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Inter-relationships among key reproductive health indicators in sub-Saharan Africa focusing on the central role of maternal literacy

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Background: Indicators of reproductive health (RH) are expected to be both inter-related and associated with key social determinants. As the provision of RH services is usually integrated, the effort to improve one RH component should influence the other components. However, there is a lack of evidence-based models demonstrating the inter-relationships. The purpose of this study was to examine the inter-relationships among key RH indicators and their relationship with women's literacy in sub-Saharan Africa (SSA).

Methods: Data were sourced from the most recent demographic and health survey conducted between 2010 and 2016 in 391 provinces of 29 SSA countries. We examined seven RH indicators along with women's literacy. The unit of analysis was at the provincial level. Structural equation modelling was used to examine the strength of relationships among these indicators and with women's literacy, using the total standardized effect sizes. Significance tests and 95% confidence intervals (CIs) for these effects were calculated using a bias-corrected bootstrap method.

Results: RH indicators are strongly interrelated and are associated with women's literacy. The strongest relationship is observed between women's literacy rate and the contraception prevalence rate, with a total standardized effect size of 0.79 (95% CI 0.74–0.83). The model of inter-relationships developed in this study may guide the design, implementation and evaluation of RH policies and programmes.

Conclusions: The key challenge in reducing fertility in SSA is to reduce people fertility desire. This could mainly be addressed by enhancing integrated approaches especially between the education and health sectors.

Keywords: inter-relationship, reproductive health, sub-Saharan Africa

Introduction

Ideally, countries' health systems improve the health and well-being of their citizens through evidence-based policy, programme management, research and partnerships.[1] Health ministries work in collaboration with different stakeholders to achieve the best from the health service programmes guided by an overarching strategy. The provision of integrated reproductive health (RH) services is a key component of a healthcare system. The integration should be apparent from the top level, where a harmonized effort results in coordination of available resources, to the grass-roots level, where RH services are provided for needy mothers in a one-stop-shop style.[2,3]

RH, an implied component of the World Health Organization's definition of health, indicates that women and men have the right to be informed of and to have access to safe, effective, affordable and acceptable methods of fertility regulation of their choice. This includes the right of all women to have access to appropriate, safe and affordable obstetric care, birth control and healthcare services[4] because it is vital to their lives, their babies, their families and the society at large.[5]

Much attention is given to improving RH in developing countries, as indicated by the existence of policies, management strategies and guidelines that are put in place by international agencies and governments to improve RH service uptake and to prevent, manage and report simple and complicated maternal cases.[6,7] Nonetheless, the burden of disease associated with RH in the developing world is still unacceptably high.[8]

Sub-Saharan Africa (SSA), a region with the highest population growth rate in the world,[9] is known to be one of the developing regions with the poorest RH status. The maternal mortality ratio, which is considered to be the key impact indicator of health status among all public health statistics, is high, mainly due to high fertility rates,[10] low coverage and poor quality of services, along with the influence of challenging operating environments and harmful traditional practices.[11]

RH services are best provided in an integrated manner.[12] In a region where the density of skilled health professionals is low,[13] an integrated approach has the potential to improve synergy and maximize efficiency.[5] The integration of RH services has many other benefits, including improvement of availability of services and supporting staff training that can improve opportunities for early identification and treatment of health problems.[14] Most importantly, integrated services lead to fulfilment of client needs.[15] Accordingly, there are considerable efforts made to integrate RH services in SSA.[16,17]

Family planning (FP), which reduces pregnancy and child birth–related risks by increasing birth intervals,[18] is enhanced by effective maternal health services provided as a continuum of care from conception to the postnatal period. This usually starts with the diagnosis of pregnancy, followed by provision of antenatal care (ANC) and skilled birth attendance (SBA) services. Postnatal care (PNC) services, which start immediately after delivery, include fertility control.[19] During postnatal visits, mothers should receive counselling services about FP options so that they can make informed decisions about birth control.[20] Moreover, exclusive breastfeeding in the first 6 months after birth, or the lactational amenorrhea period, provides effective protection against pregnancy.[21]

There has been debate about the impact of FP programmes on fertility reduction, focusing on the relative importance of reducing fertility desire and improving access to FP for reducing fertility.[22,23] It has been claimed that the difference in total fertility rate (TFR) across countries can mainly be explained by differences in fertility desire, not by access to contraception.[24,25] It has been established, however, that FP efforts are important not only for reducing fertility, but also for reducing fertility desire through access to information.[26,27]

Besides service integration, RH indicators are thought to be inter-related due to common social, demographic and cultural pre-disposing factors that may affect each of the RH indicators, although the strength of these effects may vary from one indicator to another.[28–30]

Women's empowerment,[31,32] access to services,[33] health communication[34] and educational status are among the key determinants of RH. It has also been revealed that women's literacy is the main predictor for demographic and social determinants of RH.[35] For instance, a country- and region-level multicountry trend study in SSA by Bongaarts[36] highlighted the importance of education in decreasing TFR and fertility desire as well as improving demand for and utilization of contraception. Other studies have suggested the importance of education for improving RH status. Literate women have better health outcomes[37] because they are likely to have better access to information and services[38] and better health service–seeking behaviour.[39] With these facts in mind, we hypothesize that women's literacy rate is the common predictor of RH indicators.

However, there is limited evidence on the actual strength of the inter-relationships among these indicators and their relationship with women's education in the SSA region. Existing literature has focused on relationships among specific components of RH, such as ANC and SBA,[40] fertility desire, demand for and use of FP as well as fertility status[36] or the relationship of these variables with key determinants.[28] However, the relative strength of these relationships has not yet been systematically investigated. Moreover, the effect of education on selected RH indicators is mainly assessed at a national level.[36] This study examined the inter-relationships among the common RH indicators and their association with literacy rate in SSA.

