Workforce Patterns and the PMTCT Option B Cascade in Côte d'Ivoire

Brianne H. Rowan

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Steve Gloyd
Julia Robinson
Jim Hughes

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Abstract

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Brianne Huffstetler Rowan

Chair of the Supervisory Committee: Steve Gloyd, Professor, Global Health

Background: Côte d'Ivoire continues to face regionally high rates of mother-to-child transmission of HIV despite implementation of a national program to prevent transmission (PMTCT). The aim of this study was to assess the impact of workforce density, distribution and training on PMTCT program success.

Methods: Primary and secondary data were collected from a nationally representative sample of 50 PMTCT sites between June 2015 and February 2016. Assessment of the association between workforce factors and PMTCT outcomes (testing, treatment and retention) were assessed using multivariate logistic regression with generalized estimating equations.

Results: Statistically significant positive associations were found between HIV testing and the following workforce densities (odds ratios presented are for a difference of 1 healthcare worker per 1000 new antenatal care patients): total density (OR = 1.01, 95% CI 1.01-1.01), physician density (OR = 1.03, 95% CI 1.01-1.05), density of trained staff (OR = 1.09, 95% CI 1.08-1.10) and midwife density (OR = 1.10, 95% CI 1.08-1.12). Negative associations were found between pharmacist density and testing and treatment (OR = 0.91 [0.86-0.96] and 0.83 [0.69-0.99] respectively) and between community health workers and testing (OR = 0.96, 95% CI 0.95-0.97). No associations were found between workforce indicators and retention.

Discussion: While this study showed statistically significant associations between workforce patterns and PMTCT service delivery, the effect size of these associations was small. For an average site, the largest positive association (OR of 1.10) equates to increased testing for only 7.7 patients per year per additional healthcare worker trained. The study's complex results (namely the relatively small positive odds ratios and the negative associations with pharmacist density and CHW density) more importantly highlight the need for additional research aimed at understanding how more complex workforce factors beyond density, as well as non-workforce factors, impact PMTCT success.

INTRODUCTION

In 2014, following the development of new treatment regimens for pregnant women with HIV, the World Health Organization (WHO) began to call for the elimination of mother-to-child transmission of HIV.[1] These prevention of mother-to-child transmission of HIV (PMTCT) programs have been national policy in Côte d'Ivoire since 2004, with national policy transitioning from Option A to Option B in November 2012, and with some sites implementing Option B+ as early as late 2015. Despite this, Côte d'Ivoire continues to face regionally high rates of HIV transmission from mothers to their children (estimated to be 23% in 2013).[2] Numerous barriers to program success have been described, one of which is suboptimal workforce patterns, including low density and training of healthcare workers.[3,4,5] In its most recent human resources for health strategic plan, Côte d'Ivoire identified limited professional training, poor human resources management, and limited funding as key challenges in producing and maintaining an adequate healthcare workforce.[6] Additionally, these challenges have been further exacerbated by migration and disruption caused by recurrent political conflicts.[7] As recently as 2014, the United Nations Population Fund estimated that only 48% of the maternal and newborn workforce needed was available.[8]

In 2011, the Côte d'Ivoire Ministry of Health (MOH) and Health Alliance International (HAI) conducted the first phase of a 2-part assessment of Côte d'Ivoire's national PMTCT program.[3] One finding from this phase I assessment was that workforce patterns were a major factor associated with a clinic's PMTCT performance, independent of clinic size or location. There was a significant difference between the numbers of physicians, nurses, and lab technicians per 1000 first antenatal care (ANC1) visits, as well as personnel trained in PMTCT between sites with high and low PMTCT "performance scores," (this score amalgamated several outcomes along the PMTCT cascade of care), with sites with higher numbers having a higher score.[3] Because this study assessed the association of workforce patterns with PMTCT outcomes via an overall PMTCT performance score rather than individual steps along the PMTCT cascade of care, it raised questions regarding why the association exists and what implications it has on future policy.

Côte d'Ivoire transitioned from WHO PMTCT Option A policy to the updated Option B policy in November 2012, shortly after the completion of the phase I assessment. This study is part of the MOH and HAI's larger phase II assessment of PMTCT programs in Côte d'Ivoire to evaluate the national implementation of Option B. The goal of this study was to follow-up and expand on the phase I findings related to workforce and PMTCT outcomes following this transition. Specifically, the objective was to describe the relationship between workforce density, distribution and training and the success of Option B in Côte d'Ivoire at various steps in the PMTCT cascade of care. Specific research questions of this study included the following:

1. Are workforce density, distribution and training associated with HIV testing in the PMTCT setting?
2. Are workforce density, distribution and training associated with the initiation of treatment or prophylaxis in HIV-positive patients in the PMTCT setting?
3. Are workforce density, distribution and training associated with retention in care (at 6 months and at 12 months) in the PMTCT setting?

METHODS

This cross-sectional study utilized primary and secondary data from 50 antenatal care (ANC) facilities in Côte d'Ivoire over 9 months to assess the relationship between workforce density (total and by healthcare worker subcategory & training) and PMTCT outcomes in the cascade of care. PMTCT outcomes assessed included the following steps in the PMTCT cascade of care: testing (proportion of pregnant women who were tested for HIV at ANC1), treatment (proportion of women known to be HIV-positive and who received antiretroviral therapy or prophylaxis[i]), retention at 6 months (proportion of ANC and maternity charts belonging to HIV-positive women that showed evidence of retention in care 6 months after delivery of antiretrovirals) and retention at 12 months (similar to above only at 12 months after delivery of antiretrovirals). Ethics approval was obtained from both the Population Council Institutional Review Board (IRB) and Côte d'Ivoire National Ethics and Research Committee, as well as reviewed by the HAI Ethical Review Committee, and the University of Washington IRB (which deferred to the Population Council decision).

Sampling

A nationally representative sample of 50 ANC clinics ("sites") was chosen using two-stage cluster sampling, where cluster and sample size were determined using probability proportional to size (PPS) methodology. The cluster size (number of sites per region) was determined based on the number of HIV-positive women aged 14-49 living in each of Côte d'Ivoire's 11 regions, as determined by the 2011-2012 Demographic and Health Survey from Côte d'Ivoire. A second round of PPS methodology was then used to randomly choose sites, with probability based on the number of HIV-positive women who attended each site in 2013. To be eligible, a site must have had at least 10 new patients enrolled in PMTCT services in the last year, and the site director must have been willing to participate in the study.

