Characterizing perinatal depression and its impact on infant outcomes and maternal-nurse SMS communication in a cohort of Kenyan women

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Abstract

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Objective: To examine the prevalence and correlates of perinatal depression, to determine the association between antenatal depression and infant morbidity/mortality, and to compare SMS communication patterns between women with and without perinatal depression.

Background: Perinatal depression is broadly defined as depressive symptoms with onset during pregnancy or within the 12 months following delivery, affecting approximately 20-25% of pregnant and postpartum women in low- and middle-income countries. The broad accessibility of mobile phones allows mHealth interventions to be considered as a solution for health providers to identify and treat perinatal depression.

Methods: Prospective longitudinal cohort of pregnant women seeking antenatal services at one of two public sector health clinics in Kenya. Pre-programmed SMS messages were sent to participants with content pertaining to their pregnancy status. Sociodemographic and obstetric characteristics, SMS messaging behaviors, infant health status, and depressive symptoms were assessed by a standardized questionnaire administered at enrollment (30-36 weeks gestation) and follow-up (14 weeks postpartum). Generalized estimating equation (GEE) with Poisson link was used to evaluate correlates of perinatal depression, infant outcomes, and frequency of SMS messaging.

Results: Of the 572 women with complete follow-up information, 188 (32.9%) had evidence of perinatal depression at some time point in pregnancy or postpartum. Strongest risk factors for perinatal depression included intimate partner violence, fewer years of schooling, and maternal unemployment. Antenatal depression was associated with an increased risk of infant illness or hospitalization (RR = 1.12, 95% CI: 1.11, 1.13). Women with antenatal or persistent perinatal depression sent fewer SMS messages during the study period than their counterparts without depression.

Conclusion: Our analysis demonstrated a relatively high prevalence of perinatal depression in this cohort. Differences in messaging frequency suggest two-way SMS messaging systems may have utility in identifying depressive symptoms throughout the perinatal period, making it feasible to incorporate detection and treatment modalities for mothers with depression via mHealth interventions.

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INTRODUCTION

Perinatal depression, broadly defined as an episode of major depression or depressive symptoms that occur during pregnancy and within the first year following childbirth, is a global public health concern causing adverse consequences for the mother and infant[1,2]. A recent systematic review demonstrates that worldwide at least 17.2% of pregnant women and 13.1% of postpartum women suffer from perinatal depression[3]. Prevalence is even higher in low- and middle-income countries (LMICs) where 25.8% of women have antenatal depression and 19.7% experience postpartum depression[4]. Risk factors for perinatal depression in LMICs include experiencing intimate partner violence (IPV), lower maternal educational attainment, lower socioeconomic status, unintended pregnancy, single/unmarried status at time of pregnancy, and low social support[1,2,4,5]. In studies conducted in Kenya, rates of maternal depression were higher in adolescents and women living with HIV (WLWH)[2]. Antenatal depression is the strongest risk factor for postpartum depression (PPD), with 54% of women with PPD reporting depressive symptoms prior to childbirth[2,4].

Research has consistently demonstrated a negative association between perinatal depression and health outcomes for mothers and infants[4]. In particular, perinatal depression has been associated with preterm birth, intrauterine growth restriction, prolonged labor, low birth weight, persistent perinatal depression, and even suicide[4,7]. Recent studies suggest that even subclinical depressive symptoms have a similar impact as clinical depression on maternal and infant health outcomes[6.] Compared to infants of non-depressed mothers, infants of depressed mothers appear to have poorer physical and neurocognitive development and a higher likelihood of diarrheal, febrile, and other infectious illnesses[4]. These adverse events are concerning for women in LMICs where infectious illnesses remain one of the leading causes of death for children under the age of five[8]. In 2017, enteric illnesses and respiratory infections/TB were ranked as the second and third leading causes of death, respectively, for children under the age of five in Kenya[9]. A cross-sectional study in Nairobi, Kenya found that low-income women with PPD were more likely to supplement their infants' diet rather than exclusively breastfeed, and infants of mothers with PPD were more likely to be underweight[10]. By supplementing infants' diets with water, these infants were at higher risk of exposure to infectious disease and of contracting diarrheal illnesses[10]. Yet, this study lacked the ability to assess the temporality of these outcomes, making it difficult to discern whether depression in mothers leads to suboptimal feeding practices or if the strain of caring for ill infants leads to emotional distress and subsequent depression[10]. There remains a paucity of literature from Sub-Saharan Africa, and Kenya specifically, determining the effects of perinatal depression on infant morbidity and mortality.

Identifying pregnant women with antenatal depression and those at high risk for developing postpartum depression provides a potential opportunity to intervene early, engage in therapeutic care, and reduce adverse health outcomes for women and their infants. In LMICs, perinatal depression often goes underrecognized and untreated, in part due to lack of resources[4]. Even if depressive symptoms are recognized and mental health services are available, multiple challenges of pregnancy and motherhood prohibit women from being able to seek treatment and counseling. In general, but particularly in places with a scarcity of mental health resources, novel interventions are needed to determine best practices for the diagnosis and care of women with perinatal depression. One potential solution to improving recognition, support for and treatment of perinatal depression in LMICs is mobile health (mHealth) technologies[11]. Of the few studies attempting to utilize mHealth interventions to improve mental health outcomes for women with depression, almost all of these have been conducted in high-income countries while studies in LMICs have mainly focused on the collection of maternal and child outcomes via mHealth strategies[12-15]. The aim of this study is to describe the prevalence of perinatal depression, assess correlates of depression, and evaluate the impact of maternal depression on infant outcomes in a cohort of Kenyan women. In addition we sought to

investigate the engagement of women living with depression with an mHealth intervention designed to improve maternal and infant health outcomes.

METHODS

Study Design:

This study utilizes data collected from a prospective cohort study, known as Mobile Solutions for Women, Adolescents, and Children's Health: Neonate (Mobile WACh Neo). The Mobile WACh NEO study, designed to support maternal and infant outcomes of facility delivery, infant survival and family planning uptake, enrolled 800 pregnant women seeking antenatal care services from two public facilities in Kenya: Mathare North Health Centre (Nairobi County, peri-urban) or Rachuonyo Sub-County Hospital (Homa Bay County, rural) from December 2017 to January 2019. Mobile WACh Neo participants received pre-programmed SMS messages until 14 weeks postpartum. Content and frequency of pre-programmed messages were dependent upon the woman's pregnancy status and delivered in the participant's preferred language and preferred time of day. SMS messages from participants could be sent at any time and were encouraged in response to pre-programmed messages. Study nurses managed the bidirectional SMS communication and used national guidelines and local practice standards when responding to participants. Two surveys, one at the time of enrollment and one post-intervention, were conducted with participants to collect demographic, health, and study-related information.

Intervention:

Mobile WACh NEO is a two-way SMS messaging intervention designed to engage women with a health care worker at their local clinic with the aim of improving maternal and neonatal outcomes. Messages are personalized, behavioral theory based and action oriented specific to the time point in pregnancy or postpartum. During pregnancy (gestational age at enrollment to delivery), weekly messages were sent to prepare women for delivery, including information about signs of impending labor, decision-making for delivery site, recruitment of a partner/companion to accompany the delivery, transportation planning, and securement of childcare for other children if necessary. In the immediate post-delivery period/early neonatal period (delivery to 4 weeks infant age), women received daily messages for one week followed by messages every other day that focused on assessing the status of mother and neonate, including educational messages about breastfeeding and signs of severe illness. In the subsequent postnatal period (4 weeks-12 weeks infant age), women received SMS twice a week, which contained counseling messages regarding family planning options and infant growth and development.

