Indirect estimation of age-specific induced abortion rates in Sub-Saharan Africa

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Abstract

There is a lack of international comparisons of abortion levels and age-specific abortion rates. This study evaluates two methods of indirect estimation of abortion incidence by age group and applies them using Demographic and Health Surveys from Burkina Faso, Ethiopia, Nigeria and Rwanda. The revised residual method rearranges Bongaarts' proximate determinants of fertility equation leaving the index of abortion on the left using the revised Bongaarts (2015) method, which produces age-specific abortion rates. The 'Classification Method' groups unclassified pregnancy termination data into induced or spontaneous abortions using WHO's (1996) protocol. The absolute levels of abortion from the revised residual method were sensitive to bias in the other indices measured. The classification method failed to classify most terminations into either category. Moreover, terminations were likely underreported. We show that the methods of indirect measurement of abortion need to be context-specific and are subject to bias.

Introduction

Around 35% of pregnancies in Africa are unintended. About a half of such pregnancies end in an induced abortion (from now on: *abortion*). Millions of women are treated each year due to complications of unsafe abortion in developing countries (Sedgh et al. 2014; Singh, Sedgh, et al. 2010; Singh and Maddow-Zimet 2016). Three in four abortions in Africa in 2010-14 were unsafe (Ganatra et al. 2017) and abortion remains a key contributor to maternal morbidity and mortality in the area. For instance, in 2003-09 an estimated 10% (N≈125,000) of maternal deaths in Sub-Saharan Africa (SSA) were due to unsafe abortion (Say et al. 2014). SSA was the only area in the world, where deaths attributable to unsafe abortion increased between 1990 and 2013 (Kassebaum et al. 2014). This was perhaps in part due to increased exposure: estimated abortion rate in SSA in 2010-14 increased to 31-35 abortions per 1000 women aged 15-49 from 28-32/1000 in 1990-94 (Sedgh et al. 2016). Abortion is either illegal or only allowed if woman's life is at risk in most countries in SSA. Despite its contribution to maternal mortality and morbidity, little is known about which socio-demographic groups in Sub-Saharan Africa have a higher likelihood of obtaining abortions.

Due to its stigmatised nature, political and social sensitivity abortion is understudied and often severely underreported in surveys. No method of abortion estimation is able in most contexts to provide complete reports, and the choice of method depends on the goal of the estimation; studying a population's abortion rate, socio-demographic determinants of abortion, or abortion trends over time demand different methods (Rossier 2003; Singh, Remez, et al. 2010). Due to the issues with data collection, there is a lack of international comparisons on the subject as well as studies producing age-specific abortion rates.

This study aims to test methods of estimation of abortion incidence in data-poor countries using existing datasets. Demographic and Health Surveys (DHSs) data were chosen, because these data are internationally comparable and frequently collected in SSA. Using such secondary data sources enables international comparisons of abortion trends and determinants. Such comparisons help evaluate whether the methods used are robust across contexts. The study also aims to estimate differences in the incidence of abortion by age.

This study compares two methods, which can be used to indirectly estimate abortion incidence: the residual and the classification methods. The residual method takes advantage of the proximate determinants of fertility framework (Bongaarts 1978; Davis and Blake 1956) to estimate the incidence of abortion in a population (see Data and Methods section). While this method has been used before (Johnston and Hill 1996), it was based on the old Bongaarts'

(1978) model. The revised Bongraats' (2015) method is used here, which (unlike the old version) produces age specific estimates. Its accuracy has improved markedly (Bongaarts 2015).

The classification method takes advantage of routinely collected DHS pregnancy termination data, which does not differentiate between induced and spontaneous abortions. A version of WHO's (1996) protocol is applied to classify terminations into induced and spontaneous based on circumstances preceding the termination (see Magnani et al. 1996).

This paper shows preliminary results for four countries (Burkina Faso, Ethiopia, Nigeria and Rwanda) on testing the performance of the two methods using DHS data on all women of fertile age (i.e. ages 15 to 45/49) by 5-year age groups and investigates sensitivities in the estimates produced using the revised residual method.