In addition to site-level data, patient-level data were sampled by randomly selecting up to 40 eligible Option B patient charts at each site (20 from 2014 and 20 from 2015). To be eligible for selection, the chart was required to contain data from a first antenatal care visit that occurred during the calendar years 2014 or 2015, and occurred after Option B roll-out at the site. Additionally, because half of the sites initiated Option B+ midway through the study, the initial HIV test had to have occurred before the implementation of Option B+ for the chart to be eligible.

Data Collection

All 50 sites were visited by one of three regional research teams at study baseline and end-line. Data were collected from a variety of on-site sources using standardized collection tools. Clinic workforce data (number and type of healthcare workers and number trained in PMTCT or HIV treatment) and health facility data (catchment population, presence of NGO support, urban vs. rural geography, type of facility, and if applicable, start date of Option B+) were collected from key informants (clinic directors or PMTCT point persons). Training in PMTCT or ART generally referred to formal classroom trainings, although there was some flexibility in interpretation by key informants. Data for the number of first ANC visits (ANC1) and number of patients tested for HIV at their ANC1 visit came from site-based registries. Other monthly

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[i] Under Option B treatment and prophylaxis are the same antiretroviral therapy, however prophylaxis refers to women with higher CD4 counts, who qualify for therapy only until the end

PMTCT-related activities (number of pregnant women who were known to be HIV positive prior to the pregnancy, and number of HIV-positive women started on ART or prophylaxis) were collected from onsite monthly reports.

To calculate retention, patient-level data (date of HIV test, start date of prophylaxis or treatment, visit dates) were collected from selected patient charts. Data collectors, with the help of facility staff, first identified all eligible charts, using the sampling methodology described above. If fewer than 20 patient charts were available from each year (2014 and 2015), all charts were selected. If greater than 20 were available, a randomly chosen sample of 20 was utilized. Data were abstracted from the charts into a de-identified collection tool. Charts from 2014 were collected at baseline (June and July 2015) and charts from 2015 were collected at end-line (March and April 2016).

Data Management and Analysis

The collected data were uploaded and compiled into a secure, computerized database. The final sample consisted of 46 sites. One site was excluded from the database because the site did not offer PMTCT services during the study period, a second site requested to be excluded midway through the study, and two sites were excluded because they offered testing, but referred HIV-positive patients to other sites for ART.

Workforce data and health facility data were largely complete, although a number of key informants noted uncertainties in the reported number of trained healthcare workers. Total workforce was defined as the total number of staff documented at the site. Physicians included all generalist doctors (both rotating and permanent), pediatricians, and gynecologists, as well as any other physicians listed under "other", excluding dentists and surgeons. Midwives and nurses were each documented, and managing or head nurses and midwives were included in this count. The indicator for community health workers was defined as an aggregate of social workers, community counselors, and community health agents. Similarly, the pharmacists indicator was defined as both professionally trained pharmacists as well as pharmacy managers, pharmacist assistants and other pharmacy staff. For each category, a number "trained in PMTCT or ART" was also collected, and this total was used to determine the number of trained staff at the site. Density for each category was calculated by averaging baseline and end-line workforce data at each site and dividing by the average number of ANC1 visits per month documented at that site over the 9-month study period.

Of the registry and report data used for this study, missing or corrected data constituted 8.2% of the total expected data points. The most common category of data missing was the number of women seen in maternity that were known to be HIV positive. Missing data were imputed with AMELIA II programming package[ii] in R, using multiple (m=50) expectation bootstrapping to impute data borrowing across time and space. A correlation matrix was used to identify appropriate predictor variables for this model, which included all of the health outcome data collected, as well as clinic site, facility type, catchment population, number of doctors at baseline, number of nurses at baseline and number of doctors trained at baseline. In addition to missing data, data collection teams performed plausibility checks to identify errors in the data, which were documented and investigated. For example if a greater number of women were

[ii] For more information about AMELIA II, please see: https://cran.r-project.org/web/packages/Amelia/vignettes/amelia.pdf

documented to have received HIV tests at their ANC1 visit than the documented number of ANC1 visits, these errors were adjusted such that the proportion was not greater than 1.0 by decreasing the numerator to equal the denominator.

The proportion of pregnant women tested for HIV at the ANC1 visit was calculated on a monthly basis by taking the number of HIV tests performed at the ANC1 visit and dividing that by the number of ANC1 visits each month. The proportion of HIV-positive patients on treatment was calculated for each site over the entire 9-month study period (rather than monthly) since many women would likely have started treatment in a different month than the month in which they tested positive. This proportion was calculated by taking the total number of women receiving prophylaxis or ART over the 9 month period divided by the total number of women known to be HIV-positive prior to the pregnancy or who tested positive during this pregnancy.

Retention estimates were made from a total of 1343 charts that were found to be eligible for use in analysis. Retention was determined at the patient level through a multistep process that utilized the start date of prophylaxis and the most recent visit date, abstracted from patient chart data. To be considered retained in care at 6 months, the patients' most recent visit must have been documented as occurring either more than 6 months after their prophylaxis or ART start date, or after a pre-specified date that was close enough to the 6 month mark that the patient could be assumed to have had enough medicine to last them until at least 6 months after their start date. This pre-specified date was determined at each site based on the number of days worth of treatment given at a single visit. For example, at a site where only 1 month of prophylaxis was given at a time, the patient would need to have had a clinic date after 5 months from her prophylaxis start date to be considered retained in care at 6 months. Patients who did not have a prophylaxis start date were determined to be lost to follow-up (not retained). 12-month retention was calculated similarly.

Odds ratios of the association between each of the workforce variables and each of the four PMTCT outcomes were generated using multivariate logistic regression, with robust variances to account for the correlation of data within clinics (generalized estimating equations [GEE] method). For the treatment and retention outcomes, the GEE used an exchangeable working correlation matrix to account for clustering of data by clinic site. GEE with an independent working correlation matrix was used for the testing outcome for feasibility reasons (due to the large size of the data set). There was significant collinearity between total workforce density, workforce training density and each of the individual workforce categories. To account for this, these covariates were separated out into unique regression equations. Thus, for each of the four PMTCT outcomes (testing, treatment, retention at 6 months and retention at 12 months), three separate logistic regression equations were generated (one for total workforce density, one for training density and one for the workforce subcategories). Each model also included health facility data to account for possible confounding. Specifically, the models for testing included facility type, amount of NGO support (none, one or several NGOs), urban or rural location, time of implementation of Option B plus (for sites where this occurred during the study period), catchment population, and month the test occurred in. The models for retention included the confounders listed above except for month (since treatment proportions were averaged over 9 months). The models for retention included the same health facility data excluding month and time of Option B+ implementation (since charts did not have a corresponding month and were excluded if the patient was tested following Option B+ implementation). Analysis was done using Stata SE v13 (with imputation in R, as described above).

