



Mapping a Syndemic of Psychosocial Risks During Pregnancy Using Network Analysis

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Abstract

Background Psychosocial risks during pregnancy impact maternal health in resource-limited settings, and HIV-positive women often bear a heavy burden of these factors. This study sought to use network modeling to characterize co-occurring psychosocial risks to maternal and child health among at-risk pregnant women.

Methods Two hundred pregnant HIV-positive women attending antenatal care in South Africa were enrolled. Measured risk factors included younger age, low income, low education, unemployment, unintended pregnancy, distress about pregnancy, antenatal depression, internalized HIV stigma, violence exposure, and lack of social support. Network analysis between risk factors was conducted in R using mixed graphical modeling. Centrality statistics were examined for each risk node in the network.

Results In the resulting network, unintended pregnancy was strongly tied to distress about pregnancy. Distress about pregnancy was most central in the network and was connected to antenatal depression and HIV stigma. Unintended pregnancy was also associated with lack of social support, which was itself linked to antenatal depression, HIV stigma, and low income. Finally, antenatal depression was connected to violence exposure.

Conclusions Our results characterize a network of psychosocial risks among pregnant HIV-positive women. Distress about pregnancy emerged as central to this network, suggesting that unintended pregnancy is particularly distressing in this population and may contribute to further risks to maternal health, such as depression. Prevention of unintended pregnancies and interventions for coping with unplanned pregnancies may be particularly useful where multiple risks intersect. Efforts addressing single risk factors should consider an integrated, multilevel approach to support women during pregnancy.

Trial Registration [ClinicalTrials.gov](https://clinicaltrials.gov) identifier: NCT03069417

Keywords South Africa · Network analysis · Syndemic · Pregnancy · Perinatal mental health · Depression

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Introduction

Across the world, pregnancy is a critical period for maternal and child health (MCH). Extensive literature has found that MCH outcomes are negatively impacted by a variety of risk factors experienced by mothers during pregnancy, including poverty [1, 2], lack of social support [3], exposure to partner violence [4], and depression [5–7], as well as young age [8]. Prior evidence also suggests that these psychosocial risks do not occur independently; for example, poverty has been associated with younger age at childbearing [9], while exposure to partner violence and lack of social support have each been linked to perinatal depression [10, 11]. In order to guide effective MCH interventions, there is a need to understand how multiple risks interrelate in vulnerable populations of pregnant women.

According to syndemic theory [12], when risk factors cluster together, the combination of these risk factors interacts to produce worse outcomes than any risk factor alone. The notion of syndemics was first applied to intersecting risks among individuals living with HIV, particularly MSM or men who have sex with men [13], but recently has been extended theoretically to the co-occurrence of multiple risk factors in pregnant women in low-resourced global settings [14, 15]. Limited empirical studies that explicitly describe psychosocial “syndemics” during pregnancy have tended to consider only two risk factors at once, such as HIV and unintended pregnancy [16] or HIV and food insecurity [17]. Pregnant women living with HIV—many of whom reside in sub-Saharan Africa [18]—often bear a heavy burden of multiple intersecting psychosocial disadvantages [19, 20] and may represent a particularly vulnerable population facing unique and additional risks, including HIV-related stigma [21]. These multiple intersecting risks are relevant not only for maternal well-being but also prevention of mother-to-child HIV transmission (PMTCT) [22].

To date, many syndemic studies have used relatively basic methods for characterizing the presence of multiple risks [23], often summing them together to produce an index of cumulative risk. While useful, such methods tend to consider all risk factors equally and/or additively influential [24], without capturing the complexity of interdependence among these factors, including how they mutually influence each other to varying degrees [25]. Given that one major recommendation has been to explicitly model interactions between risk factors [26], strategies are needed to conceptualize the complex interplay of psychosocial risk factors, as consistent with syndemic theory and in order to guide the appropriate modeling of potential interactions. One promising methodology is network analysis. Network analysis is an approach that mathematically estimates simultaneous relationships between all variables—or nodes—within a network [27]. Network analysis has been used to characterize interpersonal networks [28] and is

increasingly employed in psychological research to investigate symptom-based connections within and across mental disorders [29]. However, to our knowledge, it has not been applied to complex relationships between ecological risk factors. A better understanding of such relationships would allow for potential identification of key factors that are highly influential and could be targeted for maximum impact in social/public health interventions. Such interventions are critical in low- and middle-income country (LMIC) settings where resources are limited.