Data and methods

Four countries with recent DHS calendar data and Guttmacher Institute's abortion incidence estimates (see Bankole et al. 2013, 2015; Basinga et al. 2012; Moore et al. 2016) collected within two years of the DHS were selected: Burkina Faso 2010, Ethiopia 2016, Nigeria 2013 and Rwanda 2010. The 5-year retrospective DHS calendar records monthly contraceptive use, reasons for discontinuation, pregnancy history, fertility preferences and intentions. In the absence of reliable government abortion statistics, Guttmacher's studies provide a point of reference for this study's results.

The revised residual method

The residual method (see Johnston and Hill 1996) rearranges Bongaarts' proximate determinants of fertility equation leaving the index of abortion on the left. The Bongaarts' equation estimates fertility reduction from the theoretical maximum (i.e. 'total fecundity', TF) due to sexual exposure, contraceptive use, abortion, and postpartum infecundability. The revised residual method assumes that any reduction in fertility not accounted for in the other three indices is due to induced abortion. This study uses the revised Bongraats' (2015) method as the basis for the residual estimation (eq. 1).

Bongaarts method (1a) *Revised residual method (1b)*

$$f(a) = C_m(a) * C_c(a) * C_i(a) * C_a(a) * f_f(a) \qquad C_a(a) = \frac{f(a)}{C_m(a) * C_c(a) * C_i(a) * f_f(a)} \qquad \text{(Eq. 1)}$$

where the modified indices are: *f(a)* fertility rate, C_m sexual exposure; C_c contraception; C_i postpartum infecundability; C_a abortion index; and f_f total fecundity rate. All indices are age-specific, as indicated by *(a)*.

The indices $C_m(a), C_c(a), C_i(a)$ and $C_a(a)$ range from 0 (inhibits all fertility) to 1 (does not have any impact on fertility). The calculation of the indices is described in Table 1.

Table 1. Calculating revised Bongaarts indices (Bongaarts 2015, p. 545).

Index	Formula	Notes	Eq.
$C_m(a)$	$C_m(a) = m(a) + ex(a)$	, where *m(a)* = proportion in union and *ex(a)* = sexually active women* not in union.	*(2a)*
$C_c(a)$	$C_c(a) = 1 - r(a)\big(u(a) - o(a)\big)e(a)$	, where *u(a)* = contraceptive prevalence among exposed women; *o(a)* = contraceptive overlap with PPI; *e(a)* = contraceptive effectiveness; *r(a)* = fecundity adjustment.	*(2b)*
$C_i(a)$	$C_i(a) = \frac{20}{18.5 + i(a)}$	, where *i(a)* = average duration of PPI.	*(2c)*
$C_a(a)$	$C_a(a) = \frac{f(a)}{f(a) + \left(\frac{14}{18.5 + i(a)}\right) * ab(a)}$	, where *ab(a)* is a regional abortion rate as estimated by (Sedgh et al. 2012)**.	*(2d)*

Notes: PPI = postpartum infecundability. *Women who are not married or cohabiting are counted as sexually active, if they report sex within the last month, are using a contraceptive method, are pregnant or postpartum abstaining. ** In our study, the index of abortion was estimated using the revised residual method rather than eq. 2d.

The index of interest, that is, index of abortion $C_a(a)$, estimates the fertility reducing effect of abortion. It can be transformed to age-specific abortion rates and a total abortion rate (TAR), which is analogous to total fertility rate (TFR). TAR can be used to estimate the abortion rate per 1000 women of reproductive age.

The advantages of using the revised Bongaarts method rather than the old Bongaarts method (see Bongaarts 1978) include its improved accuracy in estimating TFR of a population compared to the old method (Bongaarts 2015) and that it produces age-specific rates. The old method's limitations include possible bias in the other indices (Reinis 1992), which leads to bias in the residual estimate of $C_a(a)$. The new method has taken steps to reduce such bias. In addition, the old method assumed that abortion's effect on total fecundity (TF) is negligible. The estimated TF thus may have included some fertility-reducing effect of abortion (Johnston and Hill 1996), but steps have been taken to prevent this in the revised method (Bongaarts 2015). However, as the revised residual method uses observed age-specific fertility rates (ASFRs) for index *f(a)*, any discrepancies between the observed and estimated ASFRs may still cause bias to the abortion estimate.

