


# Socio-Behavioral Factors Mediating Mother-To-Child Transmission of HIV in Selected PMTCT Clinics in Rwanda

Gad Rutayisire<sup>1,2</sup>, Roman Saba Ntale<sup>3</sup>, Semwaga Emmanuel<sup>4</sup>, Nsereko Vincent<sup>5</sup>, Uwera Marie Grace<sup>6</sup>, Tumusiime Musafiri<sup>2</sup>, Innocent Ishami<sup>2</sup>, Enock Wekia<sup>7</sup>, Noah Kiwanuka<sup>5</sup>, Bernard Ssentalo Bagaya<sup>1,8</sup>

<sup>1</sup>Department of Immunology and Molecular Biology, School of Biomedical Sciences, Makerere University College of Health Sciences, Kampala, Uganda

<sup>2</sup>Department of Biomedical Laboratory Sciences, University of Rwanda, Kigali, Rwanda

<sup>3</sup>Department of Microbiology, Soroti University, Soroti, Uganda

<sup>4</sup>Department of Gynecology, Medi Heal Hospital, Kigali, Rwanda

<sup>5</sup>Department of Epidemiology and Biostatistics, School of Public Health, Makerere University College of Health Sciences, Kampala, Uganda

<sup>6</sup>Rwanda Biomedical Center, Kigali, Rwanda

<sup>7</sup>National Tuberculosis Reference Laboratory, Supranational Reference Laboratory, Uganda National Health Laboratory and Diagnostic Services, Kampala, Uganda

<sup>8</sup>Department of Research, BMK Medical Laboratory Services, Mitiyana, Uganda

Email: gadrutal@yahoo.co.uk

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## Abstract

**Background:** Mother-To-Child Transmission (MTCT) of HIV-1 and associated mortality remain unacceptably high despite extensive implementation of Prevention of Mother-To-Child Transmission (PMTCT) of HIV in Rwanda. Socio-behavioral factors sustaining MTCT in Rwanda remain inconclusively explored. This study aimed to identify the mediating effects of socio-behavioral factors on the MTCT of HIV-1 in PMTCT clinics in Rwanda. The goal of this study is to inform the refinement of PMTCT interventions to ensure they are effectively tailored to the specific context and dynamics of Rwanda's HIV epidemic. **Methods:** A prospective cohort study was conducted in Rwanda's PMTCT clinics to investigate the socio-behavioral factors associated with MTCT of HIV. HIV deoxyribonucleic acid-polymerase chain reaction (DNA PCR) was done immediately at birth and at 18 months together with HIV-antibody testing to establish HIV status. Quantitative socio-behavioral data were collected by questionnaire, and Structural Equation Modeling (SEM) using Smart PLS V4.0 was done to test hypotheses. **Results:** Fewer Antenatal Care (ANC) visits had significant negative correlational scores with low moth-

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ers' knowledge of MTCT of HIV (p-value of 0.008 and 0.041, respectively). However, neither the number of ANC visits nor adherence to Antiretroviral Therapy (ART) significantly mediated the relationship between maternal occupation or income and mother-to-child transmission (MTCT) of HIV, as indicated by 95% confidence intervals (CIs) that included zero. **Conclusion:** While maternal occupation and income socio-behavioral factors significantly influenced MTCT of HIV, adherence to ART and to ANC did not mediate the relationship between socio-behavioral factors and MTCT of HIV. These results justify targeted interventions to address maternal health risk behavior and accessibility of care facilities (PMTCT).

## Keywords

HIV-1, PMTCT, Socio-Behavioral Factors, Mediation and Adherence

## 1. Introduction

Through advancements in antiretroviral drugs for HIV treatment and prevention, the global HIV vertical transmission has registered a 52% decline in new infections, from 320,000 [220,000 - 480,000] in 2010 to 160,000 [110,000 - 230,000] in 2021 [1] [2]. This is even a more remarkable reduction considering that there were >400,000 new mother-to-child transmissions (MTCTs) in 2000 [3]. The impressive reductions in HIV vertical transmissions have been partly attributed to the increasing global coverage of MTCT prevention of HIV. In 2000, coverage stood at 1% and increased up to 81% by 2021 [1] [2] [4]. In 2021, it was estimated that 82% of pregnant women living with HIV globally were receiving antiretroviral therapy (ART) [2].