This study sought to use network modeling to characterize the co-occurrence of psychosocial risks during pregnancy among HIV-positive women living in KwaZulu-Natal (KZN), South Africa, which has the world’s highest rates of HIV among pregnant women [30].

Methods

Participants and Procedures

The study was conducted in a large urban township in eThekweni District, KZN, South Africa. All participants were pregnant women enrolled in PMTCT care at an antenatal clinic of a large local district hospital. During recruitment between May 10, 2013 and June 2, 2014, all potential participants were screened for eligibility by a female research assistant fluent in both isiZulu and English, in a way that did not interfere with their medical care. Eligibility criteria for the study included (1) age between 18 and 45, (2) third trimester of pregnancy (28 weeks or more), (3) current antenatal care at the study site, (4) self-reported HIV-positive status, (5) fluency in isiZulu or English, and (6) access to a phone and willingness to be contacted by phone. Written informed consent was obtained from all women who were eligible and willing to participate. Recruitment continued until the target sample size of 200 for the parent study was met [31].

Participants were surveyed by an interviewer using a structured questionnaire, regarding their demographic information, depression, stigma, social support, violence exposure, and other factors related to their PMTCT care. Surveys were conducted in isiZulu or English according to participant preference in a private room at the study site, and all women were compensated with 70 ZAR (approximately 10 USD at the time) for participating. All study procedures performed in this study involving human participants were approved by the Ethics Committee at University of Witwatersrand (Johannesburg, South Africa) and Partners (Massachusetts General Hospital) Human Research Committee (Boston, USA) and were in accordance with the ethical standards of the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Measures

We included specific risk factors based on available data; while these risk factors do not comprehensively represent all possible risk factors that women may face during pregnancy (e.g., food insecurity), the included variables were selected based on existing literature, our prior qualitative work in this setting, and for their putative contributions to pregnancy-related risk in this setting [5, 32–36]. We did not measure substance use, which has often been implicated in previous syndemic literature in women’s perinatal health [14], though our prior work in KZN suggests that women in this setting do not show high levels of drinking during pregnancy, as in other areas of South Africa such as Cape Town [37]. Where multiple variables were conceptually interrelated, we included them rather than selecting a single variable for inclusions, as network analyses can account for these relationships while detecting their respective associations.

Low Income A multicategory variable measuring household monthly income was coded into a dichotomous variable in which monthly incomes below 500 Rand (approximately 40 US dollars) were classified as low-income status. Income included money received for work, government grants, other income, and gifts.

Younger Age at Childbearing In order to include age as a potential risk factor in the network, rather than simply including continuous years of age as a covariate, self-reported age was coded dichotomously so that participants below 21 years of age were classified as being of younger age at childbearing. Using a cutoff of 21 years allowed us to classify a reasonable number of participants within this range (12%), while also relying on a cutoff that has previously been used to establish age of majority in South Africa [38].

Lower Educational Attainment To index relatively lower education, self-reported years of education were coded dichotomously so that participants who did not endorse at least 12 years of schooling (i.e., completed secondary education) were classified as having lower educational attainment. Again, this cutoff allowed us to include a sizeable proportion of participants (7%) while relying on a rational cutoff.

Unemployment Participants self-reported employment status, with those lacking current employment classified as unemployed.

Unintended Pregnancy Unintended pregnancy was measured using one question from the 2009 CDC Pregnancy Risk Assessment Monitoring System (PRAMS) [39], which asked, “Thinking back to just before you got pregnant, how did you feel about becoming pregnant?” Responses were re-coded

into a dichotomous variable to reflect (1) no intention for current pregnancy (“did not want to be pregnant now or at any time in the future” or “wanted to be pregnant later”) or (0) otherwise (“wanted to be pregnant now,” “wanted to be pregnant sooner,” “did not care either way,” or “do not know”).