Evaluating the residual method

To evaluate the accuracy, we first compared the resulting abortion rates to those estimated by the Guttmacher Institute (see Bankole et al. 2013, 2015; Basinga et al. 2012; Moore et al. 2016). The evaluation of the accuracy of the abortion rate estimates was based on the Guttmacher Institute estimates, because no reliable national estimates of abortion exist in these countries.

Second, to provide intuition about the effect of measurement error and bias in the indexes used to construct the estimates of age specific abortion rates, we conducted a local sensitivity analysis. This uses the partial derivative of estimates with respect to each of the components of the proximate determinants of fertility to examine the effects of small changes in these values on abortion rates.

The expression for the $C_a(a)$ given in Eq. 1b can be re-arranged to give an expression for the age-specific abortion rate $ab(a)$ (Eq.2d).

$$
\begin{aligned}
ab(a) &= \frac{f_f(a)C_m(a)C_c(a)C_i(a)}{b(a)} - \frac{f(a)}{b(a)} \\
ab(a) &= \frac{20}{14} f_f(a)C_m(a)C_c(a) - \frac{f(a)}{b(a)} \\
b(a) &= \frac{14}{18 + i(a)}
\end{aligned}
$$

The equation for $ab(a)$ can be interpreted as describing abortion rates as the difference between the fertility rate that would exist without abortion (first term on the right hand side) and the observed fertility rate (second term), both corrected by factor $b(a)$ to account for the differing length of infecundability caused by a live birth versus an abortion.

Taking partial derivatives with respect to the measured indices, we have:

$$
\begin{aligned}
\frac{\partial ab(a)}{\partial f_f(a)} &= \frac{20}{14} C_m(a)C_c(a) \\
\frac{\partial ab(a)}{\partial C_m(a)} &= \frac{20}{14} f_f(a)C_c(a) \\
\frac{\partial ab(a)}{\partial C_c(a)} &= \frac{20}{14} f_f(a)C_m(a) \\
\frac{\partial ab(a)}{\partial f(a)} &= -\frac{1}{b} \\
\frac{\partial ab(a)}{\partial b} &= \frac{f(a)}{b^2}
\end{aligned}
$$

Converting these to elasticities provides the percentage change in abortion rates induced by a percentage point change in one of the variables used in estimation.

$$\frac{f_f(a)}{ab(a)}\frac{\partial ab(a)}{\partial f_f(a)} = \frac{20\ C_m(a)C_c(a)f_f(a)}{14\ ab(a)}$$
$$\frac{C_m(a)}{ab(a)}\frac{\partial ab(a)}{\partial C_m(a)} = \frac{20\ C_m(a)C_c(a)f_f(a)}{14\ ab(a)}$$
$$\frac{C_c(a)}{ab(a)}\frac{\partial ab(a)}{\partial C_c(a)} = \frac{20\ C_m(a)C_c(a)f_f(a)}{14\ ab(a)}$$
$$\frac{f(a)}{ab(a)}\frac{\partial ab(a)}{\partial f(a)} = -\frac{f(a)}{b\ ab(a)}$$
$$\frac{b}{ab(a)}\frac{\partial ab(a)}{\partial b} = \frac{f(a)}{b\ ab(a)}$$

As a consequence of the nature of Bongaarts' indices, which by construction are scaling factors, the elasticities of the first three elements are identical. The last two elasticities differ in sign but have the same magnitude.

The elasticities set out above reveal the relative sensitivities of abortion estimates to small changes in the proximate determinates of fertility. To aid interpretation, it is necessary to evaluate them at a set of representative age-specific schedules for abortion, age-specific fertility, sexual exposure, and total fecundity. The forms used for these schedules are set out below, and are designed to be relevant for country contexts similar to the contexts of our study countries. Single year of age schedules are used in order to more fully examine the age-specificity of sensitivity.

Natural fertility. For 'natural' fertility f_f, Bongaart's estimates are used directly, and smoothed using locally weighted scatterplot smoothing (LOESS) to provide single year of age estimates.

Age specific fertility rates. The schedule of age specific fertility rates was generated using a Hadwiger model (Hadwiger 1940) with TFR 3.5 and mean age of childbearing 26.

Sexual exposure. A logistic function is used to represent the shape of the C_m index over age. The mean age of first sexual exposure is assumed to be 19.