RESULTS

Selected characteristics of the sampled sites are listed in Table 1. The majority of sites were health centers and general hospitals located in urban areas. Nearly all sites had NGO support, and approximately half of the sites implemented Option B+ during the course of this study.

Table 1: Site Characteristics

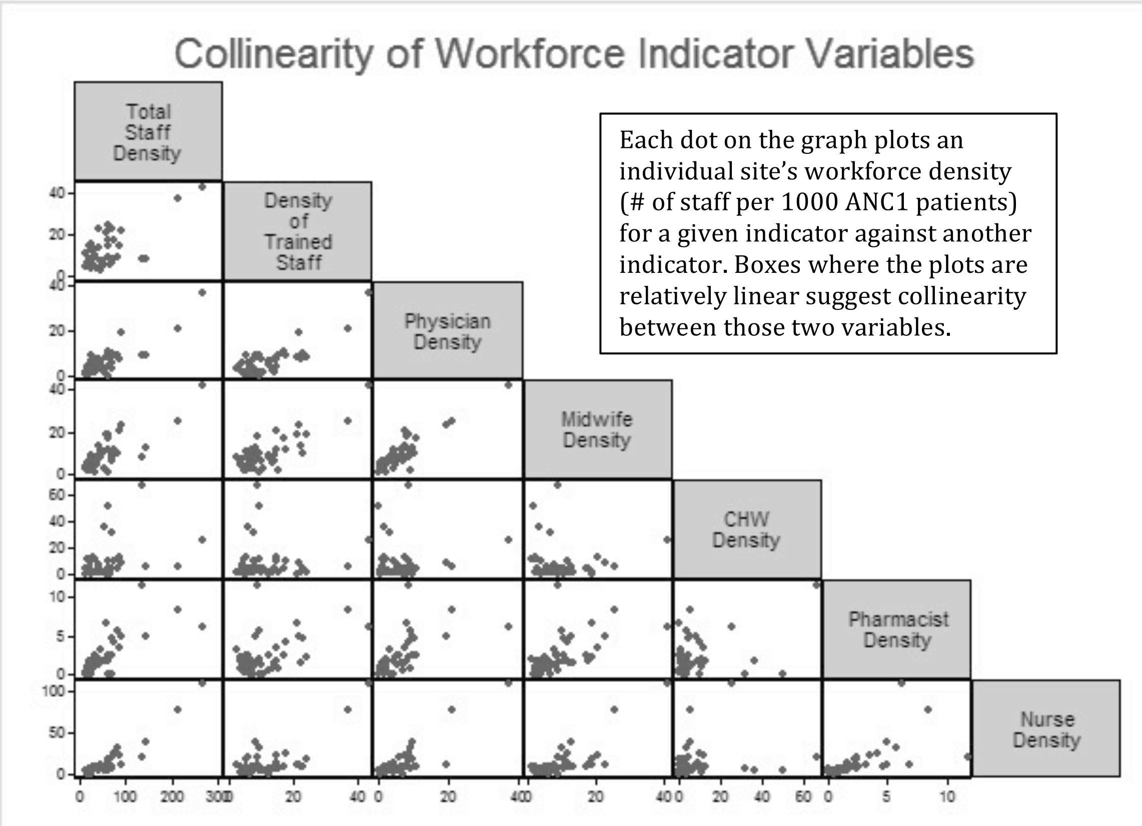
Characteristic	Sites (n = 46)	
Facility type		
- Regional Hospital	4	(9%)
- General Hospital	13	(28%)
- Urban Health Center or Mother & Infant Health Center	27	(59%)
- Rural Health Center	1	(2%)
- Rural Dispensary	1	(2%)
Sites with NGO support	45	(98%)
Site Location		
- Urban	41	(89%)
- Rural	5	(11%)
Sites that implemented Option B+ during the course of the study	23	(50%)
Characteristic	**Average**	
Catchment population size per site	63,877 (range: 8678 - 408,137)	
Number of ANC1 per month per site over the 9-month study period	148 (range: 19 - 456)	

The average characteristics of the workforce are summarized in Table 2, which lists both the total number of workers, as well as the average density of workers per 1000 ANC1 visits. Because each patient has only one ANC1 visit per pregnancy, the density can be more easily interpreted as the number of staff per 1000 patients (or a measure of staff per patient load). The total staff density, density of staff trained and subcategories of workforce density showed significant collinearity, as demonstrated in Figure 1. As any indicator increased, in general, so did the other indicators with the one exception to this trend being density of community-based health workers, which seemed less collinear than the other variables. These trends are shown in Figure 1, which graphs density of each workforce indicator against each of the other indicators.

Table 2: Average Workforce Characteristics

Workforce Indicator	Mean number per clinic	Mean density per clinic (Mean # per 1000 ANC1)
Total Staff	63.0 (8 – 218)	56.7 (13.9 – 266.5)
Staff trained in PMTCT or ART provision	14.2 (0 – 116)	11.7 (0.0 – 43.4)
Physicians	7.7 (0 – 32)	6.2 (0.0 – 37.2)
Midwives	12.8 (0 – 64)	9.5 (0.9 – 41.3)
Community counselors & Social Workers	6.7 (0 – 46)	8.6 (0.0 – 66.9)
Pharmacists	2.5 (0 – 9)	2.4 (0.0 – 11.6)
Nurses	13.2 (0 – 61)	13.0 (0.2 – 107.4)