Distress About Pregnancy Distress about pregnancy was assessed using one question from PRAMS [39], which asked, “How did you feel when you found out you were pregnant?” Responses were re-coded into a dichotomous variable to reflect (1) definite distress (“very unhappy to be pregnant” or “unhappy to be pregnant”) or (0) otherwise (“not sure/didn’t mind,” “happy to be pregnant,” “very happy to be pregnant,” or “do not know”).

Antenatal Depression Depression during pregnancy was assessed using a 16-item depression subscale derived from the 25-item Hopkins Symptom Checklist (HCSL) [40], validated for use with HIV-positive populations in various cross-cultural settings, including South Africa [41]. This subscale was previously adapted [42] to include an additional item on how much the participant cares about his/her health. Items are scored on a severity scale ranging from 1 (“not at all”) to 4 (“extremely”) and averaged to create a total score between 1 and 4, with higher scores indicating greater depressive symptoms. Internal consistency was high ($\alpha = 0.86$). For descriptive purposes, a cutoff of > 1.75 was applied to the total scores to establish clinically significant depressive symptoms [43].

Internalized HIV Stigma The six-item Internalized AIDS-Related Stigma Scale [44] was utilized to measure individuals’ perceived HIV stigma. Items describing internal representations of HIV stigma, such as self-defacing beliefs and negative perceptions of individuals living with HIV/AIDS, are coded dichotomously as (1) “agree” or (0) “disagree,” with possible summary scores ranging from 0 to 6. This scale has been validated in South Africa [45] and showed good internal consistency in this sample ($\alpha = 0.75$). For brevity, “HIV stigma” will herein be used to refer to internalized HIV-related stigma throughout the manuscript.

Violence Exposure Exposure to physical violence was assessed using a single dichotomous item, “In the last year, have you been hit, slapped, kicked, or otherwise physically hurt by someone?” from the Abuse Assessment Screen [46, 47].

Lack of Social Support A modified 10-item version of the Duke-UNC Functional Social Support Questionnaire was used to evaluate availability of emotional, informational, and tangible support [48, 49]. This scale has been used with HIV-positive women in sub-Saharan Africa [50]. Items are rated

from (1) “never” to (4) “as much as I would like” and summed to yield a continuous total score ranging from 10 to 40, with good internal consistency ($\alpha = 0.75$). Items were reverse scored so that higher scores reflect greater lack of social support. Given that distribution was initially skewed right, a square root function was applied to all scores for normalization.

Statistical Analyses

Descriptive analyses were initially conducted in SPSS (IBM SPSS Statistics v24, USA) to characterize sample characteristics and hypothesized risk factors. Network analysis was then conducted in R using the mixed graphical modeling *mgm* package [51] to estimate associations between risk factors, adjusting for variable type and the presence of all other variables in the network. The following binary risk factors were modeled as two-level categorical variables: violence exposure, low income, unintended pregnancy, distress about pregnancy, younger age, lower education, and unemployment. The remaining scale-based risk factors were modeled as continuous variables: depression, HIV stigma, and lack of social support. The *mgm* package computes conditional independence relationships between mixed variables that can be represented in undirected graphical models [51] and plotted in *qgraph* [52], where each variable is represented as a node in the network and pairwise connections between variables are represented as edges. A statistical penalty was applied to the *mgm* fit algorithm to produce a relatively sparse network in which potentially spurious edges are reduced to zero [53] using a λ regularization parameter selected using tenfold cross-validation, with the k parameter set at 2 to estimate pairwise relationships.

The resulting plot layout in *qgraph* was arranged using the Fruchterman and Reingold algorithm [54], which features more strongly connected nodes in the center of the graph and less strongly connected nodes on the periphery of the graph. First, the overall network and all non-zero edges were inspected. For reporting, edges from this cross-validated model were compared with those generated using a more sparse extended Bayesian information criterion (EBIC) approach, with different levels of the EBIC tuning hyperparameter for regularization (gamma = 0.10, 0.20, and 0.50, in order of increasing stringency) [55]. Second, community detection analyses were conducted to identify subclusters of risk factors using the *igraph* R package [56] and the *walktrap* algorithm [57]. Third, centrality statistics for the main network were examined to assess the relative influence of each risk factor in the network, in terms of node *strength* (i.e., sum of edge weights connected to a particular node), *closeness* (i.e., average of a node’s distance to all other nodes), and *betweenness* (i.e., frequency in which a node lies directly in between, or connects, two other nodes). Fourth, the *predict* function in *mgm* was used to obtain predictability estimates for each risk