Conceptual model

In order to establish the extent to which the RH indicators are inter-related, a conceptual model was developed, as shown in Figure 1. This approach, sometimes called model generating, produces a tentative and simple initial model based on facts and literature that may be modified after being tested using the actual dataset.[41] After removing a few indicators due to potential multicollinearity, the model had seven observed RH indicators—ANC, SBA, PNC, contraception prevalence rate (CPR), ideal number of children, birth interval and TFR—and one sociodemographic indicator—women's literacy rate. In this model, TFR is assumed to be the overall outcome indicator, whereas women's literacy rate is the main predictor of better RH, with direct relationships to seven of the RH indicators. It is hypothesized that provinces with higher literacy rates tend to increase their mean birth intervals and reduce their mean ideal number of children, leading to lower TFRs. A higher ideal number of children is hypothesized to contribute to shorter birth intervals and subsequent higher TFRs. In addition, it is hypothesized that better PNC will increase the CPR, which in turn will decrease the TFR.

The RH indicators included in the conceptual model form four groups, namely maternal health services (ANC, defined as receipt of at least one ANC service during the last pregnancy, SBA and PNC), fertility control (CPR), fertility desire (ideal number of children) and fertility status (birth interval and TFR).

It is also hypothesized that indicators representing each RH group, for instance the three maternal health service indicators, are more related to each other than to indicators representing another group (e.g. fertility control).

Methods

Description of data source

The study used provincial (regional) key RH and women's literacy rates sourced from the demographic and health survey (DHS) database.[42] The DHS, sponsored by the US Agency for International Development, has been collecting international data on fertility for >30 y, focussing on low- and middle-income countries. Data are collected by household surveys, with procedures and protocols reviewed by the Institutional Review Board (IRB) of

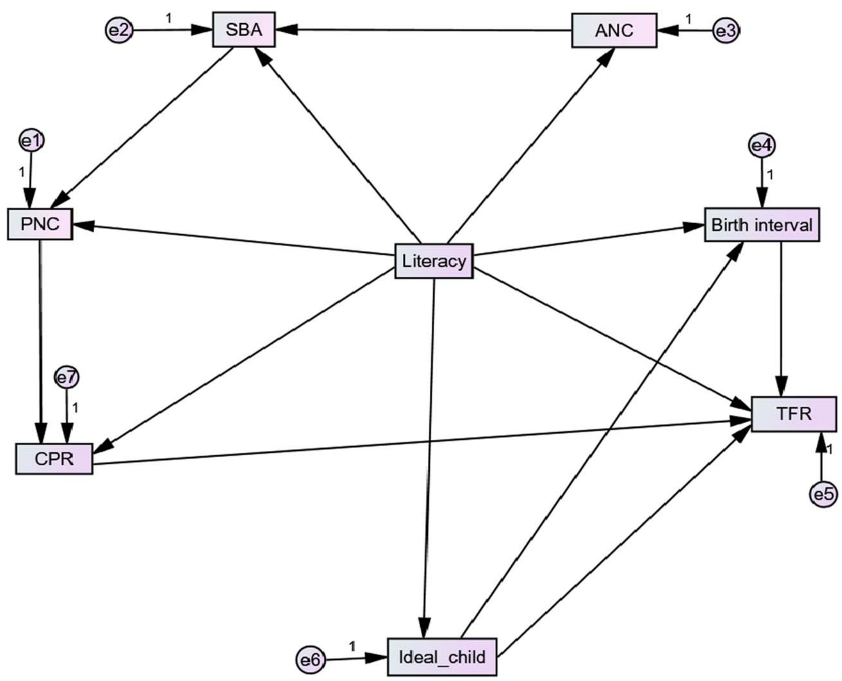

Figure 1. Conceptual framework of inter-relationship among reproductive health indicators. ANC = Antenatal care coverage, SBA = skilled birth attendance coverage, PNC = postnatal care coverage, CPR = contraceptive prevalence rate, Ideal child = mean ideal number of children, TFR = total fertility rate, Birth interval = median birth interval, Literacy = women's literacy rate.

ICF International and frequently by an IRB in each participating country. Ethical approval has been granted by all relevant bodies.[43] The DHS VI recode manual was used as a guide for identifying, coding and merging the datasets. The detailed sampling method is described in the DHS manual.[44]

Study indicators

This study used selected RH indicators from each of the four RH thematic areas: maternal health, fertility control, fertility desire and fertility status (Figure 1). The indicator data at the provincial level were aggregated using means, medians or percentages as appropriate. Percentage values were used for coverage data such as ANC, SBA, PNC and CPR. Mean values were used for TFR and the ideal number of children, and the median value was used for birth interval as per DHS's aggregation practice.[45] Descriptions of each indicator and the method of aggregation (percentage, mean or median) are displayed in the appendix (Table A2).

Data analysis

Structural equation modelling (SEM) was applied to test and describe the extent of the relationships among the various indicators using SPSS Amos version 24 (IBM, Armonk, NY, USA). SEM is a technique used to describe linear relationships among measured or latent variables.[46] Here we applied path analysis to examine the inter-relationships among the measured RH indicators. SEM allows the testing of a number of inter-relationships simultaneously.[47] It can be used for both exploratory and confirmatory research. This allowed testing of the initial conceptual model shown in Figure 1 and the subsequent development of a model that better described the data.

Model assessment, modification and validation

We used χ^2 goodness-of-fit tests to determine if the hypothesized model describes the data well.[48] However, due to the limitations of χ^2 statistics, their sensitivity to sample size and reliance on the assumption of normality,[49,50] we also considered other absolute and relative goodness-of-fit indices. We used root mean square error of approximation (RMSEA) and probability of close fit (PCLOSE; =P[RMSEA<5% in the population]) as absolute fit indices, whereas we applied the normed-fit index (NFI), goodness-of-fit statistic (GFI) and comparative fit index (CFI) as relative fit indices. RMSEA <0.08, PCLOSE >0.05, GFI, NFI and CFI >0.95 are associated with good model fit,[48,50] producing acceptable type I and type II error rates.