Scientific advancements in sub-Saharan Africa have progressed in the prevention of MTCT of HIV. This shift has been supported by the increasing number of women transitioning to optimized dolutegravir-based antiretroviral regimens, which offer greater potency, robustness, and tolerability [1] [2]. These regimens are associated with multiple benefits, including improved viral suppression, simplified dosing, fewer side effects, reduced risk of drug interactions, and better overall health outcomes for women living with HIV [2]. Women living with HIV now have access to better care, including access to integrated antenatal and HIV services, viral load monitoring, multi-month ART dispensing, and patient-centered differentiated service delivery models with post-natal follow-up of the mother-infant from day to day [2] [4] [5]. Despite this progress, HIV is among the top five causes of death globally [3] [6]. A substantial number of vertical transmissions continue to occur perinatally and during breastfeeding, driven by shortfalls in testing, treatment coverage, adherence, and retention in care among mothers [1] [2] [7] [8]. Moreover, as of 2018, 1.8 million children under the age of 15 were living with HIV globally [1] [3], with 90% of them having contracted HIV through MTCT [1]. Africa is the most affected region, having over 110,000 child

deaths due to AIDS-related illnesses as of 2021 [9]-[11]. In Rwanda, specifically, children constitute an estimated 1.8% of the total number of HIV/AIDS prevalence cases [10] [11]. It was also revealed for the first time in Rwanda that the proportion of infants aged between 0 and 14 years infected with HIV perinatally was 0.4% [12] [13]. Despite an estimated 82% of pregnant women living with HIV being on highly active antiretroviral therapy (HAART) globally [1] [2], there is still a high incidence of MTCT of HIV-1 [10] [13]. Worldwide MTCT of HIV gap has been shown in terms of disparity between the number of women living with HIV who require PMTCT services and the number of women who actually receive them [6], and this gap exists due to various factors such as the number of antenatal clinic visits [14], distance to the health center [15], health-risk behavior [16], mothers' income level, mothers' knowledge on MTCT of HIV [17] [18], limited access to healthcare, mothers' attitude towards ART, lack of awareness about PMTCT [18], stigma and discrimination [18], and insufficient resources and funding [6].

In Rwanda, the MTCT gap is a particular concern, with an estimated 12,000 to 15,000 children born to mothers living with HIV annually [10]. However, Rwanda has made significant progress in addressing MTCT with high coverage of PMTCT services (over 90%), strong healthcare infrastructure, political commitment to addressing HIV/AIDS, and innovative approaches like community-based PMTCT programs [13]. To reconcile the worldwide MTCT gap and MTCT in Rwanda, it is essential to increase global funding and resources for PMTCT programs, strengthen healthcare systems and infrastructure, address stigma and discrimination, promote awareness and education about PMTCT, support community-based initiatives, and foster political commitment and leadership [10]. Rwanda's success in addressing MTCT can serve as a model for other countries, highlighting the importance of political commitment, strong healthcare infrastructure, community engagement, and innovative approaches [10]. By learning from Rwanda's experiences and addressing the global MTCT gap, we can work towards eliminating MTCT and ensuring that all women living with HIV have access to comprehensive PMTCT services [10]. Even with the modified options B and B+ in PMTCT programs, where option B recommends ART for the pregnant mothers living with HIV from 14 weeks' gestation until birth or the cessation of breastfeeding and the use of NVP for the infant until 4 - 6 weeks of age, while option B+ advocates lifelong ART and NVP for the infant as for option B [10] [19]. MTCT still exists, with an estimated 4000 children getting infected globally. Therefore, maternal or virological factors that are contributing to this residual MTCT in the Rwandan PMTCT program require further study [20] to inform focused prevention interventions.