factor. Predictability refers to the extent to which each variable can be explained by all other variables in the estimated network [58], using either the proportion of explained variance for continuous variables or a measure of normalized accuracy for binary variables, which captures the degree to which a variable is determined by neighboring variables above and beyond an intercept-only model [58]. Estimates are provided on a scale of zero to 1, where 1 reflects full predictability. Finally, to assess stability of the main network, the *bootnet* package [59] with *mgm* specification was used to compute non-parametric bootstrapped intervals around estimated network edges and edge difference significance tests, using 1000 bootstrap samples.

Results

Descriptive Results

All 200 participants were HIV-positive pregnant women, with the majority being black and Zulu-speaking. Key demographic and psychosocial risk factors are summarized in Table 1. On average, participants were 28 years old (range 18–40 years), and 12% were under 21 years of age. The majority (77%) described their pregnancy as unintended, while 39% reported feeling initial distress about this pregnancy. Twenty-six percent met the working cutoff for clinically significant symptoms of antenatal depression. One in five participants reported exposure to physical violence in the past year.

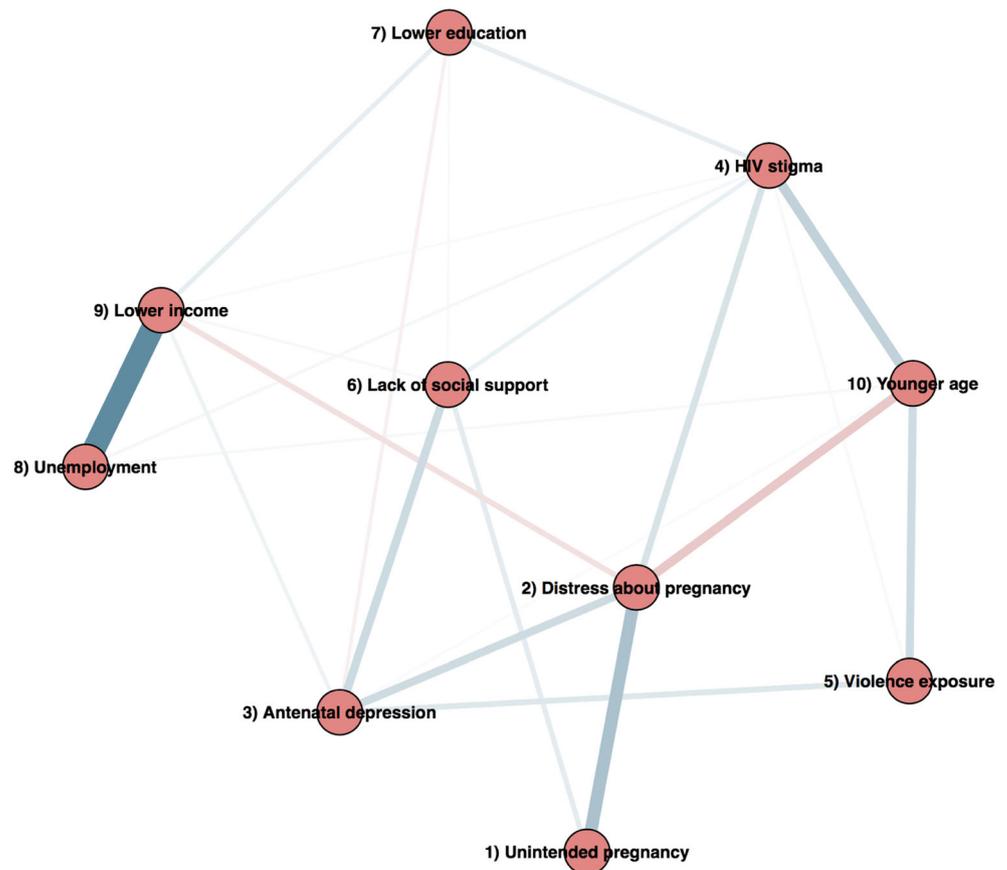
Network Analyses

The resulting network (Fig. 1) shows interconnections between psychosocial risk factors. Edge weights are summarized in descending order of absolute strength and across varying levels of regularization in Table 2. In the main estimated network, unintended pregnancy was strongly associated with distress about pregnancy ($b = 0.58$), which in turn was connected