Model validation

We randomly split (50:50) the data into a training and a validation dataset, with the training data used to evaluate the initial conceptual model as described above. When the model fit was found to be inadequate, the training data were used to further develop the conceptual model based on theory and using the standardized residual covariances to identify missing paths.

Standardized residual covariances are defined as the difference between the sample covariance and the model-implied covariance for each pair of indicator variables. Regression weights were added one at a time to the model linking the pair of indicators with the highest standardized residual covariance in absolute value. We followed this approach until all standardized residuals were less than two in absolute value. Simultaneously we removed paths with non-significant regression weights from the model, ensuring that the model was not overfitted. The validation data were then used to evaluate the goodness of fit for this final model. We reported the standardized coefficients for all paths. Significance tests and 95% confidence intervals (CIs) for the total effects were calculated using the bias-corrected bootstrap method.

Results

Background characteristics (see the appendix Table A1)

A total of 391 provinces from 29 countries were considered in this study. Among the provinces included in the study, the highest number were in Tanzania and Malawi, whereas Comoros contributed the smallest number of provinces. The Democratic Republic of the Congo, Cote d'Ivoire, Ethiopia, Ghana and Mozambique had 11 provinces, similar to the regional median number of provinces. The regional mean women's literacy rate was 56.5%. While Lesotho had the highest (97%) literacy rate, the lowest (14%) was observed in Niger. Less than half (47.1%) of married women in the region agreed with at least one reason supporting the view that wife beating is justified, but this percentage was 76.3% for Malian women.

RH characteristics

Mean values for RH indicators by country are displayed in Table 1. ANC had the highest coverage among the RH indicators in the region. The majority of the countries (62%) had >90% ANC coverage while only four countries achieved <70% coverage. The median SBA coverage was 64%, and 50% of the countries achieved between 54% and 81%, with the median institutional delivery slightly lower (median 63% [interquartile range 23]). PNC coverage was relatively low in almost every country, with a median regional coverage of 31% (interquartile range 32%). The median regional TFR was 5 children, with a minimum of 3.3 in Lesotho to a maximum of 7.6 in Niger. With a regional median coverage of 18%, CPR ranged from 5% to 66%.

Correlation among RH indicators

Table 2 shows that maternal health indicators were strongly correlated with each other at the provincial level. ANC and SBA had a moderate strength correlation (r=0.62). A slightly stronger correlation was observed between SBA and PNC (r=0.66). Despite the expectation of a strong relationship between PNC and CPR, we found only a moderate relationship (r=0.45). In contrast, there was a weak, negative, linear relationship (r=−0.21) between PNC and unmet need for FP. As expected, CPR was negatively correlated with unmet need for FP (r=−0.43). This supports the argument that when women obtain access to contraceptive services, unmet need for FP decreases.

A strong, positive, linear relationship was observed between the mean ideal number of children and TFR (r=0.72). Provinces with a higher mean ideal number of children tended to have a higher TFR. TFR also had a strong negative correlation with birth interval. A shorter birth interval allows the possibility of having more children, which in turn increases the TFR. There was therefore a strong negative relationship between ideal number of children and birth interval. All the bivariate correlations were statistically significant. Most of the significant correlations were moderate to strong in strength, demonstrating substantial associations among the RH indicators.

SEM

As shown in Table 3, the conceptual model evaluated by the training data was found to provide a poor fit with the data in terms of both the absolute and relative indices (RMSEA=0.260, NFI=0.825, GFI=0.793 and CFI=0.833). The model was improved progressively, as indicated by the standardized residual covariances, by adding one regression weight at a time as shown in Table 3. Additions were made only when they could be justified in theoretical terms. For instance, it was assumed that provinces with a high TFR tend to have low maternal health service coverage. After removing the non-significant regression weights, the final model described the data reasonably well, with all the indices within the expected range. The χ^2 test was also not statistically significant, confirming an adequate model (χ^2[8]=9.15, p=0.330; 64.5% chance of true RMSEA <5%).

Standardized direct effects

The SEM in Figure 2 shows the final model with the standardized weights estimating standardized changes in each dependent indicator for a 1 standard deviation (SD) increase in each independent indicator when the other independent variables were statistically controlled. These are referred to as standardized β coefficients. As indicated in this model, women's literacy was found to be the key predictor having a direct relationship with all seven RH indicators in the final model. For instance, women's literacy rate was a strong predictor of mean ideal number of children (β=−0.70 [95% CI −0.75 to −0.63]) when controlling for the other RH indicators. However, contrary to expectation, women's literacy rate had a negative direct relationship with PNC (β=−0.23 [95% CI −0.37 to −0.03]) and birth interval (β=−0.26 [95% CI −0.37 to −0.14]).

As expected, the RH indicators were inter-related. The strongest direct relationship was observed between CPR and median birth interval (β=0.63 [95% CI 0.50–0.77]). Maternal health indicators were interrelated and were affected by different RH indicators. For a 1 SD increase in provincial SBA coverage, PNC coverage increased by 0.51 SDs (95% CI 0.34 to 0.63). Provinces with a high TFR tended to have low PNC service coverage (β=0.22 [95% CI −0.36 to 0.09]). This model explains 65% of the variation in TFR, 69% of the variation in CPR and 67% of the variation in SBA.