Post-partum infecundability. The number of additional months of infecundability added through breast-feeding, *i(a)* was chosen to be constant over the age range, and equal to 9, in line with the discussion in Bongaarts' (2015) work.

Abortion. In line with Sedgh et al. (2012), abortion schedules are assumed to take an inverted U-shape over the age-range, with the highest rates occurring for ages 20-29. A Weibull distribution is used to model this shape, although this choice is somewhat arbitrary. A Total Abortion Rate of 1 is assumed.

Contraception. In order to provide a complete set of schedules consistent with Bongaarts' formalism, the final element must necessarily be a deterministic function of the others. The contraception index is therefore calculated as:

$$C_c(a) = \frac{ab(a) + f(a)/b}{\frac{20}{14} f_f(a) C_m(a)}$$

The classification method

The classification method classifies self-reported pregnancy terminations into spontaneous and induced abortions using a version of WHO's (1996) protocol (Magnani et al. 1996). Terminations are assumed to have been induced, if the pregnancy occurred after a contraceptive failure, after an unwanted birth, to unmarried women aged under 25 years, or exceeded the number of children they ideally wanted to have. Terminations in the third trimester, after contraceptive discontinuation in order to conceive, or to married women with 0-1 children are assumed to have been spontaneous. The method is particularly suited for estimating the number of abortions per 1000 pregnancies (i.e. the abortion ratio).

We applied the classification method to DHS calendar data on pregnancy terminations. These data do not differentiate between induced and spontaneous abortions. The method requires taking into account woman's marital status at the time of the pregnancy, but time varying data on marriage was not available. Hence, we classified women as married, if the age at which they had started their first marriage/cohabitation was younger than the age in which the termination of interest occurred and if they reported being married/cohabiting at the time of interview. This may misclassify some women, whose unions have recently dissolved, but who were in a union at the time of pregnancy of interest. All terminations were included in the analyses even if some of them happened to the same woman.

Results

The results from the revised residual method are shown in Table 2. In all four countries, the overall abortion rates among women aged 15-49 differed clearly from the Guttmacher Institute's estimates. In all countries, except Rwanda, the residual method estimated a higher abortion rate than the Guttmacher Institute. In Rwanda, the estimate for abortion rate among women aged 15-44 was negative according to the revised residual method and thus not believable.

Table 2. Abortion indices ($C_a(a)$, residual method), age-specific abortion rates (ASAR), overall abortion rate by country and Guttmacher Institute's (GI) abortion rate estimate.

Country	**Age**	**C_a(a)**	**ASAR**	**GI abortion rate estimate**
Burkina Faso 2010	*15-19*	0.845	57	
	20-24	0.846	114	
	25-29	0.884	86	
	30-34	0.933	43	
	35-39	1.066	-31	
	40-44	1.039	-9	
	45-49	0.892	8	
	Abortion rate 15-49		38	25
Ethiopia 2016	*15-19*	0.996	1	
	20-24	0.938	34	
	25-29	0.851	95	
	30-34	0.906	52	
	35-39	0.925	30	
	40-44	0.927	15	
	45-49	0.860	10	
	Abortion rate 15-49		34	22
Nigeria 2013	*15-19*	0.839	56	
	20-24	0.870	81	
	25-29	0.846	107	
	30-34	0.875	77	
	35-39	0.860	62	
	40-44	0.888	24	
	45-49	1.083	-6	
	Abortion rate 15-49		57	33
Rwanda 2010	*15-19*	1.919	-57	
	20-24	1.056	-23	
	25-29	0.870	77	
	30-34	0.927	37	
	35-39	1.027	-10	
	40-44	1.421	-67	
	Abortion rate 15-45		-7	25

Notes: Sources for Guttmacher Institute's abortion rate estimates: (Bankole et al. 2013, 2015; Basinga et al. 2013; Moore et al. 2016).

Figure 1 plots the age specific abortion rates (ASARs) estimated using the revised residual method. Abortion rates show an inverted U-shape in all countries, with women in their early- or late 20s being most likely to obtain abortions. However, in Burkina Faso and Rwanda some of the ASARs are negative signalling that the model is not predicting age specific abortion rates correctly in these countries.