Table 1 Sample characteristics

Variable	<i>N</i> (%)	Mean (SD)
1. Unintended pregnancy	153 (77%)	–
2. Distress about pregnancy	78 (39%)	28 (5)
3. Antenatal depression	48 (24%)	1.58 (0.5)
4. HIV stigma	–	2.4 (1.8)
5. Violence exposure	40 (20%)	–
6. Lack of social support	–	15.3 (5.5)
7. Lower education (< 12 years)	14 (7%)	12 (1.6)
8. Unemployment	145 (73%)	–
9. Lower income (< 500 ZAR)	63 (32%)	–
10. Younger age (< 21 years)	23 (12%)	28 (5)

Fig. 1 Visualized network of psychosocial risk factors. Strength of each conditional dependency is reflected in weight or intensity of the pairwise edge. Positive edges shown in blue, negative edges in red (in color figure)



to all but three other risk factors in the network. Specifically, distress about pregnancy was linked with higher levels of antenatal depression ($b = 0.33$) and HIV stigma ($b = 0.27$) and was paradoxically associated with older age ($b = -0.38$) and higher income ($b = -0.21$) though each of the proposed risk factors (i.e., younger age, lower income) was in fact associated with greater HIV stigma. Lower income was strongly connected with unemployment ($b = 1.11$). Unintended pregnancy was also associated with lack of social support ($b = 0.19$), which was itself independently linked to higher levels of antenatal depression ($b = 0.35$), HIV stigma ($b = 0.14$), and lower income ($b = 0.06$). In turn, antenatal depression was connected to violence exposure ($b = 0.12$) and lower income ($b = 0.07$). According to community detection analyses (Supplementary Fig. D1), unemployment and lower income formed one cluster reflecting *socioeconomic risk*; unintended pregnancy, distress about pregnancy, antenatal depression, and lack of social support formed a second cluster reflecting *psychosocial distress*; HIV stigma, violence exposure, and younger age formed a third cluster reflecting *miscellaneous social risks*; and lower education was not included in any cluster, though was most connected to HIV stigma.

According to centrality statistics (Fig. 2), the most central risk factor in the network was distress about pregnancy. In terms of *strength*—how strongly a variable was connected to

all other nodes, reflecting overall influence in the network—distress about pregnancy had the highest cumulative strength of connections to other variables, followed by lower income and unemployment. In terms of *closeness*—how close, on average, a variable was connected to all other nodes, reflecting direct influence within the network—distress about pregnancy was on average the closest to other nodes in the network, followed by younger age, antenatal depression, and unintended pregnancy. In terms of *betweenness*—how often a variable lies directly between two other nodes, and thus serves a central role in connecting other variables in the network—distress about pregnancy showed the highest levels of betweenness, followed by lower income and antenatal depression.

As summarized in Table 3 and depicted in Supplementary Materials Fig. B1, predictability of individual nodes [58] ranged between 18% (HIV stigma) and 30% (antenatal depression) of variance explained for continuous variables and 70% (distress about pregnancy) to 93% (lower education) in terms of normalized accuracy for binary variables. Network stability analyses revealed sizeable and overlapping distributions around edge weights (Supplementary Materials Fig. C1), as corroborated by edge difference significance tests (Supplementary Materials Fig. C2), suggesting caution in interpreting relative edge sizes. However, numerous edges persisted across varying degrees of regularization—such as