Standardized indirect and total effects

The standardized total effects (the sum of direct and indirect effects) along with the bias-corrected 95% CIs for these estimates are presented in Table 4. In the total standardized effects, the strongest relationship was observed between literacy rate and CPR (standardized effect size 0.79 [95% CI 0.74–0.83]), followed by the relationship between literacy rate and SBA (standardized effect size 0.73 [95% CI 0.66–0.78]). After taking

Table 1. Percentage and mean values of RH indicators in SSA countries between 2010 and 2016

Country (survey period)	ANC (%)	SBA (%)	Institutional delivery (%)	PNC (%)	CPR (%)	Unmet need (%)	Demand satisfied (%)	Birth interval (median)	Wanted TFR (mean)	Ideal number of children (mean)	TFR (mean)
Angola (2015–2016)	81.6	49.6	45.6	18.3	12.5	38.0	24.3	30.8	5.2	4.9	6.2
Benin (2011–2012)	85.8	84.1	86.9	47.0	7.9	32.6	17.4	35.6	4.0	4.6	4.9
Burkina Faso (2010)	94.9	23	66.3	12.7	15.0	24.5	36.9	35.9	5.4	5.5	6.0
Burundi (2010)	98.9	60.3	59.5	29.4	17.7	32.4	32.7	32.0	4.5	4.2	6.4
Cameroon (2011)	84.7	63.6	61.2	33.1	14.4	23.5	30.8	32.7	4.5	5.5	5.1
Chad (2014–2015)	63.7	24.3	21.7	11.6	5.0	22.9	17.6	29.3	6.1	8.2	6.4
Comoros (2012)	92.1	82.2	76.1	17.4	14.2	32.3	27.4	31.0	3.8	5.3	4.3
Congo (2011–2012)	85.9	83.1	91.5	54.9	20.0	18.4	31.7	38.8	4.8	5.0	5.1
Cote d'Ivoire (2011–2012)	90.6	59.4	57.4	56.1	12.5	27.1	27.5	36.8	4.5	5.2	5.0
Democratic Republic of the Congo (2013–2014)	88.4	80.1	79.9	31.3	7.8	27.7	16.3	30.4	5.7	6.1	6.6
Ethiopia (2016)	62.4	27.7	26.2	15.4	35.3	22.3	60.6	34.5	3.6	4.5	4.6
Gabon (2012)	94.7	87.1	90.2	22.2	19.4	26.5	33.7	37.6	3.4	4.6	4.1
Gambia (2013)	98.9	64.0	62.6	55.2	8.1	24.9	23.8	34.2	4.9	6.0	5.6
Ghana (2014)	97.3	73.7	73.1	68.1	22.2	29.9	39.2	39.4	3.6	4.3	4.2
Kenya (2014)	95.5	61.8	61.2	49.1	53.2	17.5	70.7	36.3	3.0	3.6	3.9
Lesotho (2014)	95.2	77.9	76.5	61.5	59.8	18.4	76.1	45.8	2.3	2.6	3.3
Liberia (2013)	95.9	61.1	55.8	54.7	19.1	31.1	37.2	37.4	4.2	4.8	4.7
Malawi (2015–2016)	94.8	89.8	91.4	41.3	58.1	18.7	74.6	41.0	3.4	3.7	4.4
Mali (2012–2013)	74.2	58.6	55.0	27.2	9.9	26.0	27.2	33.5	5.3	5.9	6.1
Namibia (2013)	96.6	88.2	87.4	68.0	55.3	17.5	75.0	45.1	2.9	3.2	3.6
Niger (2012)	82.8	29.3	29.8	29.0	12.2	16.0	40.8	30.9	7.4	9.2	7.6
Nigeria (2013)	60.6	38.1	35.8	29.9	9.8	16.1	31.3	31.7	5.2	6.5	5.5
Rwanda (2014–2015)	98.0	90.7	90.7	41.1	47.5	18.9	65.8	38.5	3.1	3.4	4.2
Sierra Leone (2013)	97.1	59.7	54.4	41.2	15.6	25.0	37.5	36.0	4.5	4.9	4.9
Tanzania (2015–2016)	95.2	63.7	62.6	31.4	32.0	22.1	52.9	35.0	4.5	4.7	5.2
Togo (2013–2014)	50.0	44.6	72.5	7.5	17.3	33.6	32.3	38.0	4.1	4.3	4.8
Uganda (2011)	94.9	58.0	57.4	29.9	26.0	34.3	40.5	30.2	4.7	4.8	6.2
Zambia (2013–2014)	95.7	64.2	67.4	6.4	44.8	21.1	63.8	34.9	4.5	4.7	5.3
Zimbabwe (2015)	93.3	78.1	77.0	43.1	65.8	10.4	85.2	43.7	3.6	3.9	4.0

Congo, Republic of the Congo.

Table 2. Bivariate correlations among RH indicators

	ANC	SBA	PNC	CPR	TFR	Ideal number of children	Birth interval
ANC	1						
SBA	0.618*	1					
PNC	0.500*	0.660*	1				
CPR	0.449*	0.653*	0.448*	1			
TFR	−0.349*	−0.639*	−0.557*	−0.651*	1		
Ideal number of children	−0.551*	−0.706*	−0.505*	−0.720*	0.721*	1	
Birth interval	0.408*	0.579*	0.557*	0.724*	−0.755*	−0.681*	1

*Correlation is significant at the 0.01 level (two-tailed).

