7.92	-28.01	12.16	0.444
Age	-0.24	-0.73	0.25	0.341	0.78	-0.53	2.09	0.245
Healthy diet	–2.40	-7.27	2.47	0.335	-1.84	10.31	6.63	0.671
Healthy cooking oil	-0.27	-9.50	8.97	0.955	-15.19	-0.59	30.97	0.062
Adequate physical activity	-1.27	-5.24	-2.70	0.532	4.38	-2.06	10.83	0.185
Interaction term								
SDOH*Time (12 months)	-0.90	-4.98	3.19	0.668	-0.09	-5.31	5.49	0.974
SDOH*Time (24 months)	0.23	-4.55	5.01	0.926	-3.34	-6.50	13.17	0.510

HDL: High-density lipoprotein, LDL: Low-density lipoprotein

Supplemental table 3.4: Results of mixed models for repeated measures with fixed effects of SDOH burden, time and covariates on fasting plasma glucose and body mass index women with a history of gestational hypertension and preeclampsia

	Fasting plasma glucose				Body mass index			
	Estimate	95% Confidence intervals		P-value	Estimate	95% Confidence intervals		P-value
Fixed effects								
(Intercept)	80.22	51.73	108.71	**0.000**	26.43	15.28	37.59	0.000
SDOH	-5.15	-11.14	0.83	0.098	0.56	-1.06	2.18	0.499
Time (12 months)	-4.38	-14.07	5.32	0.382	0.69	-0.34	1.72	0.194
Time (24 months)	0.18	-21.88	22.23	0.987	1.99	0.04	3.90	0.052
Age	0.11	-0.52	0.73	0.744	0.16	-0.15	0.47	0.322
Healthy diet	-3.25	-11.58	5.08	0.446	-0.32	-1.09	0.45	0.416
Healthy cooking oil	-4.61	-10.53	19.75	0.553	0.35	-1.23	1.92	0.666
Adequate physical activity	1.32	-4.18	6.83	0.639	0.11	-0.48	0.70	0.711
Interaction term								
SDOH*Time (12 months)	-3.51	-1.34	8.36	0.163	-0.42	-0.93	0.08	0.102
SDOH*Time (24 months)	-3.33	-7.72	14.37	0.561	-1.26	–2.19	-0.32	**0.011**

CHAPTER 4: Conclusion

This thesis provides evidence on the lifetime CVD risk and social determinants of cardiovascular health among women with a history of gestational hypertension and preeclampsia in Kenya. It describes the application of pooled cohort equations (PCE) to determine lifetime cardiovascular disease (CVD) risk and the role of social determinants of health (SDOH) as predictors for CVD using blood pressure and other cardiometabolic risk factors.

These studies demonstrate the high postpartum CVD risk of women with a history of gestational hypertension and preeclampsia. We report the mean predicted CVD lifetime risk was 34.7% ± 10.4 among women with gestational hypertension and preeclampsia and they were twice as likely to have a high predicted CVD lifetime risk of ≥39% compared to women who had a normotensive pregnancy. Additionally, we observed elevated cardiometabolic risk factors, including borderline hypertension, hypercholesterolemia, and obesity, at 6 months postpartum for women with a history of gestational hypertension or preeclampsia. When stratified by SDOH burden, we identified a positive correlation between a higher SDOH burden and higher blood pressure at a baseline of 6 months postpartum. Over time, an overall downward temporal trend in blood pressure was observed for all SDOH categories. We observed non-significant trends linking increased SDOH burden with higher blood pressure. However, age and physical activity showed significant positive associations with systolic blood pressure, while a healthy diet showed a significant negative association with systolic blood pressure when all factors were constant. Other cardiometabolic risk factors had variable changes with an increase in SDOH burden and did not reveal significant associations between SDOH burden, time or lifestyle factors except for a decrease in BMI with an increase in time since delivery.

While our results align with our hypotheses, indicating a high predicted lifetime CVD risk and an elevated CVD risk burden with an increase in SDOH among women with a history of gestational hypertension or

preeclampsia, additional research is imperative. More research is needed to develop CVD risk prediction tools adapted to LMIC and incorporate female-specific CVD risk factors alongside traditional CVD risk factors used in current prediction tools. Further research can focus on the utility and validity of inflammatory markers on CVD disease risk computation since an inflammatory state herald's pregnancy. To validate this CVD risk assessment tool, comprehensive data on intermediate outcomes (such as myocardial infarction, cardiomyopathy, heart failure and stroke) and long-term outcomes (such as death) in people with and without gestational hypertension or preeclampsia and other adverse pregnancy outcomes associated with a heightened CVD risk are essential. Leveraging longitudinal studies, postpartum CVD disease registries, and mortality data, we can track metabolic and inflammatory markers over time, explore different pathways and assess the predictive value of inflammatory markers for cardiovascular events and mortality. In resource-limited settings, evaluating the influence of SDOH burden in pregnant and postpartum CVD risk factors will inform tailored postpartum care frameworks for women with sociodemographic burden.

Following this thesis, my future research endeavors include delving into the use of non-laboratory versus laboratory testing for CVD screening and determining the impact of CVD risk reduction strategies targeting hypertension, obesity and dyslipidemia in reducing postpartum CVD risk through an implementation study. Furthermore, I aim to conduct a study evaluating individual SDOH factors on CVD risk factors and the association with inflammatory markers among pregnant and postpartum women. Finally, I intend to utilize the new PREVENT equations which compute 10 and 30-year total CVD risk from cardiovascular, kidney and metabolic indicators,[63] to develop a model that incorporates SDOH into CVD risk prediction in African women. The work accomplished in this thesis positions me effectively to undertake these endeavors and contribute to advancing knowledge in global CVD research.

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