Schematic 1. SMS Messaging Content and Frequency

Period	**Pregnancy** (Enrollment – Delivery)	**Early neonatal period** (Delivery- 4 weeks infant age)	**Postnatal period** (4 weeks – 12 weeks infant age)
SMS frequency	Weekly	Daily x 1 week → Every other day x3 weeks	Twice a week
Topics	Birth preparation	Infant and maternal health evaluations	Infant health and family planning

Study Population:

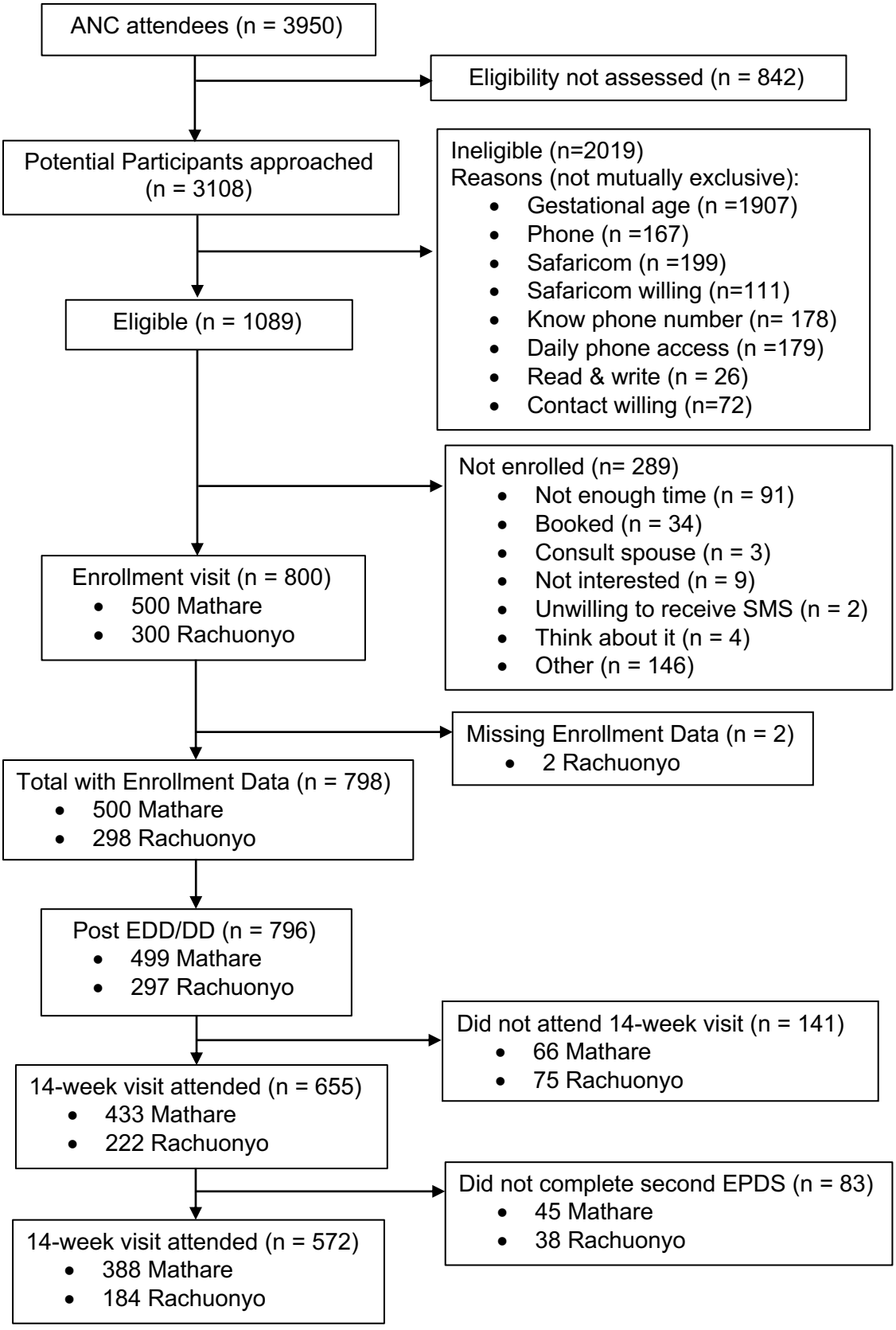
Pregnant women seeking antenatal care (ANC) services from the two sites were recruited to participate in the Mobile WACh NEO intervention. This source population encompasses both rural and peri-urban areas, an ethnically diverse population, and areas with generally low socioeconomic status. Pregnant women were eligible if they had daily access to a mobile phone, were ≥14 years of age, and were between 30-36 weeks gestation. If a woman was not sufficiently literate but had access to a partner or family member whom she would be

comfortable having read her messages, she was eligible for the study. Pregnant women were recruited by community health workers who introduced the study to potential participants, answered questions, and invited women to participate. It was emphasized that participation was completely voluntary and would not in any way affect their antenatal, postnatal, or infant care services. Women who were referred and willing to participate were given a screening questionnaire in order to assess eligibility. Oral consent was obtained for participation of interested women during the screening phase. Eligible women who agreed to participate and receive SMS messages underwent the informed consent process and were entered into the Mobile WACh system along with their preferences for SMS message delivery. Eligible women who chose not to participate were asked their reasons for non-participation, with responses recorded in the screening questionnaire.

Sample Size/ Post-hoc Power Calculation:
Since these data have been previously collected, a traditional power analysis (to determine sample size) is not relevant.

Data Collection:
Women were followed during pregnancy and for 14 weeks postpartum. Women participating were administered a standardized questionnaire at enrollment and one follow-up visit (at 14 weeks postpartum) using a tablet-based system (Open Data Kit, ODK)[16]. ODK was developed by the UW Department of Computer Science and Engineering collaborators. Collected patient information included questions pertaining to demographics, clinical history, experience with SMS and technology, intimate partner violence, and depression. SMS communication was collected continuously in the Mobile WACh platform throughout the entirety of the study period.

Figure 1. Diagram to show recruitment and enrollment of study participants



Sociodemographic factors:
Self-reported data on maternal demographic information was collected at baseline. Maternal age in years was used to classify mothers as adolescents (≤19 years old) and adults (≥20 years old) based on the WHO definitions. Women who reported their marital status as "currently married" or "come we stay"* were classified as "married/cohabitating" and all other responses (never married, divorced/separated, widowed) were classified as "not married/ not cohabitating". Education status was grouped into those with less than a primary education and those who completed at or above a primary education. The Abuse Assessment Screen (AAS) was used to evaluate intimate partner violence (IPV) in this study based on participant reports of experiencing physical abuse in the form of kicking, slapping, or other physical harm from someone close to them during the current pregnancy [18]. Household income was based on self-reported approximate monthly income in Kenyan shilling. Number of living children was a continuous variable based on mother's report of how many living children she has. The distance from home to clinic was recorded as self-reported number of minutes to travel from the clinic to her home, and the travel time was dichotomized to <30 minutes and ≥30 minutes. Family planning use was based on the participant or her partner ever using family planning methods to delay or avoid pregnancy, including abstinence, sterilization, and natural methods. Undesired pregnancy was defined as the mother reporting she did not want to have a/another baby at the time of becoming pregnant with the current pregnancy. History of miscarriage was a binary variable consisting of women who had reported at least one spontaneous abortion prior to current pregnancy.