The current research is magnifying the role of mediator or intervening socio-behavioral factors that are associated with MTCT of HIV-1 [21]. Intermediate variables are thought to transmit the effect of MTCT independent variables to an outcome (the dependent variable). It calls for more research focusing on media-

tion analysis to understand why there has been no decline in MTCT of HIV-1, with a threat of stagnation, despite the interventions implemented over the last two decades [3] [8] [21]. Socio-demographic characteristics, as well as the virological factors, converge at and work through elevation of maternal HIV viral load [18] [22] to result in MTCT of HIV-1. Documentation of quality data on socio-behavioral factors in PMTCT programs, including option B+, remains a challenge, especially in resource-limited settings, such as Rwanda [23]. The study therefore set out to document socio-behavioral factors that are associated with MTCT of HIV-1 in the PMTCT program of Rwanda. We hoped to identify potential mediators of the socio-behavioral factors associated with MTCT of HIV-1 in the PMTCT program. In parallel, the goal of examining mediators was to understand how integrated services lead to improved outcomes, with a view to refining interventions by identifying the most effective components.

## **2. Materials and Methods**

### **2.1. Study Design and Area**

A prospective cohort study [24] was conducted among mother-baby pairs where both PMTCT clinics and participants were selected through a two-stage sampling strategy described under the section on sampling strategy below. The study was conducted in ten PMTCT clinics distributed across the five provinces of Rwanda. These included Northern, Southern, Western, and Eastern provinces and Kigali City. In every study province, one urban and one rural (lower-level)-based health facility were included in the study. All hospitals in the study were referral-level health facilities for a number of other medical services, including prevention of mother-to-child transmission/voluntary counseling and testing (PMTCT/VCT) of HIV.

### **2.2. Study Population**

Expectant mothers living with HIV-1 and participating in the PMTCT program who were to deliver their child at any of the ten health facilities selected for the study were eligible. To be selected for the study, a mother had to be HIV positive, be enrolled in PMTCT, and be under ART. However, mothers whose child died before being discharged from the labor ward or did not consent to the study were excluded.

### **2.3. Sampling Strategy and Sample Size Determination**

All five of Rwanda's administrative provinces were included in the sample. We used a two-stage sampling strategy; at the first stage, within each province, clinics were first stratified as urban (within the boundaries of provincial or capital cities) and rural (outside city boundaries) to ensure equitable geographical and contextual representation across both urban and rural health systems. A fixed probability sampling (stratified random sampling) was used to select one urban and one rural facility per province to arrive at a total of 10 facilities.

A fixed probability sampling (simple random sampling) was used to achieve a total of 862 pregnant mothers living with HIV from the selected PMTCT clinics. Eligible women were those actively enrolled in the PMTCT program and presenting at the selected facilities for childbirth. At delivery, their babies were also enrolled, forming mother-baby pairs that were prospectively followed to assess HIV transmission.

From the 862 HIV-1-positive pregnant women, 32 cases of vertical HIV transmission were identified, constituting the primary analytical cohort for this prospective cohort study. Due to the small sample size, Partial Least Squares Structural Equation Modelling (PLS-SEM) was employed as a viable alternative to Covariance-Based Squares Structural Equation Modelling (CBS-SEM). PLS-SEM is increasingly recognized for its advantages, fewer statistical assumptions, and the ability to handle non-normal data distributions, making it suitable for complex models with limited data [25]-[30]. A bootstrap of 5000 samples was also used to stabilize the model. Research indicates that, despite traditional rules suggesting inadequately small samples, PLS-SEM can yield reliable results with samples as low as 50, provided that analytical power is maintained [26] [30]. This flexibility allows for the exploration of intricate relationships even when participant availability is restricted, for example, in this case, where mother-to-child transmission of HIV is minimal because of the PMTCT interventions. Thus, enhancing the applicability of SEM techniques in various fields [27] [29].

#### **2.4. Data Collection Questionnaire**

A structured socio-behavioral questionnaire having some questions rated over a five-point Likert scale was used. The questionnaire captured the demographics and socio-behavioral factors, which included attitude towards ART, which was measured on a five-point Likert scale from 9 items, responses ranging from 1 = strongly disagree to 5 = strongly agree. The sample items included 1) Does ART reduce related death from HIV? 2) HIV is controlled by ART, and 3) know how to deal with side effects.