Figure 1: Collinearity of Workforce Indicators

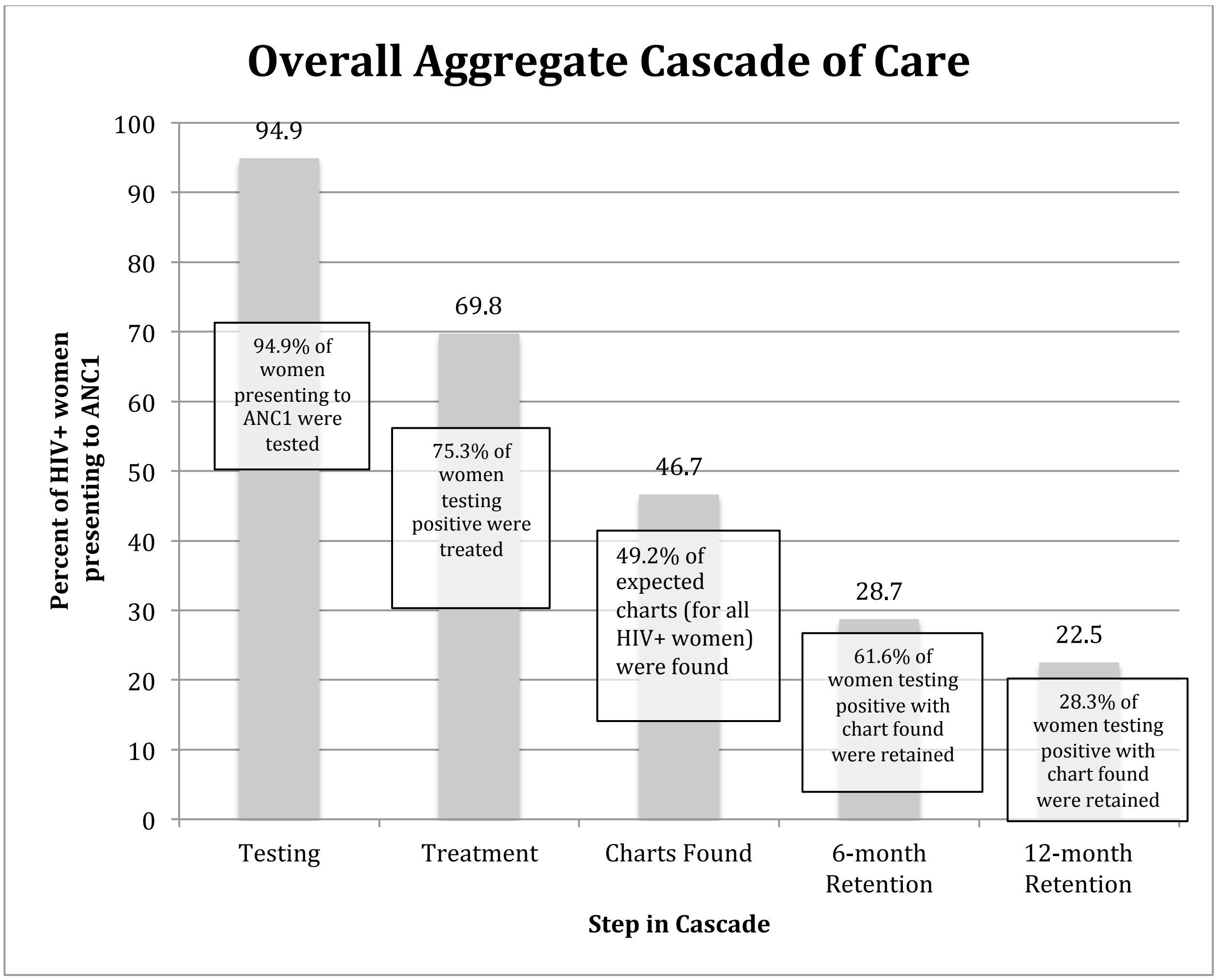


A summary of the aggregated results for the PMTCT outcomes is provided in Table 3. Note that the proportions listed in table 3 do not use the same denominator. The results in Table 3 can subsequently be extrapolated to represent a cascade of care (shown in Figure 2) by transforming the proportions in Table 3 into equivalent proportions with the same numerator (number of HIV-positive pregnant women presenting to ANC1). For example, overall aggregated treatment would be 73.5% of 94.9% (patients tested at ANC1). This extrapolation assumes that HIV-positive patients presenting to ANC1 are just as likely as HIV-negative patients to undergo HIV testing. Additionally, it includes an additional step in the cascade not included as a PMTCT outcome in this study but important in understanding the cascade of care – percentage of charts found. Since retention is calculated using patient charts, women who are HIV-positive but fail to have a chart created for them will be lost to follow-up but will not have a chart to show this. Note that the percentages in Figure 2 refer to a common denominator: number of pregnant women presenting to ANC1, whereas the denominators in Table 3 are different depending on the PMTCT outcome variable.

Table 3: PMTCT Outcomes – Testing, Treatment & Retention

Outcome	Aggregate study average	Range averages by clinic
Testing (proportion of women tested for HIV at their ANC1 visit per month)	94.9%	75.3 – 100.0%
Treatment (proportion of HIV-positive women who received prophylaxis or ART during study)	73.5%	18.5 – 100%
Retention at 6 months (proportion of charts for HIV+ women with evidence of retention 6 months from prophylaxis start date)	61.6%	25.0 – 86.7%
Retention at 12 months (proportion of charts for HIV+ women with evidence of retention at 12 months)	28.3%	0.0 – 59.0%

Figure 2: Overall Aggregate Cascade of Care



When examining the association between workforce densities and PMTCT outcomes, one particular site was noted to be an outlier. This site saw, on average, only 19 ANC1 patients per month, the lowest of any site. All other sites saw more than 30 patients per month (with study average being 148 patients per month). When included in the analysis, results included several negative associations (odds ratios less than one) between workforce density and testing and treatment outcomes. When this outlier was removed, however, several of these negative associations were no longer statistically significant. For this reason, the results in Table 4 and Table 5 are presented using the reduced data set (with the outlier removed). Please see Appendix 1 for the results from the full data set (outlier included).

Overall, after removal of the outlier, workforce densities (with the exception of pharmacist density and CHW density), showed positive statistically significant associations ($p < 0.05$) with testing but not with treatment or retention. Odds ratios presented are for a difference of 1 healthcare worker per 1000 new antenatal care patients. The largest statistically significant positive OR was seen with midwife density (OR = 1.10, 95% CI 1.08-1.12), followed by training density (OR = 1.09, 95% CI 1.08-1.10), physician density (OR = 1.03, 95% CI 1.01-1.05) and total staff density (OR = 1.01, 95% CI 1.01-1.01). Pharmacist density and CHW density showed a negative association with testing (OR = 0.91 [0.86-0.96] and 0.96 [0.95-0.97] respectively) and pharmacist density also was negatively associated with treatment (OR = 0.83, 95% CI 0.69-0.99), even after removal of an outlier. The association between pharmacist density and testing changed significantly with inclusion of the outlier (OR with the outlier = 1.07 vs. 0.91 with the outlier removed), however the negative association with treatment persisted. Table 4 lists the ORs for each of the workforce indicators with each of the PMTCT outcomes with the outlier removed. See the appendix for the ORs with the outlier included.