Table 2 Non-zero edges in the network across network estimation approaches

Variable	Variable	Cross-validated	Gamma 0.10	Gamma 0.20	Gamma 0.50	Sign
8. Unemployment	9. Lower income	1.11*	0.74	0.74	0.74	+
1. Unintended pregnancy	2. Distress about pregnancy	0.58*	0.53	0.53	0.53	+
4. HIV stigma	10. Younger age	0.42	–	–	–	+
2. Distress about pregnancy	10. Younger age	0.38*	0.18	0.18	0.18	–
3. Antenatal depression	6. Lack of social support	0.35*	0.3	0.28	0.23	+
5. Violence exposure	10. Younger age	0.34	–	–	–	+
2. Distress about pregnancy	3. Antenatal depression	0.33*	0.29	0.22	0.18	+
2. Distress about pregnancy	4. HIV stigma	0.27*	0.08	0.08	0.08	+
3. Antenatal depression	5. Violence exposure	0.23*	0.12	0.03	–	+
2. Distress about pregnancy	9. Lower income	0.21*	0.10	0.10	0.10	–
1. Unintended pregnancy	6. Lack of social support	0.19*	0.06	0.06	0.06	+
4. HIV stigma	7. Lower education	0.17	–	–	–	+
7. Lower education	9. Lower income	0.16	–	–	–	+
4. HIV stigma	6. Lack of social support	0.14*	0.02	0.02	–	+
3. Antenatal depression	9. Lower income	0.12*	0.07	–	–	+
3. Antenatal depression	7. Lower education	0.10	–	–	–	–
4. HIV stigma	8. Unemployment	0.07	–	–	–	+
6. Lack of social support	9. Lower income	0.06	–	–	–	+
8. Unemployment	10. Younger age	0.06	–	–	–	+
4. HIV stigma	5. Violence exposure	0.05	–	–	–	+
6. Lack of social support	7. Lower education	0.05	–	–	–	+
4. HIV stigma	9. Lower income	0.04	–	–	–	+
3. Antenatal depression	10. Younger age	0.04	–	–	–	+

Edge weights in descending order by strength, expressed in absolute values. Sign refers to direction of association between two variables. Gamma refers to the value of the hyperparameter used to adjust regularization in the EBIC network models

*Associations detected across both cross-validated and EBIC-based network models, highlighted in results

distress about pregnancy and antenatal depression, and antenatal depression and lack of social support (Table 2)—suggesting particularly robust connections.

Discussion

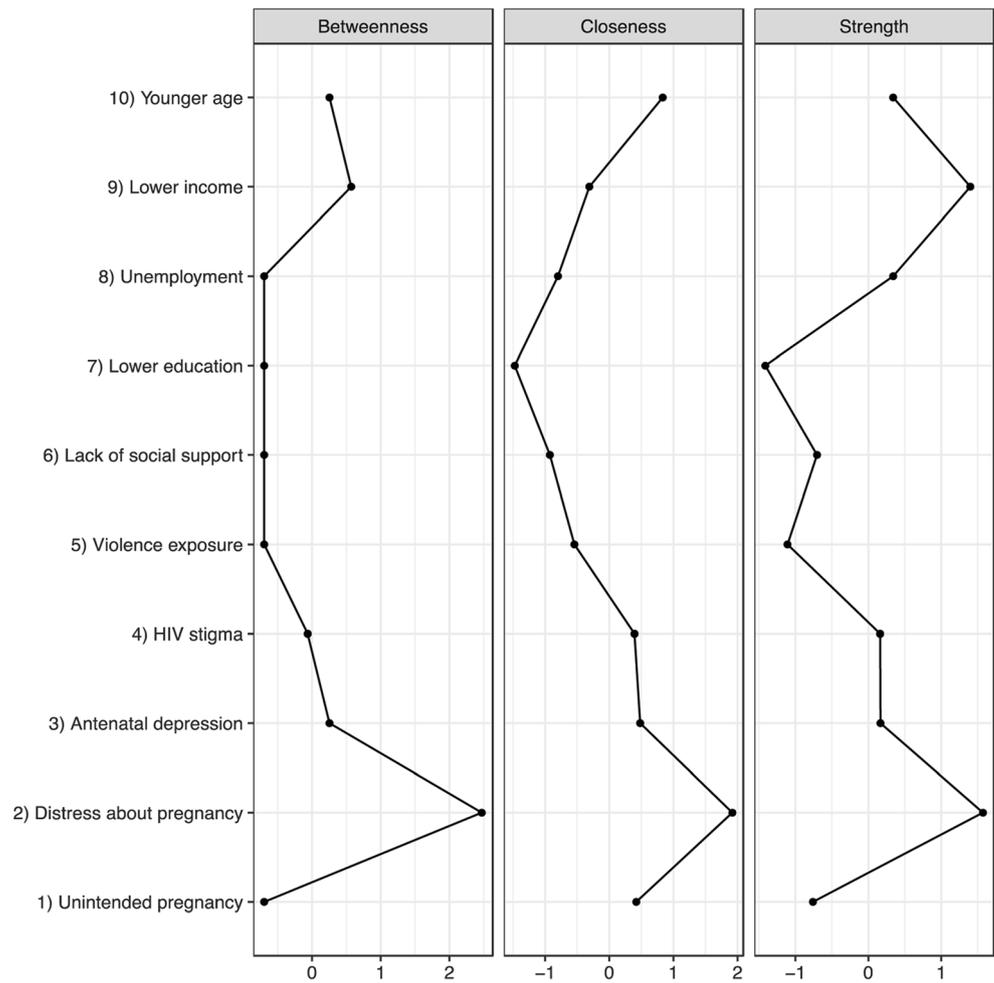
In a sample of 200 HIV-positive pregnant women in South Africa, a variety of psychosocial risks were documented, including elevated rates of depression, unintended pregnancy, poverty, and violence exposure. Network analysis revealed that these psychosocial risk factors were connected through a web of associations, featuring distress about pregnancy at the center of this network. Findings illustrate the complex interdependent nature of multiple psychosocial risks during pregnancy and highlight specific factors with particular influence that may be key targets for perinatal intervention.