Health Risk Behaviors of the mothers were measured on a continuous scale; the sample items include: Currently, how many packs or numbers of cigarettes do you smoke a day?

Distance to the health facility was measured using a four-point Likert scale with responses ranging from 1 = strongly disagree to 4 = strongly agree. The sample items included: Do you experience any problems because of staying far away from health facilities?

Data on socio-behavioral characteristics associated with MTCT of HIV-1 were collected by research assistants through structured interviews. The research assistants were trained and supervised by the principal investigator.

#### **2.5. HIV-1 Viral Load and HIV DNA PCR Testing**

All HIV viral load and DNA PCR testing were centralized and conducted at the

Rwanda National Reference Laboratory (RNRL), the designated national hub for HIV diagnostic and monitoring services. The DNAPCR tests (babies' dry blood spots) were conducted immediately at birth and at 18 months, together with HIV-1 antibody testing (babies' blood) by laboratory technologists under the supervision of the principal investigator to confirm if they were HIV positive, and the results were published [12].

### 3. Ethical Considerations

The study received administrative permission from the participating hospitals. Ethical approval was obtained from the Makerere University School of Biomedical Sciences Research Ethics Committee (**SBS-REC No:738**) as well as from the University of Rwanda Institution Review Board (**UR-IRB No:228**). All participants provided written informed consent prior to being enrolled in the study. Mothers had liberty to consult their husbands provided consent on behalf of their babies/infants. All participants' documents were labeled with identification numbers rather than names.

The research team collected the completed consent forms from participants. These forms were reviewed for completeness, accuracy, and legibility, and participants' identities and consent were verified as necessary. The consent forms were then documented in the participants' research records. The completed consent forms were stored in a secure, locked location, with access restricted to authorized research team members. The forms were stored in a manner that maintained participant confidentiality and were retained for a specified period as required by study protocols.

### 4. Statistical Analysis

Smart PLS (Partial Least Squares) V4.0 for Structural Equation Modeling (SEM) was used to analyze the quantitative data collected by a structured questionnaire for socio-behavioral factors [21]. The SEM was chosen because it is particularly useful for modeling complex behaviors, addressing measurement errors in self-reported data, and evaluating theoretical models of socio-behavioral phenomena [31] [32]. The validity of the measurement model was evaluated using several tests, including reliability, convergent validity, and discriminant validity (see **Supplementary Table S1** and **Table S2** [34]). Additionally, the Heterotrait-Monotrait Ratio of Correlations (HTMT) criterion for discriminant validity was examined [34] [35]. The impact of all independent variables on the dependent variables, as well as the impact of mediating variables on the relationships between independent variables and dependent variables, was tested and investigated using multivariate analysis [35]. Bootstrap with 5000 resamples was used to analyze the structural path without considering the route coefficient. According to reliability and validity indices, all items appeared to have good factor loading on their respective constructs and had values above the levels suggested by the literature. Composite reliability (CR) and average variance extracted (AVE) are both greater than 0.5 and

0.7, respectively [35].

## 5. Results

### 5.1. Characteristics of Maternal Study Participants

Most of the participants were from Eastern (25%) and Western (25%) provinces, while the Southern province had the lowest (12.5%) number. In addition, the majority of the participants were in a rural (53.1%) setting, while the participant average age was 33 years, and most were Catholics (34%). Over 81.3% of participants were at the secondary level of education, and none of them had completed tertiary level of education. Half (50%) of the participants were divorced mothers, while only 21% were widows. Most of the participants were either merchants, farmers (21.9%), unemployed, or sex workers (15.6%). The average monthly income was \$9.73, with a median of \$10.48, suggestive of a variation in income levels. Demographic characteristics of maternal participants are summarized in **Table 1**.