Table 4: Association between Workforce and PMTCT Outcomes (OR with $p < 0.05$ in bold)

Workforce Indicator	Odds Ratios (95% CI) Testing[a] (n = 61,281)	Treatment (n = 3,803)	6-month Retention (n = 1,343)	12-month Retention (n = 807)
Total Staff Density[c]	**1.01** (1.01-1.01)	0.99 (0.99-1.00)	1.00 (0.99-1.00)	1.00 (0.99-1.01)
Staff Density trained in PMTCT or ART provision[d]	**1.09** (1.08-1.10)	0.98 (0.95-1.01)	1.01 (0.99-1.03)	0.99 (0.97-1.02)
Physician Density[e]	**1.03** (1.01-1.05)	1.00 (0.92-1.09)	1.03 (0.97-1.10)	1.02 (0.94-1.10)
Midwife Density[e]	**1.10** (1.08-1.12)	1.02 (0.96-1.09)	1.01 (0.96-1.06)	0.98 (0.92-1.04)
Community-based health worker Density[e]	**0.96** (0.95-0.97)	1.01 (0.98-1.05)	0.98 (0.95-1.01)	1.02 (0.98-1.07)
Pharmacist Density[e]	**0.91**[b] (0.86-0.96)	**0.83** (0.69-0.99)	0.89 (0.79-1.01)	0.95 (0.80-1.13)
Nurse Density[e]	1.00 (0.99-1.00)	0.98 (0.95-1.02)	1.00 (0.97-1.02)	0.99 (0.96-1.02)

a) Used independent correlation for testing (vs. exchangeable), however all significant p-values were very low ($p \leq 0.003$).
b) With outlier was present, OR = 1.07 ($p < 0.001$)
Logistic Regression Equations Used
c) Logit (outcome) = $\beta_o + \beta_1$(total staff density) + confounders
d) Logit (outcome) = $\beta_o + \beta_2$(density trained) + confounders
e) Logit (outcome) = $\beta_o + \beta_3$(physician density) + β_4(midwife density) + β_5(CHW density) + β_6(pharmacist density) + β_7(nurse density) + confounders

DISCUSSION

This study reveals a small but statistically significant association between increased HIV testing at the first ANC visit and each of the following: midwife density, physician density, total staff density and density of staff trained in PMTCT or ART. This study did not find evidence of a significant association between workforce patterns and retention in care. The greatest association with increased odds of testing was seen with increased density of midwives and increased density of staff trained in PMTCT or ART, followed by increased physician density and increased total staff density. Pharmacist density was negatively associated with testing and treatment, although the inclusion or exclusion of an outlier altered the association with testing significantly, making this association challenging to interpret. CHWs were also negatively associated with testing. Nurse density did not appear to be independently associated with any of the PMTCT outcomes.

It is challenging to understand what these associations might mean without having an idea of what each OR means in terms of the magnitude of workforce changes. The ORs can be interpreted as the multiplicative change in the odds of a patient achieving the given outcome, between a given site and a site with one additional staff member per 1000 ANC1 patients. The ORs reported cannot be interpreted as relative risk, since the outcomes are not rare. The implication of these ORs in terms of overall number of patients tested or treated varies depending on the site's testing rates and number of patients seen per month. At a site with an average testing rate of 95%, and an average number of patients seen per month (148), an OR of 1.10 translates into 7.7 additional patients per year who would benefit from testing in association with the additional staff member (in this case a midwife). Furthermore, only a small percentage of patients tested are positive and benefit from further treatment. This interpretation is provided for each of the statistically significant odds ratios in Table 5. It is evident from Table 5 that the effect size of the associations seen in this study was very small, on the order of fewer than 10 additional patients tested per year at an average site due to one additional staff member, with the exception of the associations with pharmacist density, which were substantial (up to a difference of 67.2 patients per year for an average site).

Positively Associated with Testing: Total Density, Physician Density, Midwife Density and Training Density

The positive associations identified between total density, physician density, midwife density and training density with HIV testing are consistent with the statistical associations found previously in the phase I national assessment of PMTCT in Côte d'Ivoire between these categories and overall PMTCT success. However, this study elucidated that these associations may be small at best and might only be occurring at the level of HIV testing. HIV testing was not included in the amalgamated phase I PMTCT outcome measure, which focused more on infant and child outcomes). Although causation cannot be directly determined, it is plausible to infer that higher numbers of midwives, physicians, total staff and staff trained in PMTCT may be contributors to increased testing rates (even if minimally). Qualitative research from the larger phase II study suggests that midwives and physicians are the primary healthcare workers tasked with the role of performing HIV testing in this population and that training staff in PMTCT is associated with increased staff engagement in PMTCT services. These could certainly be

Table 5: Significance of Findings

Workforce Indicator	Outcome	OR	Interpretation at an average site (approximately 145 ANC1 per month) with average testing, treatment and retention rates
Total staff density	Testing	1.01	0.8 additional patients tested per year at sites with 1 greater total staff per 1000 ANC1 patients.
Density of staff trained	Testing	1.09	7.0 additional patients tested per year at sites with 1 greater total staff trained in PMTCT or ART per 1000 ANC1 patients.
Physician density	Testing	1.03	2.5 additional patients tested per year at sites with 1 more physician per 1000 ANC1 patients.
Midwife density	Testing	1.10	7.7 additional patients tested per year at sites with 1 more midwife per 1000 ANC1 patients.
Community-based health worker Density[e]	Testing	0.96	3.5 fewer patients tested per year at sites with 1 more CHW per 1000 ANC1 patients.
Pharmacist density	Testing	0.91*	8.3 fewer patients tested per year at sites with 1 more pharmacist per 1000 ANC1 patients.
	Treatment	0.83	67.2 fewer patients treated per year at sites with 1 more pharmacist per 1000 ANC1 patients.

These results were calculated by taking the proportion of those tested or treated at an average site (95% and 73.5%, respectively) and finding the odds of testing and treatment (odds = proportion / [1-proportion]). The odds ratio for each category was then multiplied by the odds of testing or treatment and subsequently converted back into a proportion. The difference in the two proportions was multiplied by the average number of ANC1 patients per month (148) and multiplied by 12.
* When outlier included, this OR = 1.07 ($p < 0.05$)

consistent with the quantitative results found in this study. However, since total workforce and training density were analyzed separately, we cannot know from this study whether they are independent contributors to increased testing rates. In fact, the collinearity of the workforce variables makes it challenging to know whether one variable in particular is affecting PMTCT testing, and if so, which one.