Infant and delivery information:
Preterm births were defined as delivery prior to 37 weeks estimated gestational age. The type of delivery was classified as either a vaginal delivery, planned Cesarean section (C-section), or unplanned/emergency C-section, based on self-report. Infant morbidity was defined as a mother affirming her child had been to any clinic/hospital for any illness after delivery but before follow-up at 14 weeks or her child had been admitted to the hospital after delivery. Infant mortality was based on maternal report of infant death.

Depression status:
The prevalence of depressive symptoms was assessed by dichotomizing self-reported participant Edinburgh Postnatal Depression Scale (EPDS) scores into: <10, categorized as "no depression" and ≥10, categorized as "depression". For the purposes of this study, we stratified women in this cohort into four patterns of depressive symptoms: 1) antenatal depression, 2) postpartum depression, 3) persistent perinatal depression and 4) any perinatal depression. Antenatal depression is an EPDS score ≥10 on the enrollment survey, and postpartum depression is an EPDS score ≥10 on the 14-week follow-up survey. Participants with an EPDS score ≥10 on both the enrollment and follow-up surveys were categorized as having persistent perinatal depression, similar to previous studies[3,22]. Therefore, women with postpartum depression can represent new-onset postpartum depression (incident depression) or continuation of depression from the antepartum period[22]. Any perinatal depression is defined as an EPDS score ≥10 on either the enrollment survey or 14-week follow-up survey, thus encompassing women with antenatal depression only, postpartum depression only, and persistent perinatal depression. Any perinatal depression is meant to account for the fact that depressive symptoms during the perinatal period are dynamic and have historically not been accounted for longitudinally but rather only in the antenatal or postpartum periods[3].

* "Come we stay" implies a man and a woman are in an intimate relationship and cohabitating, i.e. sharing a common living space, but are not in a formal marriage or union as sanctioned by law, cultural practice, or religion.[19]

SMS message data:
All SMS messages sent to and received from participants were recorded in the Mobile WACh messaging platform. The sender of the message was classified as the system, the participant, or the nurse. For the purposes of this analysis, only messages that originated from the participants were used to assess level of interaction with the two-way messaging system. Validation messages sent by participants in order to verify enrollment in the study were excluded from analysis. Character counts of messages were documented based on the original text messages sent. The initiation of at least one SMS message by participants was categorized into ever having sent an SMS (≥1 SMS sent by participant) and never having sent an SMS (0 messages sent by participant). Messages whose character count was ≥10 characters were classified as long SMS messages. Long SMS messages capture conversational messages rather than simple responses of "yes", "no", and "okay", all of which require less than 10 characters in English, Swahili, Luo, and Sheng.

Statistical Analyses:
Statistical analysis was performed using the program R studio version 1.2.5001 (Boston, 2019). All tests were considered statistically significant at an alpha level of 0.05.

Descriptive analyses for baseline sociodemographic and obstetric characteristics of women in this overall cohort (all included in enrollment) and of women who completed a second EPDS at follow-up (retained cohort) were conducted. Frequencies and proportions were calculated for binary variables while medians and interquartile ranges were calculated for continuous variables.

Correlates of depression were identified using univariable and multivariable generalized estimating equation (GEE) with Poisson link and clustering by facility site with exchangeable correlation structure and robust standard errors. Poisson regression was used to generate effect estimates that could be interpreted as relative risk despite common outcomes. GEE was used to account for similarities by site. Due to the dependence between measurements on the same individual at different times, exchangeable correlation structure was used with robust standard errors since heteroscedasticity was assumed. Multivariable models were run to control for potential confounders. All correlates served as confounders and were determined based on literature review. Thus the multivariable analysis adjusted for the following a priori confounders: adolescence, marital status, education level, employment status, HIV status, monthly income, number of living children, primigravid status, history of miscarriage, experience of intimate partner violence (IPV) during pregnancy, presence or absence of desired pregnancy, and presence or absence of previous family planning use. The main analysis focused on the correlates of any perinatal depression and secondary analyses were conducted on the other three patterns of depression. For the continuous variable of monthly income, results were interpreted as the relative risk of having a certain pattern of depression when comparing a mother with an additional 1000 KSh in monthly household income to a mother of a certain monthly household income. The relative risk for the variable "living children" was interpreted as the risk of having a certain pattern of depression comparing a mother with one additional living child to a mother with a certain number of living children in her household

Association of antenatal depression with infant outcomes of preterm birth, infant morbidity, and infant mortality was analyzed using GEE with Poisson link, clustered by site with exchangeable correlation structure and robust standard errors. Univariable and multivariable regressions were run. Confounders in multivariable analyses were chosen a priori from literature review and included adolescence, marital status, education level, employment status, IPV during

pregnancy, HIV status, monthly income, distance from clinic, type of delivery, location of delivery, complications during pregnancy, complications during delivery, and infant death.

The binary outcome of any SMS message sent, the sum of the number of total SMS messages, and the sum of the number of long SMS messages sent by two-way participants were compared between women with and without depression using univariable and multivariable generalized estimating equation (GEE) with Poisson link and clustering by facility with exchangeable correlation structure and robust standard errors. Analyses were conducted to identify correlates and messaging impacts of antenatal depression and persistent perinatal depression since these two patterns of depression were present at the start of the study, allowing for causality to be interpreted. To account for women's typical SMS messaging behaviors, the following confounders were defined a priori for multivariable analyses based on women's self-reported answers to questions regarding: 1) individual's response rate to system-generated SMS messages (all/almost all of the messages, some of the messages, very few/none of the messages), 2) the physical sharing of the study phone with someone else, 3) presence or absence of 24/7 phone access, 4) SMS as the primary mode of communication or not, 5) the quantitative number of SMS messages sent and received during a typical week prior to the study, and 6) presence or absence of difficulty receiving SMS messages from the system during the study.

Chi-squared tests were used to assess whether there were any differences in the proportion of women who self-reported consults with the project nurse and who found the consult helpful among women with and without depression. These tests compared women with antenatal and persistent perinatal depression, respectively, to women who never had any EPDS score ≥ 10. Fisher's exact tests were used when sample sizes were too small to get accurate results from Chi-squared tests.

Ethical Considerations:
This study was reviewed and approved by the Ethics Review Committee at the Kenyatta National Hospital and the Institutional Review Board at the University of Washington. Data analysis was performed using only de-identified data. The researchers have no financial conflicts to disclose.

RESULTS

Participant characteristics and prevalence of depression

From a total of 800 participants, 798 participants were included in this analysis. Two participants had missing enrollment information due to data entry error and were excluded. There were 143 women lost-to-follow up and 83 women without a follow-up EPDS score because their exit interview was performed by phone, and EPDS was excluded via phone follow-up. Thus, a total of 226 participants (28.3%) did not have outcomes for postpartum depression and were excluded from the analysis. Baseline characteristics were taken from the 798 participants with enrollment data and 572 retained participants who completed follow-up data (Table 1). As shown by Table 1, the median age of women in our retained cohort was 25 years and 10.2% of participants were adolescents. Approximately 11.3% of women were not married nor cohabitating and 8.2% had less than a primary level of education. Most women were multigravidas. Approximately 34.2% of women noted this current pregnancy occurred despite their desire to not have a/another baby. On average, a woman had one child living at home. Among the 572 participants with two completed EPDS surveys, 188 (32.9%) of participants reported depressive symptoms at some time, 163 (28.5%) reported antenatal symptoms, 52 (9.1%) reported postnatal symptoms, and 27 (4.7%) reported persistent symptoms (Table 2).