Notably, women in this sample reported high levels of unintended pregnancy, with most reporting that they had not intended to become pregnant. Despite these high rates, a relatively smaller proportion of women reported initial distress about their pregnancy, suggesting that only about half of those

with unintended pregnancies may have difficulty accepting this news. This subset of women might be important to identify, as distress about pregnancy was the most central risk factor in this network and associated with several other psychosocial risks, including antenatal depression. While it is possible that pregnancy-related distress led to feelings of depression in these mothers, it is also possible that women with pre-existing depression were more vulnerable to general distress regarding unexpected life events. However, directional causality cannot be established from this cross-sectional data, which instead has generated a hypothesis about the central role of emotional aspects of unintended pregnancies among women in this setting.

Findings served to consolidate known associations between risk factors while further accounting for their simultaneous relationships in the presence of co-occurring factors. For example, IPV exposure has been associated with depressive symptoms during pregnancy [60], as observed in this study, though the typically robust size of this association may have been attenuated when accounting for other risk factors such as lack of social support. Lack of social support, which showed a substantial association with antenatal

Fig. 2 Network centrality statistics for each risk factor



depression in this sample, has also been linked to depression during pregnancy. Findings complement those from a recent study in pregnant South African women [61], which found that lack of social support interacted with another marker of poverty, food insecurity, to predict antenatal depression—supporting the need to account for interactive influences of multiple risk factors. While HIV stigma has been related to

antenatal depression [62], this study suggested that its influence on depression or vice versa might be indirectly mediated through other proximal risk factors. Recent IPV was also not highly connected to other risk factors, potentially due to its simple binary measurement and/or to the relatively common nature of these exposures in low-resourced South African townships [63, 64].

Table 3 Predictability of individual risk factors by the full estimated network

Variable	Predictability (between 0 and 1)	Type
1. Unintended pregnancy	0.77	Normalized accuracy
2. Distress about pregnancy	0.70	Normalized accuracy
3. Antenatal depression	0.30	Variance explained
4. HIV stigma	0.18	Variance explained
5. Violence exposure	0.80	Normalized accuracy
6. Lack of social support	0.26	Variance explained
7. Lower education	0.93	Normalized accuracy
8. Unemployment	0.73	Normalized accuracy
9. Lower income	0.74	Normalized accuracy
10. Younger age	0.89	Normalized accuracy