Table 3. Progressive model fit indices based on standardized residual covariance between indicators

Regression weights added	SRC	Fit indices									
		χ^2	DF	Sig	Normed χ^2	GFI	TLI	CFI	NFI	RMSEA	PCLOSE
Conceptual model		211.465	15	<0.001	14.098	0.793	0.689	0.833	0.825	0.260	<0.001
PNC→Birth interval	4.500	167.745	14	<0.001	11.982	0.832	0.739	0.870	0.861	0.238	<0.001
Ideal child→Birth interval	−3.925	123.040	13	<0.001	9.465	0.878	0.799	0.907	0.898	0.209	<0.001
Ideal child→ANC	−2.604	103.119	12	<0.001	8.593	0.896	0.820	0.923	0.915	0.198	<0.001
CPR→Birth interval	3.086	54.136	11	<0.001	4.921	0.939	0.907	0.963	0.955	0.142	<0.001
TFR→PNC	−1.889	48.231	10	<0.001	4.823	0.942	0.909	0.968	0.960	0.140	<0.001
Ideal child→CPR	−1.562	30.957	9	<0.001	3.440	0.962	0.942	0.981	0.974	0.112	0.009
Ideal child→PNC	−1.234	30.069	8	<0.001	3.759	0.963	0.935	0.981	0.975	0.119	0.006
TFR→SBA	−1.155	14.416	9	0.044	2.059	0.982	0.975	0.994	0.988	0.074	0.200
*Non-sig paths removed		27.226	11	0.004	2.475	0.969	0.965	0.986	0.977	0.087	0.065
**TFR→PNC	−1.271	16.501	10	0.065	1.650	0.979	0.985	0.994	0.986	0.058	0.350
***ANC→PNC	0.773	11.272	6	0.274	1.252	0.986	0.994	0.998	0.991	0.036	0.589
Ideal child→SBA	−0.383	9.150	8	0.330	1.144	0.988	0.997	0.999	0.992	0.027	0.645
Final model											
Training data		9.150	8	0.330	1.144	0.988	0.997	0.999	0.992	0.027	0.645
Validation data		16.082	8	0.041	2.010	0.981	0.976	0.993	0.987	0.072	0.207

SRC, standardized residual covariance. Other abbreviations are written in full under Figure 1.

*The following non-significant paths were removed at this stage: PNC→CPR (p=0.081), PNC→CPR (p=0.874), ideal child→PNC (p=0.620), TFR→PNC (p=0.079).

**The model using the validation data provided a poor fit: χ^2(10)=42.034, p<0.001; RMSEA=0.128, PCLOSE=0.001.

***The model using the validation data provided a poor fit: χ^2(9)=27.329, p=0.001; RMSEA=0.101, PCLOSE=0.024.

indirect effects into account, there was a positive relationship between literacy rate and birth interval (standardized effect size 0.51 [95% CI 0.42–0.58]) and a positive relationship between literacy rate and PNC (standardized effect size 0.43 [95% CI 0.33–0.53]) as originally expected. In addition, there was a negative relationship between TFR and PNC (standardized effect size −0.32 [95% CI −0.46 to −0.16]) and between birth interval and TFR (standardized effect size −0.45 [95% CI −0.57-−0.34]) as expected. Provinces with a lower TFR tended to have higher use of maternal health services, and CPR was a positive predictor of birth interval (standardized effect size 0.65 [95% CI 0.51 to 0.78]). Women's literacy rate was the strongest predictor of TFR (standardized effect size −0.62 [95% CI −0.70 to −0.54]), with higher TFR when literacy rates were low, but the effect of the

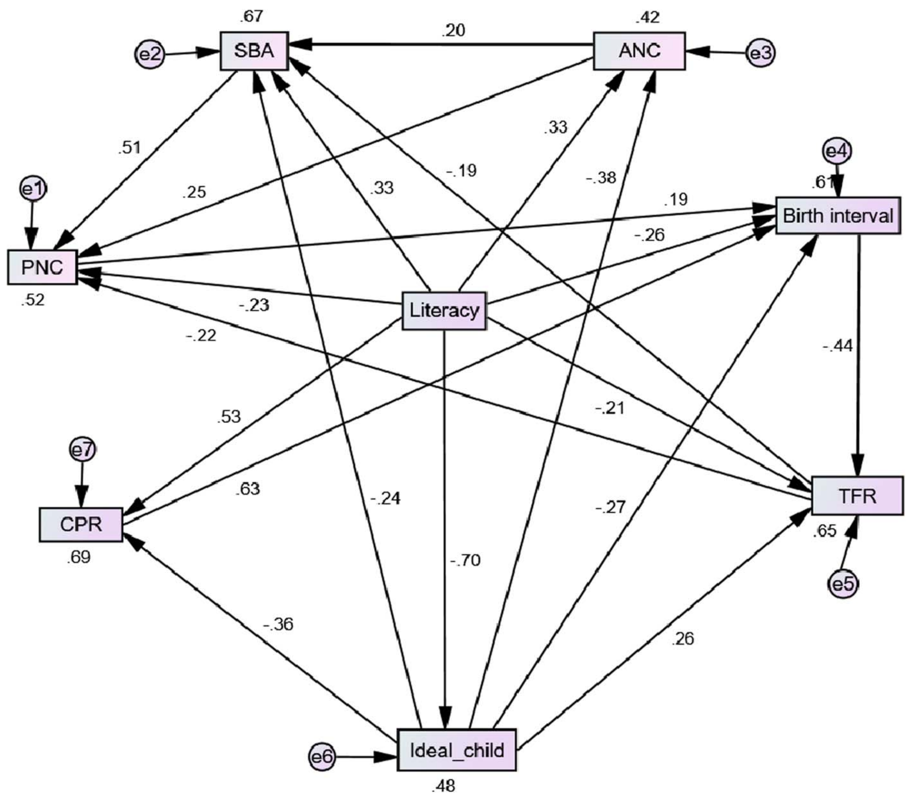

Figure 2. Structural equation model of RH indicators with standardized (β) weights and R^2 values shown.

mean estimate for the ideal number of children was also strong (standardized effect size 0.52 [95% CI 0.38–0.62]), with a larger mean ideal number of children associated with a higher TFR.