Even if a causal relationship did exist between any of these workforce factors and HIV testing, it seems unlikely that workforce intervention based on these associations could be seen as a cost-effective use of limited resources, particularly when compared to the many other factors that increase PMTCT service delivery. Although testing is one of the first steps in the PMTCT cascade (and thus an important gateway outcome), the fact that it was the only PMTCT outcome to have a positive statistically significant association with workforce density, in combination with the fact that the average HIV testing rate was found to be 95%, suggests that it may be important to focus on these other steps of the PMTCT cascade.

Much of the literature that suggests that increased workforce density is associated with increased HIV service delivery comes from countries with overall physician, nursing and midwife densities significantly lower than Côte d'Ivoire's workforce densities. Although Côte d'Ivoire – with a physician density of 0.13 and a nurse and midwife density of 0.48 per 1000 people – is far from reaching the WHO recommendation of 23 doctors, nurses and midwives per 1000 people, it still performs much better than many other countries in sub-Saharan Africa. Uganda, for example, has demonstrated significant increases in HIV service provision as a result of significant increases made to their healthcare workforce,[9] however in 2005 they had healthcare workforce densities that were approximately half that of Côte d'Ivoire.[10] It may be the case that there is a threshold, above which, workforce challenges can be managed without too great of an impact on PMTCT service provision. A five-country study (Angola, Burundi, Lesotho, Mozambique and South Africa) from 2013 found that even countries with widely disparate workforce capacities were able to meet HIV service provision challenges through task shifting, use of temporary or retired staff, and other community, NGO or health system initiatives.[11] It is likely that similar adjustments are being made to meet workforce demands in Côte d'Ivoire.

Negatively Associated with Testing and Treatment: Pharmacist Density

The negative associations between testing and treatment with pharmacist density were surprising, since it is unclear how pharmacists might play a role in HIV testing at all and easy to imagine that more pharmacists would lead to more patients receiving treatment. Although there are limited studies from sub-Saharan Africa, numerous studies in the United States suggest that clinical pharmacist involvement in HIV care improves outcomes.[12] However this study demonstrated the opposite. The association between pharmacist density and testing is admittedly somewhat challenging to interpret, since the inclusion or removal of a single outlier site changed both the effect size and the direction of the association significantly. However, the negative association between pharmacist density and treatment remained stable regardless of the outlier inclusion.

This negative association between pharmacist density and treatment was not seen in the phase I national assessment,[3] nor has it been described in this way in other literature. The majority of studies out of Sub-Saharan Africa regarding pharmacist involvement in HIV care surround patient satisfaction, which is largely positive.[13,14] One qualitative study out of South Africa does suggest that pharmacists have largely been 'left out' of HIV trainings and that pharmacies have not necessarily undergone the structural adjustments that other departments have undergone to adapt to HIV service programs.[15] A study from Zimbabwe suggested that pharmacists may have negative attitudes towards patients with HIV because they result in higher workload, which could have the potential to affect patient outcomes.[16] The applicability of these findings to Côte d'Ivoire is unclear.

One possible explanation surrounds the definition of pharmacist used for this study. Included in the category of "pharmacist" were not only certified pharmacists, but also pharmacy assistants and pharmaceutical staff. One possible explanation is that sites with a larger number of "pharmacists" actually had more staff in the pharmacy with less training, leading to lower numbers of patients receiving treatment. Additionally, pharmacist density, in remaining consistent and utilizing the data available, was calculated using a denominator of number of ANC1 visits per month. Given that pharmacists are involved in the treatment of non-PMTCT patients, and likely see only those patients requiring treatments, this may be poorly representative of actual density per workload. It is clear that further research needs to be done to explore the role of pharmacists in PMTCT programs in Côte d'Ivoire and the underlying cause of this association, which is likely more complicated than it appears here.

Community Health Workers: The Odd One Out?

The other negative association found in this study was between CHWs and testing. Although this was a small association, it is consistent with previous findings in the phase I assessment.[3] Additionally, this association was found in the context of CHWs being the only category of healthcare workers to not be co-linear with the other categories of workforce. The collinearity between the other workforce variables likely suggests that clinics with more staff, in general, have more of all types of staff, not just a single category. The exception to to this trend is for the density of community health workers. This might suggest that some clinics with fewer staff are employing more CHWs to help fill their workforce needs. It is possible that if CHWs (who are less trained and cannot adequately substitute for the clinical needs filled by a physician, nurse or midwife) are being employed to fill this gap, they may be associated with lower testing rates.

In Côte d'Ivoire, CHWs include community counselors and social workers, both of which are non-professional positions (unlike the other categories of healthcare workers). Qualitative work for the phase II assessment suggests that the roles of community counselors and social workers overlap and are generally focused on connecting patients with clinic services, performing home visits and ensuring follow-up – essentially they are the frontline outreach personnel. Theoretically then, it would be expected that CHWs would play a role in encouraging patients to come to the clinic and to be retained in care, but not necessarily in testing or treatment rates, although at least one study suggests that CHWs can improve early testing rates for pregnant women.[17] Our findings are not consistent with this literature and thus future research is needed to understand why the negative association between the density of CHWs and testing has now been seen twice in national PMTCT assessments in Côte d'Ivoire, perhaps exploring why CHW density does not correlate as strongly with the density of other clinic staff and whether this has implications for health outcomes.

Putting it All Together

In light of these results, the question emerges of whether more is always better. That is, these results suggest a relationship between workforce patterns and the PMTCT cascade that is complex and not monotonic. Rather than a higher density necessitating better outcomes, it may be that there is an optimal workforce density for which Côte d'Ivoire and other countries should be aiming, or that other workforce factors, such as organization and productivity may be key players. In fact, although it is difficult to study, several studies suggest that the effect of workforce is probably non-linear and dependent on other factors than just numbers.[18,19] Using only density and logistic regression, as was done in this study, it is challenging to fully define what is likely a more complex relationship between workforce and the PMTCT cascade. Indeed, qualitative work from the larger phase I and II national assessment suggests that although healthcare workers perceive worker availability, workload and training to be important, numerous other facilitators and barriers may interact with these inputs to determine whether they influence the PMTCT cascade.