**Table 1.** Sociodemographic characteristics of the population.

Variable	Frequency	Percentage (%)
<b>Province</b>		
Kigali City	5	15.6
East	8	25.0
South	4	12.5
West	8	25.0
North	7	21.9
<b>Residence Type</b>		
Urban	15	46.9
Rural	17	53.1
<b>Religion</b>		
Catholic	11	34.4
Anglican	6	18.8
Moslem	8	25.0
SDA	4	12.5
No religion	1	3.1
Others	2	6.3
<b>Education level</b>		
Primary	2	6.3
Secondary	26	81.3
No formal education	4	12.5
Tertiary	-	-
<b>Marital status</b>		
Married	-	-

## Continued

Divorced	16	50.0
Widow	7	21.9
Single	9	28.1
<b>Main occupation</b>		
Casual worker	-	-
Unemployed	5	15.6
Merchant	7	21.9
Farmer	7	21.9
Privately employed		
House wife	6	18.8
Government Civil Servant	2	6.3
Sex worker	5	15.6
Student	-	-
<b>Continuous Demographic factors</b>	<b>Mean</b>	<b>Std. Deviation</b>
Average Age	33.19	5.855
Monthly Average Income (\$)	9.73	10.48

## 5.2. Influence of Socio-Behavioral Factors on MTCT of HIV in the PMTCT Clinics

Firstly, we examined the impact of various social behavioral factors on the MTCT of HIV in the PMTCT clinics under the study, aiming to assess their influence on the risk of MTCT of HIV. The association of socio-behavioral factors with MTCT of HIV is summarized in **Table 2**.

**Table 2.** Correlation analysis to test the linear relationship for the total effect of Socio-behavioral factors on MTCT of HIV-1.

Hypothesis	Pearson r coefficient	t-statistics	P values
Adherence to Antiretroviral Therapy	-0.033	0.734	0.232
<b>Number of Antenatal clinic visits</b>	<b>-0.007</b>	<b>2.394</b>	<b>0.008</b>
Mothers' attitude towards ART	0.013	1.01	0.156
Distance to the health centre	0.027	0.883	0.189
Health-risk behavior	0.005	0.765	0.222
<b>Mothers' knowledge of MTCT of HIV</b>	<b>-0.014</b>	<b>1.736</b>	<b>0.041</b>
Mothers' income	-0.004	1.009	0.156

**Table 2** shows that only two factors were statistically significant, and these are the number of antenatal care (ANC) visits ( $r = -0.007$ ,  $p = 0.008$ ) and mothers' knowledge on MTCT of HIV ( $r = -0.014$ ,  $p = 0.041$ ). The effect sizes were extremely small, indicating minimal clinical significance. For instance, the inverse correlation between ANC visits and MTCT suggests a trend where increased clinic

attendance may slightly reduce the risk of HIV transmission. However, with an effect size of  $r = -0.007$ , the actual impact is negligible. Similarly, improved maternal knowledge about MTCT, while associated with reduced transmission, yielded a trivial correlation ( $r = -0.014$ ), suggesting that although educational interventions are important, their isolated influence may not be sufficient to substantially change MTCT outcomes.

### 5.3. Mediation Analysis

A mediation analysis was carried out to assess whether the number of antenatal care visits mediates the relationship between mothers' income and occupation with MTCT of HIV. We also sought to assess whether adherence to ART mediated the relationship between mothers' attitude towards ART, Health Risk behaviors and distance to health facilities with MTCT of HIV-1 in Rwanda's PMTCT clinics. We generated 5 hypotheses for the mediation analysis:

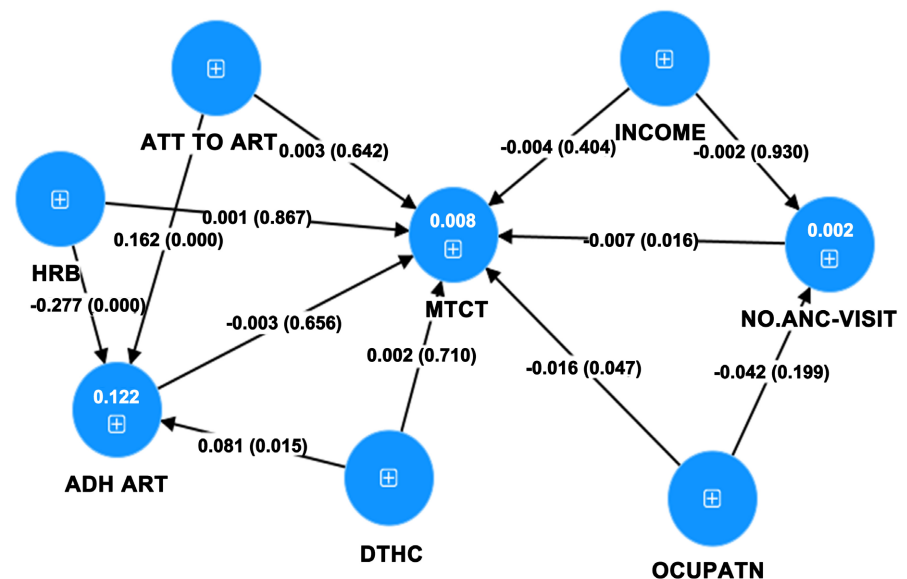
H1: Adherence to ART mediates the relationship between distance to health facility and MTCT of HIV in PMTCT clinics.