Discussion

This study examined the inter-relationship among key RH indicators and women's literacy. The analysis was conducted at a subnational level where each country in the region was represented by its provinces. This allows for examination of the indicators intracountry that would otherwise be obscured with a national analysis. In the final model, literacy rate had direct links to all the RH indicators. In line with the existing literature about social determinants of health, especially the power of literacy on overall health literacy,[51] findings in this study suggest that improving women's literacy rate is a key tool for improving RH service uptake. Moreover, the indirect relationships between women's literacy and RH indicators implies that improving women's literacy rate may also have a long-term effect on key RH status indicators such as TFR.

There were statistically significant relationships among the RH indicators included in this study. This may reflect common background factors such as socio-economic status, education status and access to and quality of healthcare services. It may also be due to the policy landscape of a country and the implementation capacity of the respective provinces or attributed to the integrated provision of RH services within each province. As stated elsewhere,[25] neighbourhood cultural effects may contribute to high fertility desire. Women living in areas where TFR is high or where having more children is the norm would be less likely to make use of FP. Ecological interventions on intervening community and societal factors to increase awareness and the ability of women to have a manageable number of children may be a key means for improving demand and utilization of FP services.

The correlation and standardized β coefficients in the final model suggested that provinces with high ANC service coverage tended to have high SBA coverage. High SBA coverage in turn resulted in increased PNC service uptake. Even though ANC, SBA and PNC are expected to be highly corrected to form unmeasured/latent variables, the relationships between these indicators were not strong enough for a latent variable called maternal health to be constructed. This indicates that the relationships among these maternal health indicators was not uniform across provinces. First, ANC service addresses service coverage (quantity) rather than service quality,[52] which may result in an inflated count in some provinces. Second, SBA and PNC services require clinical care services[53] while ANC services can be provided by community health workers in provinces where health facilities are not within travelling distance. Third, there may be differences in the cascade of maternal services from ANC to PNC across different provinces. This is evidenced by changes in the gap between the coverage of ANC and SBA services among countries across time.[28,29] These three maternal health services should be treated separately rather than as a single latent variable due to the differential effects of literacy on these services. The effect of

Table 4. Standardized indirect and total effect sizes with bootstrap-generated CIs using the bias-corrected (BC) percentile method (standardized effect size estimates >0.5 in bold)

Path			Standardized indirect effects with 95% CI				Standardized total effects with 95% CI			
			Estimate	95% bootstrap CI		BC sig level	Estimate	95% bootstrap CI		BC sig level
				lower	Upper			Lower	Upper	
ANC	←	Literacy	0.26	0.13	0.42	0.011	**0.59**	0.50	0.66	0.013
ANC	←	Ideal child	0.00	—	—	—	−0.38	−0.58	−0.19	0.009
Ideal child	←	Literacy	0.00	—	—	—	−**0.70**	−0.75	−0.63	0.019
CPR	←	Ideal child	0.00	—	—	—	−0.36	−0.45	−0.23	0.012
CPR	←	Literacy	0.25	0.17	0.31	0.016	**0.79**	0.74	0.83	0.009
Birth interval	←	Literacy	**0.77**	0.65	0.89	0.010	**0.51**	0.42	0.58	0.018
Birth interval	←	Ideal child	−0.31	−0.39	−0.23	0.009	−**0.58**	−0.69	−0.48	0.014
Birth interval	←	CPR	0.02	0.01	0.03	0.006	**0.65**	0.51	0.78	0.006
Birth interval	←	ANC	0.07	0.03	0.13	0.007	0.07	0.03	0.13	0.007
Birth interval	←	PNC	0.01	0.00	0.01	0.009	0.19	0.10	0.29	0.012
Birth interval	←	SBA	0.10	0.06	0.17	0.006	0.10	0.06	0.17	0.006
Birth interval	←	TFR	−0.06	−0.12	−0.03	0.007	−0.06	−0.12	−0.03	0.007
TFR	←	Ideal child	0.26	0.19	0.36	0.010	**0.52**	0.38	0.62	0.023
TFR	←	Literacy	−0.41	−0.47	−0.30	0.025	−**0.62**	−0.70	−0.54	0.012
TFR	←	Birth Interval	−0.01	−0.02	0.00	0.010	−0.45	−0.57	−0.34	0.01
TFR	←	ANC	−0.03	−0.06	−0.01	0.005	−0.03	−0.06	−0.01	0.005
TFR	←	CPR	−0.29	−0.41	−0.22	0.004	−0.29	−0.41	−0.22	0.004
TFR	←	PNC	−0.09	−0.14	−0.05	0.013	−0.09	−0.14	−0.05	0.013
TFR	←	SBA	−0.04	−0.08	−0.03	0.007	−0.04	−0.08	−0.03	0.007
SBA	←	ANC	−0.03	−0.06	−0.01	0.007	0.21	0.09	0.34	0.005
SBA	←	Literacy	0.40	0.31	0.54	0.006	**0.73**	0.66	0.78	0.002
SBA	←	Ideal child	−0.17	−0.26	−0.10	0.005	−0.41	−0.54	−0.30	0.007
SBA	←	TFR	−0.01	−0.02	0.00	0.006	−0.20	−0.36	−0.09	0.007
SBA	←	Birth interval	0.09	0.04	0.16	0.008	0.09	0.04	0.16	0.008
SBA	←	CPR	0.06	0.02	0.11	0.006	0.06	0.02	0.11	0.006
PNC	←	SBA	0.01	0.01	0.02	0.007	**0.53**	0.36	0.65	0.008
PNC	←	ANC	0.11	0.05	0.18	0.003	0.36	0.23	0.54	0.009
PNC	←	Literacy	**0.66**	0.56	0.76	0.014	0.43	0.33	0.53	0.006
PNC	←	TFR	−0.11	−0.19	−0.06	0.003	−0.32	−0.46	−0.16	0.016
PNC	←	Ideal child	−0.42	−0.51	−0.31	0.014	−0.42	−0.51	−0.31	0.014
PNC	←	CPR	0.09	0.04	0.16	0.012	0.09	0.04	0.16	0.012
PNC	←	Birth interval	0.14	0.07	0.22	0.012	0.14	0.07	0.22	0.012

literacy on PNC was relatively low (standardized effect size 0.43) compared with the effects of literacy on ANC (standardized effect size 0.59) and SBA (standardized effect size 0.73) in particular.