Limitations

As a cross-sectional study, causation cannot be confirmed, and although we attempted to include all likely confounders, there is no doubt that in this real-world setting other non-measured variables could be playing a role, including changes across time, which were not assessed. The PMTCT outcomes measured in this study steps along the PMTCT cascade, however in understanding their implications, it is important to remember that all of them are a surrogate measure for the primary goal of PMTCT: prevention of transmission of HIV to the infant. Since our study was based in clinics, studying actual HIV transmission would have introduced significant bias into our results, since the women delivering at the clinic are much more likely to have been tested, treated and therefore have lower rates of HIV transmission than those not seen in the clinic. Sampling bias may still have occurred, given that in order to be eligible for inclusion in the study, sites were required to have had at least 10 new HIV-positive patients in the last year. Thus, this study likely represents the situation at larger sites (which also tend to be more urban and have more HCWs) rather than the smaller sites. The fact that the site with the least number of ANC1 patients per month was found to be an outlier compared to the rest of the sites supports the conclusion that the findings from this study may not be applicable to smaller sites with fewer ANC1 patients per month or fewer HIV-positive patients.

The most significant limitation in this study, however, had to do with data quality. One data quality limitation emerged from the use of key informants for workforce data collection, which introduced some inconsistencies. Baseline and endline workforce data at some sites were noted to be quite different, and it was unclear whether this might have been due to differences in data collection or simply due to changes that occurred during the 9-month period. There were a significant number of comments made during data collection about the numbers of temporary physicians and midwives, which were sometimes included in the category of "other staff" and sometimes included in their own individual categories. These inconsistencies raise the question of what role these temporary workers might play in contributing to or detracting from any association between workforce density and PMTCT outcomes. Qualitative work from the larger phase II assessment found that healthcare workers perceived temporary workers to be less engaged in PMTCT care, which might mean the future studies need to further explore the impact of temporary staff independent of permanent clinic staff.

Training was another area where data quality was challenging. Although "training in PMTCT or ART" referred generally to MOH-led trainings, the specifics were somewhat self-interpreted by key informants. Thus, training was interpreted somewhat differently from site to site and from baseline to end-line. Some directors noted that they were referring specifically to Option B or Option B+ training, while others referred to general training in PMTCT. Often training was marked as unknown, and thus the number trained is likely an underestimate; this could bias our results towards an OR of 1.0, diminishing our ability to see an association. Future research should develop a system for more clearly denoting differences in training in order to accurately assess the impact of training on PMTCT. Additionally, improvements in systematic documentation of trainings occurring at ANC sites by the Côte d'Ivoire MOH with stakeholder support and input could allow for assessment of trainings using a more systemic record assessment process, rather than through interviews with key informants. This would improve the ability to study the effect of trainings as well as likely improve Côte d'Ivoire's ability to plan for and assess the process of training implementation internally.

As discussed in the methods section, completeness of registries and charts varied substantially as well. Registry incompleteness was mitigated somewhat through the use of imputation for missing PMTCT outcomes. This imputation process may have slightly inflated the statistical significance of the association between physician density, training density and nurse density and the PMTCT outcomes since the imputation method used workforce variables to determine the value of the imputed outcomes. The effect of this would likely be very small, given that the model only used subparts of these variables (i.e., numbers of trained doctors at baseline, which is only a part of what went into the total number of trained staff), however we acknowledge this as a possibility. What is more likely, is that our adjustment of proportions greater than one down to one, has introduced some bias into our results. By reducing the numerator in these situations to match the denominator, we are placing less weight on these sites and their data than may actually be accurate, and thus biasing our results downwards. How this could affect workforce associations is unclear, and would depend on whether sites with these types of systemic errors consistently had more or less staff or subcategory of staff.

The variability in the number of charts found from site to site is also problematic and may have introduced a selection bias into the retention analyses. In order for a patient to be included in the retention analysis, a chart had to have been created for that patient and their HIV test date had to have been documented. Despite national policy mandating that all HIV-positive patients have a chart created for them, many sites had far fewer charts than HIV-positive patients, a finding that was present during the phase I national assessment as well, and was attributed in part to chart stock-outs and alternative informal registries, among other factors.[3] Charts were found with varying reliability from site to site, but it is clear that some sites faced more challenges than others in ensuring chart creation for HIV-positive patients. It is easy to imagine that sites that are less likely to reliably create charts for their HIV-positive patients might also be worse at retaining them in care. In this scenario, chart sampling would bias the results towards higher retention rates. If sites with fewer staff are less able to create patient charts, and the existence of a chart facilitates retention in care, we may be underestimating the association between workforce and retention in care by failing to capture the possibility that fewer staff is associated with lower retention. On the other hand, the opposite could also be true. Sites that are less reliable at creating charts may only do so for women who return for a second visit and are thus more likely to be retained in care. If sites with fewer staff create fewer charts this would over-estimate an association between staff and retention.

Other statistical challenges limiting our results included collinearity of the variables. Collinearity was most strongly present when total workforce density and training density were included in the models. By removing these variables and analyzing them individually in separate models, the estimates for the ORs stabilized. This does result in the limitation that the ORs for each of these values does not take into account the possibility of one being a confounder for the other. In fact, given that overall as total workforce density increases, so does each of the subcategories as well as the staff trained, it is difficult to ascertain which of the variables is more likely to be representative of the true association with the PMTCT outcomes. It would be prudent for future researchers to attempt to better understand how a particular subcategory of staff would be expected to contribute to improved PMCTC outcomes, possibly through more specific in-depth interviews with staff an patients, and base individual quantitative questions off of these theoretical understandings so as to avoid the collinearity encountered when addressing multiple workforce variables at once.

Conclusion

This study provides an assessment of the specific relationships between workforce indicators and individual steps along the PMTCT cascade, albeit with significant limitations. In summary, total workforce density, density of trained staff, midwife density and physician density were all positively and statistically significantly associated with HIV testing in the PMTCT setting, however with a very small effect size, suggesting that these are minimal drivers in the Option B PMTCT cascade in Cote d'Ivoire. Pharmacist density had a larger effect size on testing and treatment, however was negative and challenging to interpret in light of outliers and requires further exploration. A negative association between CHW density and testing was also found but with a much smaller effect size. The challenges faced by this study in attaining these findings highlights the need for improved systematic data collection and data quality regarding both PMTCT outcomes and workforce data. Furthermore, the results – complicated associations between healthcare workers and HIV testing and treatment identified in this study, and the lack of associations identified at later steps in the PMTCT cascade (retention) – highlights the need for further research, both on more nuanced workforce factors (beyond density alone) as well as non-workforce factors that might be the key to improving PMTCT in Côte d'Ivoire.