H2: Adherence to ART mediates the relationship between attitudes towards ART and MTCT of HIV in PMTCT clinics.

H3: Adherence to ART mediates the relationship between health risk behavior (HRB) and MTCT of HIV in PMTCT clinics.

H4: Number of antenatal care (ANC) visits mediates the relationship between mothers' occupation and MTCT of HIV in PMTCT clinics.

H5: Number of antenatal care (ANC) visits mediates the relationship between mothers' income and MTCT of HIV in PMTCT clinics. (Figure 1)



**Figure 1.** Path diagram Model for the mediation analysis [36]. ANC-Visit = Antenatal care visit, Income, OCUPATN = Occupation, ADH ART = Adherence to Antiretroviral Therapy, ATT TO ART = Attitude to Antiretroviral Therapy, DTH = Distance to Hospital, HRB = Health Risk Behavioural, MTCT = Mother to child transmission.

**Table 3.** Mediation analysis. Inner model coefficients and P values.

Hypothesis	Total effect $\beta$ -Coeff	p-value	Direct effect $\beta$ -Coeff	p-value	Indirect effect $\beta$ -Coeff	p-value	95% Confidence interval		Comment
							LCI	UCI	
DTH -> ADH ART -> MTCT	0.002	0.734	000	0.687	000	0.687	-0.001	0.001	No mediation
ATTITUDE TO ART -> ADH ART -> MTCT	0.003	0.679	000	0.675	000	0.675	-0.002	0.002	No mediation
HRB -> ADH ART -> MTCT	0.002	0.776	000	0.664	0.001	0.664	-0.003	0.004	No mediation
OCUPATN -> NO. ANC-VISIT -> MTCT	-0.015	<b>0.05</b>	000	0.312	000	0.312	000	0.001	No mediation
INCOME -> NO. ANC-VISIT -> MTCT	-0.004	0.404	000	0.937	000	0.937	0000	000	No mediation

DTH = Distance to health facility, ATT TO ART = attitude towards ART, ADH ART = Adherence to ART, MTCT = Mother to child transmission, OCUPATN = occupation, NO. ANC-VISIT = number of antenatal care visits, INCOME = wealth index of the mothers.

**Table 3** shows the results of a mediation analysis to understand the relationship between socio-behavioral and economic factors and MTCT in the presence of a mediator. None of the hypothesized mediation effects were statistically significant, as indicated by the 95% confidence intervals that include zero for all. Even though the total effect had a p-value of 0.05 for the hypothesis “OCCUPATION -> NO. ANC-VISIT -> MTCT”, the indirect effect was not statistically significant ( $p = 0.312$ ), which means that the number of antenatal care visits does not significantly mediate the relationship between occupation and mother-to-child transmission (MTCT) of HIV. The direct effects are all zero, indicating that the effects were all negligible. We would conclude that, based on this analysis, there is no evidence of mediation for any of the hypothesized relationships in the study.