The strongest association was observed between women's literacy rate and CPR followed by the relationship between women's literacy rate and SBA. This suggests that women's literacy is a key mechanism in order to improve utilization of contraceptive and maternal health services. The standardized total effect sizes indicate that the mean ideal number of children was a negative predictor of CPR as well as median birth interval. However, it was a positive predictor of TFR. At the individual level, a high ideal number of children suggests low demand for contraception. Therefore it is unlikely there would be 'unmet or met need' for FP; rather it suggests there is 'no unmet need' for FP. Targeting women with a high ideal number of children should be a priority for FP services. It was once said that the difficult task is not about reducing unwanted fertility but it is about reducing people's fertility desire.[54]

While improving women's literacy rate was found to be a key predictor for reducing the ideal number of children, desired number of children was an important predictor of contraceptive use (β=−0.36), indicating a direct pathway. While literacy and ideal number of children had direct and indirect effects on TFR, CPR had an indirect effect on TFR through birth interval. However, the relationship may not be that simple, as it may be mediated or moderated by important demographic transitions such as change in infant mortality rate, as well as epidemiological transitions, such as changes in disease patterns. Two theories have been suggested for explaining the positive relationship between TFR and infant mortality.[55] A high TFR may be a response to high infant mortality. On the other hand, it has also been argued that close spacing of births, a key predictor for TFR in the current study, contributes to high infant mortality. In the absence of definitive information about fertility desire and fertility status, previous research suggests that among the key factors driving fertility are fecundability, survival chances, contraceptive practices and other RH milestone practices such as age at first marriage.[56] In the SSA region, where age at first marriage is low[57] and CPR is <18%, integration of RH services with clinical care services as well as with community-based youth services is important to ensure that necessary services are provided throughout the life cycle—adolescence, pregnancy, childbirth, postnatal period and childhood.[12,58]

Two unexpected findings from the fitted model were the negative direct relationships of literacy rate with PNC and birth interval. These relationships contradicted the simple correlations where a positive relationship was observed in both cases. There is evidence in developed countries that private health facilities, more likely attended by educated women, are less likely to provide the required PNC services.[59] However, further research is needed to determine if this is the case in SSA. As shown in the model, positive relationships were observed in the total effect sizes for this model, due to the indirect effects through ANC, SBA and CPR services. Therefore, as expected, a higher literacy rate for a province is associated with higher PNC coverage and longer median birth intervals.

CPR had a strong direct effect on birth interval (standardized effect size 0.65) and birth interval was an important predictor of TFR (standardized effect size −0.45). These results confirm findings from previous studies about the role of CPR in increasing birth interval and ultimately reducing fertility rates.[60] The negative relationship between TFR and maternal health indicators such as SBA and PNC can be partly explained by the fact that provinces with a high TFR tend to have low women's empowerment, as indicated in this study and elsewhere,[31] which negatively impacts on the utilization of maternal health services. Supporting the direction of effect from TFR to SBA, prior research that examined the effect of parity on SBA services[61] noted that high parity was a negative predictor of SBA service uptake.

The existence of strong relationships among RH indicators suggests that integrated policies and strategies may be more effective in improving RH outcomes than those that focus on a single indicator. Our findings confirm that improving women's literacy will be critical in improving CPR and thereby reducing fertility in SSA countries, with implications for integrated policy-making, implementation and evaluation in addressing maternal health and RH issues in the region. More specifically, the model of inter-relationships developed in this study may be an important tool in policy analysis, as it describes the strengths of inter-relationships among key RH indicators that are also outcomes/impact indicators of common RH programmes in SSA.

The findings of this study also substantiate the need for integrated approaches to maternal health and FP services in SSA. The fact that women's literacy came out as a strong predictor of RH indicators suggests that responsibilities for improving RH outcomes is not limited to the healthcare system, but extends to the educational sectors as well. Given the considerable inter-relationships among RH indicators, system-wide effects of programmes should be considered in the design, implementation and evaluation of maternal health and population control initiatives and policies in SSA. The model developed in this study would be useful in guiding any evaluation of RH programmes in SSA.

This study has demonstrated the application of SEM in examining the inter-relationships among RH indicators in SSA. Unlike the traditional regression analysis approaches, SEM provides a basis for a more holistic analysis of inter-relationships among the RH indicators. Future studies could consider this approach for analysis of inter-relationships in individual-level data for specific countries. The model developed in this study could also be used to guide the design and analysis of further research concerning RH indicator relationships using similar techniques.

There are some limitations associated with this study. First, the study focused on aggregated indicator data at the province level, so there is a possibility of ecological bias[62] because the provinces are heterogeneous even within a country. Second, there existed time differences in the data collection period of the DHS from 2010 to 2016, and this could affect the comparability of the data across provinces.

Conclusions

Based on the findings of this study, the following conclusions can be drawn. The SEM developed in this study described the training and the validation data. In the resulting model, literacy rate stood out as a strong predictor of most of the RH indicators included in this study and had a direct effect on all RH indicators included in the model. It was also the most important predictor of CPR, ideal number of children, birth interval, SBA, ANC and TFR when indirect and direct effects were considered simultaneously. There existed moderate to high correlation among the RH indicators, suggesting that RH indicators are inter-related to each other in the SSA context. Maternal health indicators (especially SBA and PNC) and birth interval were influenced by the majority of RH indicators, and CPR was found to be the main predictor of birth interval. The ideal number of children had both a direct and indirect relationship with TFR. The key challenge in reducing fertility in SSA is to reduce people's fertility desire. This could mainly be addressed by enhancing integrated approaches, especially between the education and health sectors. This study applied aggregated data with time differences among surveys, therefore further research might be needed to assess the significance of the inter-relations using individual records.