*Network estimated using tenfold cross-validation

Surprisingly, we found that sociodemographic risk factors such as low income and younger age were inversely associated with distress about pregnancy; results suggest that when adjusting for other risk factors, unintended pregnancy might be particularly distressing for someone who is older (not of younger age) and has greater financial means (not of lower income). This could be a statistical artifact since younger age and low income were each positively related to HIV stigma, which was associated with distress about pregnancy. On the other hand, it could be that younger women are experiencing their first pregnancy and happy to confirm their fertility status, while those from the lowest income category might be eligible for governmental assistance through child support grants [65], thus offsetting anticipated stressors of having a child. Finally, internalized HIV stigma was independently associated with pregnancy-related distress on top of these other factors, suggesting that HIV status and perceived stigma may be an additional dimension of psychosocial risk to consider for mothers living with HIV [66].

This study had a number of limitations to note. First, we relied on data from an existing study focused broadly on HIV and pregnancy, for which some psychosocial indicators (e.g., violence, income status) were not measured in depth. While our depression measure has been validated for research with perinatal populations in African countries, it was not specifically designed for use in the perinatal period like other existing measures [67]. We also wanted to study theoretically hypothesized risk factors and so used rational cutoffs to dichotomize continuous variables on an absolute scale such as age, though we separately verified that results were broadly consistent when using the continuous version of these variables. Second, we drew on a relatively small sample size for network analysis, which may affect stability of results. Results thus should not be interpreted for strong clinical/policy implications—however, they have generated hypotheses about plausible links between multiple risk factors in this population, and the potential importance of unintended pregnancy and related distress as a marker for broader risk, which can be tested further. Third, as mentioned previously, directionality of observed relationships has not been established. Some static risk factors (e.g., age, income) may tend to precede others, but other factors (e.g., depression) may both contribute to and be influenced by others in the network. This precludes definite conclusions about upstream versus downstream factors and the ability to draw strong inferences of where precisely to intervene. Network analysis studies that incorporate factors measured across time, or other studies that draw on network analysis findings to inform longitudinal structural model testing, may provide necessary corroborating evidence. While the focus of this study was to characterize the interrelationships of these risk indicators during pregnancy, future prospective studies should also be designed to examine prospective relevance for postpartum health outcomes.

Despite its limitations, this study has potential to inform future research and intervention. While the goal of this study was to visualize the interdependence of multiple psychosocial risk factors, future applications of this method could use network results to derive more precise predictors of MCH outcomes, potentially weighted by their influence in the network. In terms of clinical intervention, our study suggests that it is possible to identify the most influential risk factors in a vulnerable population. Identifying influential risk factors is especially critical in LMICs where resources are limited. Combined interventions that address a number of key MCH domains have been shown to be efficacious even in low-resourced areas of South Africa but are intensive to deliver [68]. Targeting factors that are central to syndemic networks may create the largest impact across risk factors without having to comprehensively address each one. The observed centrality of distress about pregnancy suggests the clinical relevance of assessing emotional aspects of unintended pregnancies in this population. Alternatively, factors that are more peripheral to the network are likely to be more exogenous factors that could benefit from upstream intervention and have ripple effects across other risk factors. For example, lack of social support was the only risk factor directly linked to unintended pregnancy; it is possible that working with women to identify and leverage specific sources of support, albeit limited, and to discuss family planning issues may have a protective effect against unintended pregnancy and its downstream consequences.

In conclusion, our results characterize a network of psychosocial risks during pregnancy in a sample of HIV-positive women in South Africa. Emotional aspects of unintended pregnancy emerged as a central feature of this network, suggesting that unintended pregnancy in contexts of internalized HIV stigma, sociodemographic risk, and lack of social support is particularly distressing and may even contribute to further risks to MCH, such as depression. Prevention of unintended pregnancies and interventions for coping with unplanned pregnancies may be especially critical in populations where multiple risks intersect. In addition, efforts targeting single risk factors (e.g., depression) should recognize the influence of other contextual variables and consider an integrated, multilevel approach to supporting the well-being of HIV-infected women during the perinatal period.

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Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Ethical Approval This study has been approved by the appropriate ethics committees—Ethics Committee at University of Witwatersrand (Johannesburg, South Africa) and Partners (Massachusetts General Hospital) Human Research Committee (Boston, USA)—and has therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments.

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