Table 1. Baseline Characteristics for Women in our Cohort

Variables	Total Cohort (n = 798) *n* (%) or median (IQR)	Retained Cohort (n = 572) *n* (%) or median (IQR)
Age in years	24 (21- 29)	25 (22-29)
Adolescents	97 (12.3%)	58 (10.2%)
Marital Status Not Married/Cohabitating	101 (12.9%)	64 (11.3%)
Education level Less than primary education	81 (10.2%)	47 (8.2%)
Employment Status Unemployed	563 (70.6%)	394 (68.9%)
Primigravida	294 (36.8%)	194 (33.9%)
Number of Living Children	1 (0-2)	1 (0-2)
History of Miscarriage	83 (10.4%)	65 (11.4%)
Undesired Pregnancy	281 (35.3%)	195 (34.2%)
Never Used Family Planning	263 (33.0%)	160 (28.0%)
Median monthly household income in KSh	10,000 (4625-14,000)	10,000 (6000-14,000)
Experiencing intimate partner violence during pregnancy	30 (3.8%)	19 (3.3%)
Living with HIV	52 (6.5%)	36 (6.3%)
Distance from home to clinic ≥30 min	541 (67.9%)	358 (62.7%)
Share the phone with someone	141 (17.7%)	81 (14.2%)

Table 2. Prevalence of perinatal depression

Depression Type	Total *n* of Cohort	*n* with Depression	Prevalence of Depression (95% CI)
Any Perinatal Depression	572	188	32.9% (29.0%, 36.7%)
Antenatal Depression†	572	163	28.5% (24.8%, 32.2%)
Postpartum Depression	572	52	9.1% (6.7%, 11.5%)
Persistent Perinatal Depression	572	27	4.7% (3.0%, 6.5%)

†In the enrollment group of 798 participants, 256 (32.1%) participants had antenatal depression (95% CI: 28.8%, 35.3%).

Correlates of any perinatal depression

Table 3 demonstrates correlates of any perinatal depression. The risk of any perinatal depression was higher in women with undesired pregnancies (RR = 1.30; 95% CI: 1.11, 1.52), and in those who experienced IPV (RR = 1.73; 95% CI: 1.57, 1.90). All associations remained significant in multivariable analyses.

Table 3. Correlates for Any Perinatal Depression

Correlates	Any Perinatal Depression n (%) or Median (IQR)		Relative Risk (95% CI)	p-value	Adjusted Relative Risk‡ (95% CI)	p-value
	Yes (n = 188)	No (n = 384)				
Adolescent	22 (12.0%)	36 (9.4%)	1.10 (0.86, 1.39)	0.45	1.01 (0.79, 1.28)	0.96
Not Married/Cohabitating	26 (14.3%)	38 (9.9%)	1.18 (0.88, 1.58)	0.26	1.00 (0.96, 1.05)	0.86
Less than primary education	15 (8.0%)	32 (8.3%)	1.02 (0.99, 1.05)	0.13	1.04 (0.94, 1.15)	0.43
Unemployed	127 (67.6%)	267 (69.5%)	1.07 (0.93, 1.23)	0.34	1.03 (0.95, 1.11)	0.50
Primigravida	63 (33.5%)	131 (34.1%)	1.09 (0.95, 1.24)	0.21	1.14 (1.04, 1.24)	0.005*
Living Children[ƒ]	1 (0-2)	1 (0-2)	1.01 (0.95, 1.06)	0.83	1.05 (0.99, 1.10)	0.08
History of Miscarriage	16 (8.5%)	49 (12.8%)	0.81 (0.61, 1.08)	0.15	0.81 (0.74, 0.88)	<0.0001*
Undesired pregnancy	83 (44.1%)	112 (29.3%)	1.30 (1.11, 1.52)	0.001*	1.23 (1.13, 1.35)	<0.0001*
Never Used Family Planning	58 (30.9%)	102 (26.6%)	1.00 (0.98, 1.02)	0.99	0.98 (0.79, 1.22)	0.87
Monthly Income (in KSh)[^]	8000 (2000-12,000)	10,000 (8000-14,000)	1.00 (0.99, 1.01)	0.98	1.00 (0.99, 1.01)	0.87
Intimate Partner Violence	10 (5.3%)	9 (2.3%)	1.73 (1.57, 1.90)	<0.0001*	1.76 (1.64, 1.90)	<0.0001*
Living with HIV	13 (7.0%)	23 (6.0%)	0.88 (0.43, 1.81)	0.73	0.86 (0.48, 1.54)	0.62

‡Adjusted for all other correlates listed in table.

ƒThis relative risk is given as the risk of having any perinatal depression comparing a mother with one additional living child to a mother with a certain number of living children in her household.
^This relative risk is given as the risk of having any perinatal depression comparing a mother with an additional 1000 KSh in monthly household income to a mother of a certain monthly household income.

Correlates of antenatal depression

The correlates for antenatal depression are presented in Table 4. An elevated risk of antenatal depression was observed in women with undesired pregnancies (RR =1.28; 95% CI 1.16, 1.41), women who experienced IPV (RR = 1.81; 95% CI: 1.59, 2.05), women with lower monthly incomes (RR = 0.99; 95% CI: 0.99, 0.99), and women who were unemployed (RR 1.19, 95% CI: 1.18,1.20). All associations remained significant in multivariable analyses.

Table 4. Correlates for Antenatal Depression

Correlates	**Antenatal Depression** n (%) or Median (IQR)		Relative Risk (95% CI)	p-value	Adjusted Relative Risk[¶] (95% CI)	p-value
	Yes (n = 163)	No (n = 409)				
Adolescent Age	21 (13.2%)	37 (9.1%)	1.19 (0.76, 1.88)	0.44	1.04 (0.71, 1.52)	0.85
Not Married/Cohabitating	24 (15.3%)	40 (9.8%)	1.24 (0.90, 1.71)	0.18	1.10 (1.00, 1.21)	0.04*
Less than primary education	13 (8.0%)	34 (8.3%)	1.04 (0.97, 1.10)	0.31	0.99 (0.94, 1.05)	0.74
Unemployed	113 (69.3%)	281 (68.7%)	1.19 (1.18, 1.20)	<0.001*	1.09 (1.08, 1.11)	<0.0001*
Primigravida	55 (33.7%)	139 (34.0%)	1.12 (0.94, 1.35)	0.21	1.21 (1.02, 1.42)	0.03*
Living Children	1 (0-2)	1 (0-2)	1.01 (0.95, 1.07)	0.79	1.08 (1.08, 1.08)	<0.0001*
History of Miscarriage	16 (9.8%)	49 (12.0%)	0.95 (0.84, 1.08)	0.41	0.94 (0.90, 0.99)	0.03*
Undesired pregnancy	73 (44.8%)	122 (30.0%)	1.28 (1.16, 1.41)	<0.0001*	1.17 (1.14, 1.20)	<0.0001*
Never Used Family Planning	53 (32.5%)	107 (26.2%)	1.04 (0.96, 1.13)	0.36	1.00 (0.90, 1.12)	0.97
Monthly Income (in KSh)	6000 (1500-10,500)	10,000 (8000-15,000)	0.99 (0.99, 0.99)	<0.0001*	0.99 (0.99, 0.99)	<0.0001*
Intimate Partner Violence	9 (5.5%)	10 (2.4%)	1.81 (1.59, 2.05)	<0.0001*	1.79 (1.65, 1.94)	<0.0001*
Living with HIV	12 (7.4%)	24 (5.9%)	0.90 (0.50, 1.61)	0.71	0.83 (0.53, 1.31)	0.43

[¶]Adjusted for all other correlates listed in table.