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Appendix 1

Table A1. Background characteristics of the women surveyed

Country	DHS period	Provinces, n (N=391)	Women who are literate, %	Final say in all of the decisions, %	Access to electricity, %	Worked in the last 12 months, %	Teenagers childbearing, %	Problems in accessing healthcare[a], %	Wife beating justified[b], %	No access to mass media, %
Angola	2015–2016	18	58.1	65.4	41.6	65.1	34.5	70.2	25.2	26.2
Benin	2011–2012	18	35.1	48.3	38.4	63.6	16.5	68.6	16.2	45.7
Burkina Faso	2010	14	22.5	12.0	13.1	74.8	23.6	78.5	43.5	48.1
Burundi	2010	5	61.5	49.6	5.3	73.4	9.6	86.0	72.9	38.7
Cameroon	2011	17	69.2	23.7	53.7	62.2	25.2	39.0	46.5	40.1
Chad	2014–2015	21	22.1	17.4	7.7	42.9	35.9	29.3	73.5	81.4
Comoros	2012	3	63.3	34.6	69.3	36.6	11.3	78.2	39.0	38.0
Congo	2011–2012	14	82.2	28.4	41.6	64.2	32.9	72.8	60.7	34.8
Cote d'Ivoire	2011–2012	11	37.7	23.6	55.8	67.1	29.6	77.6	47.9	45.5
Democratic Republic of the Congo	2013–2014	11	63.8	33.5	13.5	67.2	27.2	76.0	74.8	66.3
Ethiopia	2016	11	42.0	70.6	25.6	33.3	12.5	70.0	63.0	73.6
Gabon	2012	14	88.7	43.7	89.3	43.7	27.6	80.8	50.2	7.5
Gambia	2013	8	45.0	39.2	44.5	42.6	17.5	43.0	58.4	29.6
Ghana	2014	11	67.1	61.6	78.3	73.4	14.2	50.7	28.3	30.8
Kenya	2014	8	87.8	55.8	36.0	61.4	18.1	46.1	41.8	22.9
Lesotho	2014	10	97.0	65.4	27.8	37.8	19.1	41.8	33.3	31.7
Liberia	2013	20	47.9	65.9	9.8	54.9	31.3	62.3	42.5	55.5
Malawi	2015–2016	38	72.1	46.9	10.8	62.6	29.0	73.9	16.3	62.8
Mali	2012–2013	9	20.6	8.9	25.6	42.6	39.3	58.6	76.3	45.8
Namibia	2013	17	93.4	74.6	47.4	42.7	18.6	43.3	28.2	27.1
Niger	2012	10	14.0	12.3	14.4	24.5	40.4	70.2	59.6	59.0
Nigeria	2013	6	53.1	31.3	55.6	61.8	22.5	51.0	34.7	50.4
Rwanda	2014–2015	5	80.2	65.4	22.8	77.7	7.3	58.6	41.4	36.2
Sierra Leone	2013	18	35.5	45.4	13.5	68.1	27.9	71.9	62.8	56.2
Tanzania	2015–2016	39	76.8	35.2	22.5	72.3	26.7	65.5	58.0	46.1
Togo	2013–2014	7	52.3	29.4	45.7	70.3	16.5	65.7	28.7	39.4
Uganda	2011	8	64.2	37.5	14.6	69.3	23.8	64.9	58.3	21.0
Zambia	2013–2014	10	67.5	53.8	27.9	48.8	28.5	50.2	46.9	34.1
Zimbabwe	2015	10	94.4	72.1	33.7	41.3	21.6	58.6	38.7	45.2

[a]Access to healthcare: Problem in any of the following issues: knowing where to go for treatment, getting permission to go for treatment, getting money for treatment, distance to health facility, having to take transport, not wanting to go alone, concern that there may not be female privacy.
[b]Wife beating: Attitude towards wife beating for any of the following reasons: burns food, argues with husband, goes out without telling husband, neglects children, refuses to have sex with husband.

Table A2. Description of RH indicators

Indicator	Province-level aggregated value
Skilled ANC	Percentage of women with live births in the 5 y preceding the survey who received ANC from a skilled provider
Skilled birth attendance	Percentage of live births in the 5 years preceding the survey assisted by a skilled provider. Skilled provider includes doctor, nurse, midwife and auxiliary nurse or midwife
Institutional delivery	Percentage of live births in the 5 y preceding the survey delivered at a health facility
PNC	Percentage of women giving birth in the 2 y preceding the survey who received their first postnatal check-up in the first 2 d after birth from a doctor, nurse or midwife
CPR	Percentage of married women who were taking contraceptives during the survey
Unmet need for FP	Percentage of married women who were not pregnant and who wanted to delay or who did not want any children but who were not using any FP method
Demand satisfied by modern contraceptive	Percentage of women with demand for FP who received contraceptive services (met need for FP divided by unmet need plus met need)
TFR	The average number of children a woman would have if the current fertility status continues
Ideal children	Mean ideal number of children of all women
Birth interval	Median birth interval (months)
Teenage motherhood	Percentage of teenagers who began childbearing
Background and sociodemographic indicators	
Literacy	Percentage of women who were literate
Mass media	Percentage of women who had access to any mass media
Working	Percentage of women who had been working in the last 12 months
Decisions	Percentage of women who had the final say in all decisions
Beating justified	Percentage of married women who believed that wife beating is justified for at least one specific reason