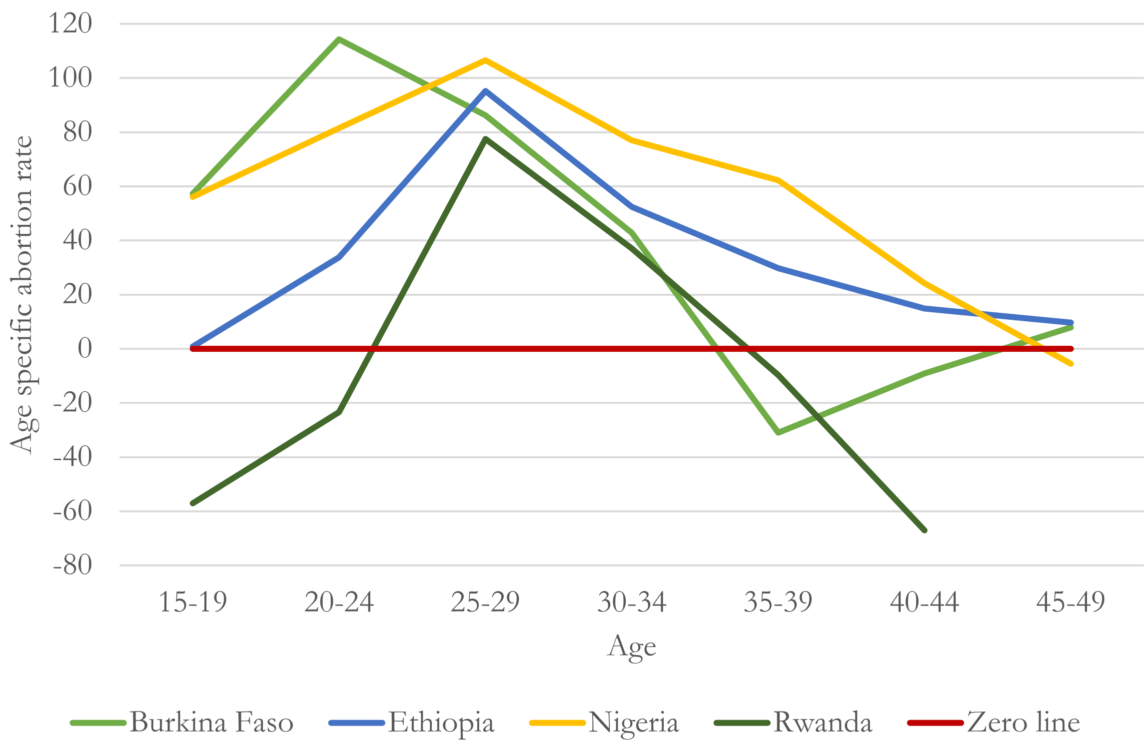


Figure 1. Age specific abortion rates by country according to the revised residual method.

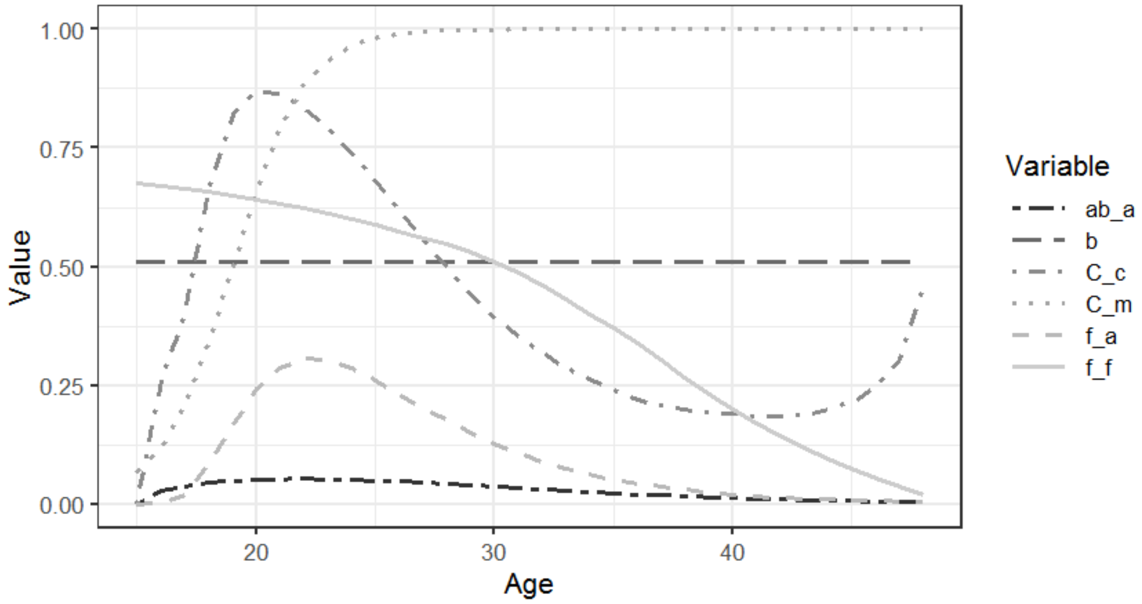
Exploring bias and uncertainty in the revised residual method using sensitivity analyses