Correlates of postpartum depression

Table 5 describes associations with postpartum depression. A higher risk of postpartum depression was associated with women with less than a primary level of education (RR = 1.47; 95% CI: 1.35, 1.60) and women with one additional living child at home (RR = 1.22; 95% CI: 1.15, 1.29). The association remained significantly elevated for women with less than primary education in the multivariable analysis. A lower risk of postpartum depression was observed in women who were primigravida (RR = 0.78; 95% CI: 0.76, 0.80), and this association reversed in the multivariable analysis (aRR = 1.33; 95% CI: 1.29, 1.37).

Table 5. Correlates for Postpartum Depression

Correlates	**Postpartum Depression** n (%) or Median (IQR)		Relative Risk (95% CI)	p-value	Adjusted Relative[¶] Risk (95% CI)	p-value
	Yes (n = 52)	No (n = 520)				
Adolescent Age	4 (8.0%)	54 (10.4%)	0.74 (0.23, 2.39)	0.61	0.79 (0.32, 1.99)	0.62
Not Married/Cohabitating	6 (11.8%)	58 (11.3%)	0.99 (0.80, 1.22)	0.89	0.81 (0.51, 1.29)	0.38
Less than primary education	6 (11.5%)	41 (7.9%)	1.47 (1.35, 1.60)	<0.0001*	1.51 (1.29, 1.78)	<0.0001*
Unemployed	34 (65.4%)	360 (69.2%)	0.93 (0.49, 1.76)	0.83	0.97 (0.62, 1.52)	0.89
Primigravida	14 (26.9%)	180 (34.6%)	0.78 (0.76, 0.80)	<0.0001*	1.33 (1.29, 1.37)	<0.0001*
Living Children	1 (0-2)	1 (0-2)	1.22 (1.15, 1.29)	<0.0001*	1.18 (1.00, 1.40)	0.05
History of Miscarriage	7 (13.5%)	58 (11.2%)	1.25 (0.40, 3.88)	0.70	0.84 (0.32, 2.25)	0.74
Undesired pregnancy	21 (40.4%)	174 (33.6%)	1.18 (0.84, 1.67)	0.34	1.07 (0.68, 1.70)	0.77
Never Used Family Planning	13 (25.0%)	147 (28.3%)	0.79 (0.48, 1.30)	0.35	0.88 (0.46, 1.69)	0.70
Monthly Income (in KSh)	8000 (2000-16,000)	10,000 (6000-14,000)	1.01 (0.99, 1.02)	0.30	1.01 (1.00, 1.02)	0.05*
Intimate Partner Violence	2 (3.8%)	17 (3.3%)	1.24 (0.94, 1.64)	0.12	1.53 (1.13, 2.07)	0.006*
Living with HIV	5 (9.8%)	31 (6.0%)	1.39 (0.59, 3.27)	0.45	1.45 (0.85, 2.47)	0.17

[¶]Adjusted for all other correlates listed in table.

Correlates of persistent perinatal depression

The correlates of persistent perinatal depression are given in Table 6. There was a higher risk of persistent perinatal depression associated with women with less than a primary education (RR = 1.89; 95% CI: 1.74, 2.06), women who were unemployed (RR = 1.58; 95% CI: 1.32, 1.89), women with an additional living child (RR = 1.32; 95% CI 1.24, 1.41), women with a history of miscarriage (RR = 2.59; 95% CI: 2.04, 3.28), women with a lower monthly income (RR = 0.96; 95% CI: 0.95, 0.96), and women living with HIV (RR = 1.75; 95% CI: 1.50, 2.03). All of these associations remained significant in multivariable analyses except the risk associated with women with less than a primary education. A lower risk of persistent perinatal depression was observed in women who were primigravida (RR = 0.76; 95% CI: 0.74, 0.78), and this association reversed in the multivariable analysis (aRR = 1.76; 95% CI: 1.29, 2.40).

Table 6. Correlates for Persistent Perinatal Depression

Correlates	Persistent Perinatal Depression n (%) or Median (IQR)		Relative Risk (95% CI)	p-value	Adjusted Relative Risk[#] (95% CI)	p-value
	Yes (N = 27)	No (n = 545)				
Adolescent Age	3 (12.0%)	55 (10.2%)	1.02 (0.75, 1.40)	0.88	0.95 (0.86, 1.05)	0.30
Not Married/Cohabitating	4 (15.4%)	60 (11.1%)	1.16 (0.85, 1.59)	0.35	1.34 (1.05, 1.71)	0.02*
Less than primary education	4 (14.8%)	43 (7.9%)	1.89 (1.74, 2.06)	<0.0001*	1.39 (0.91, 2.10)	0.12
Unemployed	20 (74.1%)	374 (68.6%)	1.58 (1.32, 1.89)	<0.0001*	1.36 (1.06, 1.75)	0.02*
Primigravida	6 (22.2%)	188 (34.5%)	0.76 (0.74, 0.78)	<0.0001*	1.76 (1.29, 2.40)	0.0004*
Living Children	2 (0.5-3)	1 (0-2)	1.32 (1.24, 1.41)	<0.0001*	1.39 (1.25, 1.54)	<0.0001*
History of Miscarriage	7 (25.9%)	58 (10.6%)	2.59 (2.04, 3.28)	<0.0001*	1.46 (1.00, 2.13)	0.05*
Undesired pregnancy	11 (40.7%)	184 (33.9%)	1.00 (0.95, 1.04)	0.87	0.75 (0.66, 0.86)	<0.0001*
Never Used Family Planning	8 (29.6%)	152 (27.9%)	0.84 (0.63, 1.13)	0.25	0.95 (0.76, 1.19)	0.67
Monthly Income (in KSh)	2000 (1500-6600)	10,000 (6500-14,000)	0.96 (0.95, 0.97)	<0.0001*	0.97 (0.96, 0.98)	<0.0001*
Intimate Partner Violence	1 (3.7%)	18 (3.3%)	1.35 (0.86, 2.14)	0.20	1.51 (0.99, 2.30)	0.05
Living with HIV	4 (15.4%)	32 (5.9%)	1.75 (1.50, 2.03)	<0.0001*	1.43 (1.34, 1.52)	<0.0001*

[#]Adjusted for all other correlates listed in table.

Antenatal Depression and Infant Outcomes

A total of 271 infants were hospitalized or seen in the clinic after birth for a morbidity rate of 474 per 1000 births. One hundred forty-two infants were preterm (25.0%) and 18 (3.2%) infant deaths occurred (Table 7). In the univariate analysis, antenatal depression was associated with an increased relative risk of infant morbidity (RR = 1.12, 95% CI: 1.11, 1.13). After adjusting for confounders defined a priori, the association between antenatal depression and infant morbidity was no longer significant (aRR = 1.03, 95% CI: 1.00, 1.06). There was no significant association between antenatal depression and preterm birth in either the univariate or multivariate analyses. The association between antenatal depression and infant mortality could not be adequately determined since the model could not converge due to small sample size.