## 6. Discussion

We set out to assess socio-behavioral factors associated with MTCT of HIV-1 in Rwanda’s PMTCT clinics and whether adherence to ART and the number of antenatal care visits mediated their relationship with MTCT of HIV. Our finding of a significant negative correlation between ANC visits and MTCT of HIV was in line with an Ethiopian study that found that increased access to antenatal care significantly contributes to a reduction in MTCT of HIV attributable to increased access to HIV preventive interventions and education [14]. Low attendance of antenatal care (ANC) clinics by mothers living with HIV can be attributed to socio-economic barriers such as financial hardship, high healthcare costs, and transportation expenses, all of which hinder access to consistent medical care. Additionally, a lack of partner support, particularly in situations where women struggle to disclose their HIV status, can lead to reduced emotional and logistical support, thereby limiting their autonomy and motivation to seek ANC services regularly. The findings are in line with those of [18].

The weak association observed emphasizes the importance of a multifactorial

approach to reducing mother-to-child transmission (MTCT) of HIV. In our context, the impact is likely driven not merely by the number of antenatal care (ANC) visits, but by the quality of those visits and the effectiveness of the interventions delivered. This finding calls for policymakers and practitioners to go beyond single-focus strategies. Instead, they should embrace integrated, comprehensive interventions that will address clinical care, partner involvement, and socioeconomic barriers, which are essential to achieve meaningful reductions in MTCT of HIV.

Equally, finding that mothers' knowledge of MTCT of HIV correlated with reduced MTCT agrees with others [37]-[39], reinforcing the need to increase mothers' knowledge of MTCT of HIV as a cornerstone of implementation of PMTCT activities designed to minimize the risk of MTCT of HIV during pregnancy, childbirth, and/or breastfeeding.

Two factors, adherence to ART and the number of ANC visits undertaken by the mothers, were chosen as mediator variables because several studies in diverse populations have demonstrated their correlation with the prevention of MTCT of HIV [38]-[40]. Therefore, characterizing and addressing socio-cultural factors that are directly or indirectly (through a mediator variable) associated with MTCT of HIV-1 would have a national-level impact on the numbers of babies born with or acquiring HIV during infancy [6] [18] [21] [41]. The study recruited a representative number of participants from Western and Eastern provinces, which are the most populous [11] [41] and have the busiest PMTCT clinics. Although Rwanda's PMTCT coverage has reached approximately 97% of health facilities [42], being one of the highest in Sub-Saharan Africa [19] [42], reductions in MTCT of HIV-1 have severely slowed or stagnated over the past decade [42]. Reasons for the slowing or stagnation of MTCT rates are many, including socio-behavioral factors. The African continent remains a culturally diverse and conservative population, with variations in practices and behaviors that contribute to HIV dynamics in various communities or even between countries as a whole [18] [43] [44]. Interrogation of cultural practices is crucial for community customization and tailoring of prevention interventions within PMTCT programs for maximum impact.

Adherence to ART is crucial for the maintenance of optimal therapeutic blood levels of ART and hence has a direct effect on viral suppression [42]. Therefore, adherence to ART has a direct effect on reducing the risk of MTCT of HIV in Rwanda [2] [45]. However, adherence to ART, including Rwanda's PMTCT program or clinics, is a function of a combination of factors [46]. These include the distance mothers have to travel to access ART services and/or ANC clinic visits, attitudes towards ART, as well as mothers' health risk behaviors [42] [45]-[47]. It was plausible to hypothesize that adherence to ART could mediate part or all of the effects of these three socio-behavioral factors on MTCT of HIV in Rwanda through moderation. However, adherence to ART did not moderate the effects of distance to ANC clinic visits, attitudes towards ART, or health risk behaviors on the likelihood of MTCT of HIV in Rwandan PMTCT clinics. The relationship of these three factors with MTCT of HIV-1 is independent of adherence to ART.

Our results show that few ANC visits and a low level of mothers' knowledge on MTCT were significantly associated with MTCT of HIV. These findings were not different from other studies that have realized similar results [11] [45] [48]. The two factors indeed are interrelated: VCT and PMTCT. These services are integrated into the ANC services package in Rwanda's healthcare system, often with counseling being repeated at every ANC visit [45] [49]. In addition, increased ANC visits and associated counseling positively impact mothers' knowledge of MTCT of HIV and attitude towards HIV care services, including adherence to ART [50]. This therefore explains why there is a significant relationship between the number of ANC visits and MTCT of HIV-1. However, the number of ANC visits played no mediation role in explaining the relationship between maternal occupation or income and MTCT of HIV, which aligns with previous literature [39] [41] [51]. Our findings continue to support the idea that, regardless of maternal occupation or income thresholds, PMTCT of HIV strategies must concentrate on early and increased numbers of antenatal care clinic visits.