The local sensitivity analysis reveals the relative sensitivities of abortion estimates to small changes in the proximate determinates of fertility. Figure 2 shows the assumed schedules of the Bongaarts' indices in the sensitivity analyses.

Evaluating the elasticities at these representative rates provides us with an idea of the potential size of the error in abortion estimates induced by mis-measurements of the other variables (Figure 3).

Figure 3 shows that a 1%-point increase in total fecundity (f_f), sexual exposure (C_m) and the index of contraception (C_c) lead to an inflation of the age-specific abortion rates up to 12%. The problem is the worst for women in their early 20s. The pattern is very similar for the factor *b(a)*, which is needed to estimate the index of abortion (Bongaarts 2015). On the other hand, a 1%-point increase in age-specific fertility rates leads to decrease in estimated age-specific abortion rates of up to 12%. Again, the problem is the worst for women in their early 20s.

Figure 2. Age-specific values of the indices used in the sensitivity analyses.



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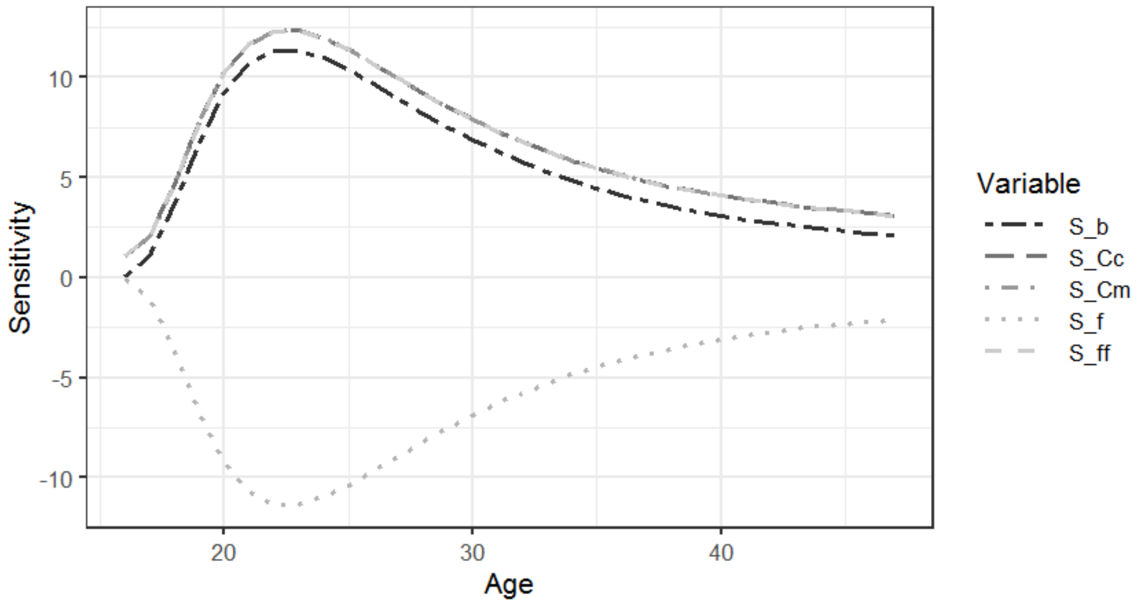

Figure 3. Age-specific percentage changes in the abortion rates when the variable of interest increases by 1%-point.