Table 7. Risk of Infant Outcomes Amongst Antenatally Depressed Mothers

Outcome (n)	Proportion with Outcome (n; %)	Relative Risk (95% CI)	p-value	Adjusted Relative Risk (95% CI)[§]	p-value
Infant Morbidity					
Antenatal depression (n = 163)	84 (51.5%)	1.12 (1.11, 1.13)	<0.0001*	1.03 (1.00, 1.06)	0.06
No antenatal depression (n = 409)	187 (45.7%)				
Preterm Birth					
Antenatal depression (n = 162)	41 (25.3%)	1.22 (0.75, 1.99)	0.42	1.32 (0.90, 1.94)	0.15
No antenatal depression (n = 406)	101 (24.9%)				
Infant Mortality					
Antenatal depression (n = 163)	5 (3.1%)	0.77 (0.65, 0.91)	0.002*	----------	------
No antenatal depression (n = 409)	13 (3.2%)				

[§]Adjusted for adolescence, marital status, education level, employment status, IPV during pregnancy, HIV status, monthly income, primigravida status, distance from clinic, type of delivery, location of delivery, complications during pregnancy, complications during delivery, and infant death.

Generation of SMS messages by participants to the study messaging system

Participant initiation of SMS messages

Using SMS data from the two-way messaging system, all 572 participants in the retained cohort validated and received messages from the two-way messaging system used in the study. Over 90% of women in all subgroups ever sent an SMS message (Table 8). The likelihood of ever sending an SMS message to the messaging system was significantly lower for mothers with antenatal depression as compared to mothers who did not have antenatal depression (RR = 0.99, 95% CI: 0.98, 1.00) and remained significant in the multivariable analysis (aRR = 0.97; 95% CI: 0.97, 0.98). There was no significant association between persistent perinatal depression and likelihood of ever sending an SMS.

Table 8. Likelihood of engaging with SMS system by ever sending an SMS message versus never sending an SMS message comparing depressed vs. non-depressed mothers

Depression Type (n)	Proportion who ever sent an SMS (n (%)	Relative Risk (95% CI)	p-value	Adjusted Relative Risk[ǂ] (95% CI)	p-value
Antenatal Depression					
Yes (n = 163)	150 (92.0%)	0.99 (0.98, 1.00)	0.05*	0.97 (0.97, 0.98)	<0.0001*
No (n = 409)	384 (93.9%)				
Persistent Perinatal Depression					
Yes (n = 27)	25 (92.6%)	1.00 (0.93, 1.07)	0.91	0.96 (0.91, 1.00)	0.08
No (n =545)	509 (93.4%)				

[ǂ]Adjusted for self-reported SMS behaviors listed in Methods.

Counts of participant initiated SMS messages

The median number of SMS messages sent by participants over the entire study period and the median number of long SMS messages sent by participants during the study were analyzed to assess the potential impact of depressive symptoms on interactions with the messaging system. Mothers with antenatal depression sent significantly fewer total SMS messages (RR = 0.77; 95% CI: 0.72, 0.82) and fewer long SMS messages (RR: 0.81; 95% CI: 0.79, 0.84) as compared to their counterparts without depression (Tables 9 & 10). These significant associations were maintained in the multivariable analyses. No significant association was seen between persistent perinatal depression and median total SMS messages (Table 9). Women with persistent perinatal depression sent fewer long SMS messages (RR = 0.78; 95% CI: 0.62, 0.97), and this multivariate analysis remained significant.

Table 9. Ratio of mean participant SMS counts of depressed vs. non-depressed mothers

Depression Type (n)	Total SMS Count Median (IQR)	Relative Risk (95% CI)	p-value	Adjusted Relative Risk[ǂǂ] (95% CI)	p-value
Antenatal Depression					
Yes (n = 163)	14 (5-38)	0.77 (0.72, 0.82)	<0.0001*	0.91 (0.87, 0.96)	<0.0001*
No (n = 409)	25 (8-44)				
Persistent Perinatal Depression					
Yes (n = 27)	15 (8-35)	0.74 (0.54, 1.01)	0.05	0.81 (0.70, 0.94)	0.005*
No (n =545)	22 (7-44)				

[ǂǂ]Adjusted for self-reported SMS behaviors listed in Methods.

Table 10. Ratio of mean participant SMS messages sent with greater than or equal to 10 characters in length of depressed vs. non-depressed mothers

Depression Type (n)	Long SMS Count Median (IQR)	Relative Risk (95% CI)	p-value	Adjusted Relative Risk[##] (95% CI)	p-value
Antenatal Depression					
Yes (n = 163)	12 (3-28)	0.81 (0.79, 0.84)	<0.0001*	0.92 (0.89, 0.96)	<0.0001*
No (n = 409)	19 (6-34)				
Persistent Perinatal Depression					
Yes (n = 27)	13 (7-31)	0.78 (0.62, 0.97)	0.03*	0.86 (0.76, 0.98)	0.02*
No (n =545)	17 (5-33)				

[##]Adjusted for self-reported SMS behaviors listed in Methods.

Participants Utilization of Nurse Consults

Participants who consulted the nurse at any time

Among the 572 women with complete depression data, 423 (74.0%) women reported that they ever consulted the study nurse. There were no significant differences between women with antenatal depression and those with persistent perinatal depression as compared to their non-depressed counterparts who consulted the project nurse at any time (Table 11).

There were significantly fewer mothers with antenatal depression who consulted the study nurse regarding infant health concerns as compared to women without depression (76.3% vs. 86.8%, p = 0.01) (Table 12). Otherwise there was no difference in the reasons why women with antenatal depression and those with persistent perinatal depression, respectively, consulted the nurse as compared to women without perinatal depression. All participants responded that the consult was helpful (Table 13).

Table 11. Proportion of depressed mothers vs. non-depressed mothers who consulted the project nurse at any time

Depression Type (n)	Proportion Who Did Consult Nurse (n;%)	p-value
Never Any Perinatal Depression (n = 384)	287 (74.7%)	Reference
Antenatal Depression (n = 163)	118 (72.4%)	0.60
Persistent Perinatal Depression (n = 27)	16 (59.3%)	0.10

Table 12. Proportion of depressed mothers vs. non-depressed mothers who consulted the project nurse for a specific reason

Reason for Consult	Depression Type (n)	Proportion of Consults for this Reason n(%)	p-value
Pregnancy Questions/Concern	Never Any Perinatal Depression (n=287)	249 (86.8%)	Reference
	Antenatal Depression (n=118)	109 (92.4%)	0.20
	Persistent Perinatal Depression (n=16)	12 (75.0%)	0.30
Postpartum Questions/Challenges	Never Any Perinatal Depression (n=287)	140 (48.8%)	Reference
	Antenatal Depression (n=118)	63 (53.4%)	0.50
	Persistent Perinatal Depression (n=16)	8 (50.0%)	1.00
Family Planning	Never Any Perinatal Depression (n=287)	167 (58.2%)	Reference
	Antenatal Depression (n=118)	57 (48.3%)	0.09
	Persistent Perinatal Depression (n=16)	7 (43.8%)	0.40
Infant Health Questions/Concerns	Never Any Perinatal Depression (n=287)	249 (86.8%)	Reference
	Antenatal Depression (n=118)	90 (76.3%)	0.01*
	Persistent Perinatal Depression (n=16)	13 (81.2%)	0.50

Table 13. Amongst the mothers who made a nurse consult, the proportion of depressed vs. never depressed mothers who found the nurse consult helpful

Depression Type (n)	Proportion Who Found Nurse Consult Helpful (n; %)
Never Any Perinatal Depression (n=287)	287 (100%)
Antenatal Depression (n=118)	118 (100%)
Persistent Perinatal Depression (n=16)	16 (100%)

Participants with ill infants who consulted the nurse about infant's illness

Two hundred seventy-one women reported on the follow-up survey that their infants had had an illness that necessitated a clinic/hospital visit or hospital admission at the time of birth. Of the 271 mothers with ill infants, 253 (93.4%) mothers reported whether or not they contacted the study nurse about their infant's illness. Mothers with antenatal depression were less likely to consult the study nurse about their ill infant than mothers without depression (19.0% vs. 32.3%, p = 0.04) (Table 14). All participants who made consults regarding their infant's illness reported the consult was helpful (Table 15). Thus, the Chi-squared test could not detect a difference.