APPENDIX 1

Association between Workforce and PMTCT Outcomes (OR with p < 0.05 in bold) with outlier included

	Odds Ratios (95% CI)			
Workforce Indicator	Testing[a] (n = 61,281)	Treatment (n = 3,803)	6-month Retention (n = 1,343)	12-month Retention (n = 1,343)
Total Staff Density[c]	**1.01** (1.01-1.01)	**0.99*** (0.96-1.00)	1.00 (0.99-1.00)	1.00 (0.99-1.01)
Staff Density trained in PMTCT or ART provision[d]	**1.08** (1.07-1.09)	0.98 (0.95-1.01)	1.01 (0.99-1.03)	1.01 (0.98-1.03)
Physician Density[e]	**1.04** (1.02-1.06)	1.00 (0.92-1.09)	1.04 (0.98-1.11)	1.02 (0.95-1.09)
Midwife Density[e]	**1.09** (1.07-1.11)	1.02 (0.96-1.09)	1.00 (0.96-1.05)	0.96 (0.91-1.02)
Community-based health worker density[e]	**0.97** (0.96-0.98)	1.01 (0.98-1.03)	1.00 (0.98-1.02)	1.02 (0.99-1.04)
Pharmacist Density[e]	**1.07**[b] (1.03-1.12)	**0.81** (0.70-0.93)	0.95 (0.85-1.04)	0.93 (0.83-1.05)
Nurse Density[e]	**0.98*** (0.97-0.99)	0.99 (0.96-1.02)	0.99 (0.97-1.01)	1.01 (0.99-1.03)

* No longer statistically significant when outlier removed
a) Used independent correlation for testing (vs. exchangeable), however all p-values were very low ($p \leq 0.001$).
b) When outlier removed, OR = 0.91 (95% CI 0.86-0.96, $p < 0.001$)
Logistic Regression Equations Used
c) Logit (outcome) = $\beta_o + \beta_1$(total staff density) + confounders
d) Logit (outcome) = $\beta_o + \beta_2$(density trained) + confounders
e) Logit (outcome) = $\beta_o + \beta_3$(physician density) + β_4(midwife density) + β_5(CHW density) + β_6(pharmacist density) + β_7(nurse density) + confounders

REFERENCES:

[1] Elimination of mother-to-child transmission (EMTCT) of HIV and Syphillis: Global guidance on criteria and processes for validation. 2014. Available at: http://apps.who.int/iris/bitstream/10665/112858/1/9789241505888_eng.pdf?ua=1&ua=1 (accessed, June 24, 2016).

[2] UNAIDS. Côte d'Ivoire: 2014 Progress Report on the Global Plan. Country Report 2014. Available at: http://www.unaids.org/sites/default/files/media/documents/UNAIDS_GlobalplanCountryfactsheet_cotedivoire_en.pdf (accessed June 1, 2014).

[3] Gloyd S, Robinson J et al. PMTCT cascade analysis in Côte d'Ivoire: Results form a national representative sample. *HIVCore Final Report*. Washington, DC: USAID | Project Search: HIVCore. 2014. Available at: http://catalogue.safaids.net/publications/pmtct-cascade-analysis-côte-d'ivoire-results-national-representative-sample (accessed June 3, 2016).

[4] Gulaid L and Kiragu K. Lessons learnt from promising practices in community engagement for the elimination of new HIV infections in children by 2015 and keeping their mothers alive: summary of a desk review. *J Int AIDS Soc*. 2012;15(suppl 2):17390.

[5] Paintsil E and Andiman WA. Update on successes and challenges regarding mother-to-child transmission of HIV. *Curr Opin Pediatr*. 2009;21(1):94-101.

[6] Côte d'Ivoire Ministry of Health. Strategic Plan for the Development of Human Resources for Health in Côte d'Ivoire: 2009-2013. 2008. Available at: http://www.who.int/workforcealliance/countries/CotedIvoire_PlanStrategique_2009_2013_Fr.pdf?ua=1 (accessed March 30th, 2016).

[7] Gaber S and Patel P. Tracing health system challenges in post-conflict Côte d'Ivoire from 1893 – 2013. *Glob Public Health*. 2013;8(6):698-712.

[8] UNFPA. The State of the World's Midwifery 2014: A Universal Pathway. A Woman's Right to Health. 2014:88. Available at: http://www.unfpa.org/sowmy (accessed June 3, 2014)

[9] Jaskiewicz W, Oketcho V et al. Investing in the Health Workforce to Increase Access to and Use of HIV and AIDS Services in Uganda. *AIDS*. 2016. May 9. [Epub ahead of print].

[10] African Health Workforce Observatory. 2010. Country Monitoring: Uganda and Côte d'Ivoire. Available at: http://www.hrh-observatory.afro.who.int/en/home.html (accessed July 25, 2016).

[11] Cailhol J, Craveiro I, et al. Analysis of human resources for health strategies and policies in 5 countries in Sub-Saharan Africa, in response to GFATM and PEPFAR-funded HIV-activities. *Global Health*. 2013;25(9):52.

[12] Kibicho J, Pinkerton SD et al. Are community-based pharmacists underused in the care of persons living with HIV? A need for structural policy changes. *J Am Phamr Assoc*. 2015;55(1):19-30.

[13] Okoye MO, Ukwe VC et al. Satisfaction of HIV patients with pharmaceutical services in South Eastern Nigerian hospitals. *INt J Clin Phamr*. 2014;26(5):914-921.

[14] Agu KA, Oqua D et al. Assessment of satisfaction with pharmaceutical services in patients receiving antiretroviral therapy in outpatient HIV treatment setting. *Int J Clin Pharm*. 2014;26(3):636-647.

[15] Gilbert L. 'Pharmacists have been left out of the loop': exploring the role of pharmacists in the management of HIV/AIDS in South Africa. *Int J of Pharm Practice*. 2016;24(1):40-48.

[16] Ball DE and Mazarurwi P. HIV/AIDS knowledge and attitudes amongst pharmacists in Zimbabwe. *Cent Afr J Med*. 2003 49(3-4):27-31.

[17] Lema IA, Sando D et al. Community health workers to improve antenatal care and PMTCT uptake in Dar es Salaam, Tanzania: a quantitative performance evaluation. *J Acquir Immune Defic Syndr*. 2014;67(Suppl 4):195-201.

[18] Birch S, Kephart G et al. Human Resources Planning and the Production of Health: Development of an Extended Analytical Framework for Needs-Based Health Human Resources Planning. *J Publ Health Mngmt & Pract*. 2009;15(6):S56-S61.

[19] WHO and Management Sciences for Health. Tools for Planning and Developing Human Resources for HIV/AIDS and other health services. 2006. Available at: http://www.who.int/hrh/tools/tools_planning_hr_hiv-aids.pdf?ua=1 (accessed June 24, 2016).