## 7. Conclusion and Recommendations

We conclude that the number of ANC visits correlates with reduced MTCT of HIV but does not mediate the relationship between maternal occupation and or income and MTCT of HIV. Equally, adherence to ART correlates with a reduction in MTCT but does not explain the relationship between the socio-behavioral factors of mothers' distance to ANC clinics, attitudes towards ART, or health risk behaviors on the likelihood of MTCT of HIV in Rwandan PMTCT clinics. Our results highlight the importance of continued studies to describe the mechanistic ways by which socio-behavioral factors modulate risk of MTCT in the context of Rwanda's PMTCT programs. Results show that equitable access to PMTCT clinics as well as counseling services for increased knowledge about MTCT of HIV in mothers should remain integral components of the PMTCT program in Rwanda.

### Recommendations to Policymakers

Policymakers should expand conditional transport vouchers or community-based outreach programs to improve access for economically disadvantaged women, particularly in rural or hard-to-reach areas, to improve retention in care.

Nationwide health communication strategies, delivered through community health workers, radio programs, and ANC providers, should focus on increasing mothers' understanding of HIV transmission risks during pregnancy, childbirth, and breastfeeding.

The ART adherence programs should be embedded within broader socio-behavioral interventions, including home-based follow-up, peer support groups, and mobile phone reminders.

## 8. Limitations

First, the study relied on self-reported measures of ART adherence and socio-be-

havioral variables, which are subject to recall and social desirability biases. Secondly, while the study attempted to assess mediation effects, small sample size limitations, where mother-to-child transmission of HIV was minimal because of the PMTCT interventions, may affect the generalizability of the findings, and therefore future studies could target a larger sample size for generalizability of the findings.

Lastly, although our sample included clinics from all five provinces, the disproportionate recruitment from more populous provinces like Western and the Eastern region may introduce geographic sampling bias. Future studies could employ longitudinal designs with biomarker confirmation to more accurately capture adherence trajectories and explore causal pathways in greater depth.

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### Authors' Contribution

Bernard S. Bagaya, Gad Rutayisire, Noah Kiwanuka, Roman Saba Ntale, Emmanuel Semwanga, Enock Wekia, Nsereko Vincent: Conceptualization, Methodology, Supervision, Data analysis, Manuscript writing and review.

Gad Rutayisire, Uwera Marie Grace, Tumusiime Musafiri, Innocent Ishami: Data collection, Laboratory Assays, review of manuscript.

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### Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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## Supplementary

**Table S1.** Construction of validity and reliability.

	Cronbach's Alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	Average variance extracted (AVE)
ATDART	0.66	-0.865	0.72	0.59
HRB	0.852	0.859	0.931	0.87
KN MTCT	0.821	-4.988	0.509	0.89

ATDART: Attitude towards ART, HRB: Health Risk Behaviors, KN MTCT: Knowledge of MTCT.

**Table S2.** Discriminant validity Fornell Lacerker Criterion.

	ADH ART	ANC-VISIT	ATD ART	DTH	MTCT	HRB	KN MTCT	income
ADH ART	1.000							
ANC-VISIT	0.004	1.000						
ATD ART	0.107	0.019	0.599					
DTH	0.482	0.045	0.071	1.000				
MTCT	-0.012	-0.034	0.072	0.028	1.000			
HRB	-0.039	-0.094	0.063	-0.006	0.041	0.933		
KN MTCT	-0.006	0.387	0.083	0.009	-0.015	-0.047	0.538	
INCOME	0.009	0.011	0.009	0.028	0.005	0.139	-0.021	1.000

ADH ART: Adherence to ART, ANC\_VISIT: Antenatal Care Visit, ATDART: Attitude towards ART, DTH: Distance to Health Facility, MTCT: Mother-to-Child Transmission of HIV, HRB: Health Risk Behaviors, KN MTCT: Knowledge of MTCT.