Table 14. Amongst mothers whose infants were ill, the proportion of depressed mothers vs. non-depressed mothers who consulted the project nurse about their infant's illness

Depression Type (n)	Proportion who Consulted nurse for ill infant (n;%)	p-value
Never Any Perinatal Depression (n=167)	54 (32.3%)	Reference
Antenatal Depression (n=79)	15 (19.0%)	0.04*
Persistent Perinatal Depression (n=8)	2 (25.0%)	1.00

Table 15. Amongst the mothers who consulted the project nurse about their infant's illness, the proportion of depressed vs. never depressed mothers who found the nurse consult for their infant helpful

Depression Type (n)	Proportion Who Found Nurse Consult Helpful (n; %)
Never Any Perinatal Depression (n=54)	54 (100%)
Antenatal Depression (n=15)	15 (100%)
Persistent Perinatal Depression (n=2)	2 (100%)

DISCUSSION

This prospective study of pregnant women in Kenya demonstrated a relatively high prevalence of any perinatal depression and of antenatal depression with evidence that antenatal depression elevated the risk of infant morbidity. This is one of few studies to evaluate depressive symptoms longitudinally in both the antepartum and postpartum periods. In this cohort, 188 of 572 women had any perinatal depression (32.9%), which is mainly due to the large proportion of women who had antenatal depression (28.5%). Conversely, only 52 (9.1%) women had postpartum depression, which is much lower than anticipated. One study of pregnant Sudanese women established a similar postpartum depression prevalence of 9.2% at 12 weeks postpartum[20], but most African studies have reported a higher prevalence of postpartum depression[21]. Of the 52 women with postpartum depression, 27 of them had antenatal depressive symptoms (51.9%) and thus were classified as having persistent perinatal depression. Consequently, 25 of the 52 women with postpartum depression (48.1%) reported a new onset (incidence) of depression. This is consistent with Gelaye et al.'s finding that a little more than half of women who have postpartum depression subsequently were found to have depressive symptoms present in the antenatal period. Other studies have similarly demonstrated that antenatal depression is a significant risk factor for the development of depression in the postpartum period[2,22]. Taken together, all of these results highlight the importance of screening for depression in the perinatal period and demonstrate the need to include the antepartum period in perinatal depression research.

It is evident that rates of perinatal depression are affected by psychosocial stressors and the broader social context of a mother's life. Experiencing (being a victim of) IPV was the strongest risk factor for perinatal depression. For univariate analyses, experiencing IPV was significantly associated with antenatal and any depression in the univariate analyses and was significantly associated with all depression subtypes except for persistent perinatal depression in the multivariate analysis, where the risk of developing depression was increased but not quite significant. Other studies corroborate our findings and have demonstrated strong associations between IPV and increased risk of incident and persistent perinatal depression[2,4,22]. Additionally, women with less than a primary education had a significant increased risk of postpartum and persistent perinatal depression. Other studies have similarly shown a positive association between less years of formal schooling and perinatal depression[4,23,24]. Participants living with HIV had an associated increased risk for persistent perinatal depression. The association between HIV and perinatal depressive symptoms has been well-documented in both the antenatal and postnatal periods[25,26]. Living with HIV has been independently associated with depressive symptoms in non-peripartum periods and has not been shown to differ in severity when a woman is pregnant, postpartum, or not in a pregnancy-related period[25]. There should remain a high suspicion for depressive symptoms in women living with HIV throughout the

duration of pregnancy. Finally, maternal unemployment was a significant risk factor for antenatal depression, with an even stronger association between maternal unemployment and persistent perinatal depression. Previous literature in high-income countries have provided evidence that maternal unemployment is a risk factor for perinatal depression while a recent study in South Africa found a borderline risk of antenatal depression associated with maternal unemployment[21,27]. Surprisingly, adolescent age was never significantly associated with an increased risk of developing perinatal depression, and being unmarried/not cohabitating with a partner was only significantly associated with an increased adjusted relative risk of developing antenatal and persistent perinatal depression, respectively. The lack of association between any pattern of depression and adolescence may in part be due to the fact that this study's enrollment drew from women already seeking antenatal care who were at least 14 years old (omitting adolescents ages 10-13) and did not specifically recruit adolescents. Accessing prenatal care is often challenging for adolescent women for a variety of systemic reasons, including social stigma and fear of disdainful attitudes of health care providers[28]. Thus, previous literature studies examining the relationship between younger age and perinatal depression often actively seek to enroll and/or only enroll adolescents in order to better understand how age plays a role in the development of perinatal depression, which was not done in our study[29,30]. Overall, our results support other previous studies with regards to sociodemographic factors associated with perinatal depression.

Obstetric characteristics revealed varied associations with perinatal depression. Consistently, women with more living children had an increased risk of developing perinatal depression. In contrast, Ongeri et al. found that women with postpartum depression were significantly less likely to have three or more children amongst a cohort of women from Nairobi. However, this finding that women who already have children are at significantly increased risk of perinatal depression coincides with our finding that being a primigravida was associated with a significantly decreased risk of postpartum and persistent perinatal depression. These findings may indicate that the increasing demands of motherhood and childcare predispose women to develop perinatal depression while enthusiasm surrounding a first pregnancy may act as a protective factor against depression. However, being primigravid was associated with an increased risk of all four patterns of depression in the multivariable analyses.

There were positive and negative associations of undesired pregnancy and history of miscarriage with perinatal depression. Having an undesired pregnancy significantly increased the risk of any perinatal depression and antenatal depression. After adjusting for a priori confounders, we found having an undesired pregnancy significantly decreased the risk of persistent perinatal depression. Conversely, a history of miscarriage was significantly associated with a significantly increased risk of persistent perinatal depression but a decreased risk of any perinatal depression and antenatal depression on multivariate analyses. There have been a plethora of studies suggesting that undesired pregnancies are associated with an increased risk of perinatal depression[23], which is consistent with most of our findings. There were a couple of studies that suggest undesired pregnancy is highly associated with depressive symptoms in the first trimester with waning significance over time[23,31]. While antenatal depression was captured in the third trimester in our study, our findings may characterize the evolving psychological state of women with undesired pregnancies who initially did not desire to have any or more children. As women with undesired pregnancies come to terms with the reality of their situations, they may develop beneficial coping skills, which may protect them from having persistent depressive symptoms into the postpartum period despite any presence or absence of initial depressive symptoms in the antenatal period. Similarly, having to deal with a previous pregnancy loss may fortify a woman's capacity to handle the stress of, and even provide hope/enthusiasm for, a current pregnancy in the antenatal period. However, in the long-

term, the memory of a pregnancy loss in the face of a new maintained pregnancy with subsequent live birth may predispose women to having a higher risk persistent perinatal depression if antenatal depression was present.

The impact of antenatal depression on infant outcomes is quite heterogenous in our cohort. Our findings demonstrate the risk of having an ill infant necessitating a clinic or hospital visit was higher amongst women with antenatal depression than those without depression. Previous literature has focused on the positive association between postpartum depression and diarrheal/ other infectious illnesses in infants[4,10,32]. One study conducted in Pakistan did find an increased risk of ≥5 diarrheal episodes per year for infants exposed to antenatal depression but no increased risk of acute respiratory infections amongst infants whose mothers had antenatal depression[33]. Taken together, these findings suggest antenatal depression in a mother may be a risk factor for infant illness. Additionally, there is ample research that has documented the association between antenatal depression and increased likelihood of preterm birth[4,5,32]. Surkan et al. even go insofar as to suggest how physiologic changes associated with depression, including increases in cortisol and dysregulation of the immune system, can lead to preterm birth. However, our study did not replicate these findings as we did not find any significant associations between antenatal depression and preterm birth. Interestingly, antenatal depression was associated with a significant reduction in the risk of a woman's infant dying in the immediate postpartum period in this study. Yet, very small numbers were observed of infant mortality in this cohort, and infant mortality was defined only up to 14 weeks of age, as compared to most research which extends mortality in children up to one year of age[35]. Due to this small sample size, an adequate multivariate analysis for an association between antenatal depression and infant mortality could not be conducted. Previous studies in rural Ghana and Ethiopia did not find any association with antenatal depression and infant mortality[5]. Further work investigating the relationship between depressive symptoms preceding delivery and infant outcomes is necessary to further understand how infants and their health trajectories are impacted by mothers with antenatal depression.

As a group, mothers with antenatal depression and those with persistent perinatal depression sent significantly less total and less long SMS messages, respectively, compared to their counterparts without depression. This suggests that women with antenatal and persistent perinatal depression are less likely to consistently send messages to the two-way messaging system throughout the whole pregnancy and postpartum period as compared to women without depression. Thus, a lower responsiveness to messages or a lower frequency of initiating messages may indicate a woman is struggling with depressive symptoms. Moving forward, tracking messaging behaviors could allow for the development of a mechanism to trigger the system into screening for depressive symptoms and/or for more personalized messages to be delivered to women to explore how best to support them individually.

Approximately three-quarters of women without any depression consulted the nurse with a question or concern. Women with antenatal and persistent perinatal depression consulted the nurse at similar rates although women with persistent perinatal depression trended towards having a lower proportion of women who ever consulted the nurse. All women who ever initiated a consult for any reason with the nurse and those who sought advice about their infant's health found these consults helpful, suggesting women who utilized the messaging system were satisfied with the advice and support provided to them by this platform. There was little difference in the topics for which women consulted the study nurse, except that women with antenatal depression were less likely to consult the nurse about infant health questions. A similar trend was found amongst mothers whose infants were seen at a clinic/hospital for an illness or whose infants were admitted after delivery. In this group of women with ill infants,

mothers with antenatal depression were significantly less likely to consult the nurse about their infant's health. This raises further questions about the ways in which antenatal depression in mothers affects prenatal care engagement and overall treatment-seeking behavior. Given antenatal depression was a significant risk factor for infant morbidity in this study, the question remains whether attachment difficulties or other behavioral actions associated with antenatal depression in mothers leads to an elevated risk of her infant becoming ill or if physiologic changes due to antenatal depression subsequently predispose infants to developing less robust immune systems, leading to higher rates of illness[5,35]. However, this finding may simply represent a disinclination of women with antenatal depression to incorporate new modes of maternal-nurse communication into their lives since our infant morbidity measure was based off of maternal reports that mothers ultimately sought medical care for their ill infants. Additionally, these findings are based off of women's recollections of their interactions with the study nurse. It has been proposed that depression affects information processing, memory, and attention, but this theory has not been as well substantiated for perinatal depression[34]. But it should not be overlooked that our results may reflect an attentional difference or short-term memory impairment for women with antenatal depression with regards to how they recall their actions during pregnancy. Further investigation into health-seeking behaviors of women with perinatal depression, especially antenatal depression, is warranted, and there should be a continued effort to explore how mHealth interventions can benefit prenatal and postnatal engagement of women regardless of their depression status.

Limitations

One study limitation is selection bias. There were 1039 eligible women and 800 women enrolled in the study. Those who were eligible but did not enroll mainly noted they did not feel they had sufficient time to participate in the study or were otherwise busy. Of the 800 enrolled women, 2 women were excluded due to missing enrollment data. Of the 798 women in this cohort, 143 women (18%) did not complete the study through the 14-week follow up. Additionally, there was incomplete data for some of the women who did follow-up at 14-weeks postpartum, including 83 women (10%) who had partial completion of the follow-up and did not complete an EPDS survey at 14-weeks postpartum, meaning there was no EPDS screening for postpartum depression for 226 women (28%). It is important to note that 64 of the 143 women lost to follow-up had antenatal depression and another 29 (out of 83) women who had some follow-up data but did not complete a second EPDS also had antenatal depression. Thus, 93 (41.2%) of the 226 women who do not have follow-up information had antenatal depression as compared to the 163 (28.5%) of women in the retained cohort who had antenatal depression. Given that over one-quarter of the women in this study did not have complete information for postpartum depression scores and the rates of antenatal depression were vastly different between those who followed up and those who did not, our findings are largely limited by selection bias due to the culled population from which we drew conclusions.

In the absence of available mechanisms for clinical diagnosis, we used the Edinburgh Postnatal Depression Scale (EPDS) to screen for depressive symptoms. Only two EPDS scores were collected for each participant, at baseline and at the end of the study at 14 weeks. Follow up time after delivery was limited to one timepoint of data collection, measuring only immediate maternal and infant outcomes. Thus, our assertion of depression in women relies on a screening tool, which is suggestive of an underlying pathology of depression but not a definitive diagnosis. However, literature suggests that the presence of depressive symptoms negatively influence maternal and child health outcomes in a manner similar to clinical depression[4].

The majority of this analysis relies on self-reported answers to questions. Self-reported data is subject to bias (i.e. reporting bias and social desirability bias), which may result in exaggerated

and/or understated answers. Depression itself may contribute to memory bias. Subsequently, SMS message data and self-reported data are not comparable but should reflect similar trends.

Conclusion

This study sought to characterize perinatal depression by determining its risk factors and impact in a longitudinal cohort of Kenyan women who participated in a two-way mobile communication system with a trained nurse. Our results are consistent with previous research, that intimate partner violence, lower educational achievement, and undesired pregnancy are associated with a higher risk of perinatal depression. We did not find strong support for previously described positive associations between perinatal depression and women living HIV, adolescents, and non-married/non-cohabitating women. Women with antenatal depression were more likely to have ill infants but no association was seen between antenatal depression and preterm birth. There was limited evidence to draw conclusions about the association between antenatal depression and infant mortality. Overall, women with antenatal depression and persistent perinatal depression sent less total SMS messages and less long SMS messages. All participants felt advice from the study nurse was helpful. Future studies should incorporate screening, diagnosis, and treatment of perinatal depression at multiple time points into standard care and investigate how depression impacts neonatal health in the immediate postnatal period. To advance perinatal depression work conducted here and in previous studies, we recommend that more longitudinal perinatal depression studies explore how to support and engage with expectant mothers through various modalities, including but not limited to mHealth interventions.

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