Notes: The sensitivities of ff, Cm and Cc are the same, so the three lines lie on top of each other.

Classification method

Table 3 shows the results of the classification method. The method fails to classify most reported terminations into either category (spontaneous or induced) leaving the majority of terminations into the category of 'unclassified termination'. It is likely that all terminations were underreported in these data, because the ratio of all terminations per 1000 pregnancies was much lower than expected. For instance, Casterline (1989) suggested that 100-150 spontaneous abortions take place per every 1000 pregnancies, which is considerably more than the 51-72 terminations per 1000 pregnancies reported in these data.

Table 3. Classification method results (overall and age-specific): number of terminations per 1000 pregnancies.

	Age	Weighted N pregnancies	Abortion ratio	Miscarriage ratio	Unclassified ratio	Termination ratio
Burkina Faso	*15-19*	2338	4.7	63.0	0.0	67.7
	20-24	4808	3.7	31.8	9.4	44.9
	25-29	4480	2.3	16.9	25.4	44.6
	30-34	3126	2.7	15.5	31.1	49.3
	35-39	2041	10.1	12.3	35.8	58.2
	40-44	822	13.6	16.7	66.3	96.6
	45-49	109	6.7	27.2	102.8	136.7
Total		17724	4.5	26.3	22.3	53.1
Ethiopia	*15-19*	1306	9.7	46.7	2.3	58.7
	20-24	3466	2.1	21.6	11.2	34.9
	25-29	3500	5.0	20.1	18.1	43.2
	30-34	2417	9.4	19.2	29.6	58.2
	35-39	1505	17.0	8.4	36.3	61.7
	40-44	530	30.1	27.0	34.9	92.0
	45-49	85	0.0	89.0	152.3	241.3
Total		12809	7.9	22.4	20.5	50.8
Nigeria	*15-19*	4660	15.2	55.5	1.2	71.9
	20-24	9253	15.0	31.2	11.1	57.3
	25-29	9591	5.9	28.4	28.4	62.7
	30-34	6854	7.3	23.4	41.4	72.1
	35-39	4226	11.8	26.3	59.9	98.0
	40-44	1664	16.6	25.3	67.9	109.8
	45-49	410	13.1	40.9	112.6	166.6
Total		36658	10.9	31.4	29.4	71.7
Rwanda	*15-19*	514	13.3	38.3	0.0	51.6
	20-24	2919	6.2	56.1	3.2	65.5
	25-29	3146	2.4	33.7	13.3	49.4
	30-34	2128	8.4	24.7	25.4	58.5
	35-39	1329	23.3	17.9	34.8	76.0
	40-44	766	78.8	22.8	43.1	144.7
Total		10802	13.1	35.5	17.1	65.7

Discussion

The residual method is sensitive to any biases in the other three indices measuring fertility reduction, and the sensitivity analyses show that even small biases in measurement of the indices can result in large discrepancies in the abortion rate estimates. While the shape of age-specific abortion rates created by the revised residual method was credible, the method does not seem to be able to reliably estimate the level of abortion.

Previous research conducted in Turkey, suggests the classification method performs well even though it cannot take into account the increased miscarriage risk of older women, or abortions due to birth spacing (Magnani et al. 1996). However, the results for the four countries studied here are unsatisfactory. The proportion of unclassified terminations increases by age. This indicates that not being able to take into account the increased risk of miscarriage by age is an important issue with these data. The large proportion of unclassified terminations also suggests that the criteria used to classify the terminations are not suitable for these contexts. The contraceptive use patterns and reasons for discontinuation, fertility preferences, and marital status used to classify terminations as induced or spontaneous, may have not been suitable for these four country contexts. While the criteria can be modified to increase the performance of this method in each context, more research is needed into why women have abortions in these countries and who these women are before the classification method can be improved. The likely underreporting of all terminations also creates issues in using the classification method for estimating abortion trends.

There main limitation of the study is that the 'true' abortion rates are not known, making it difficult to evaluate the performance of the methods. However, the implausible results of both methods and the sensitivity analyses conducted for the revised residual method suggest that the performance of these methods is not reliable in these contexts.

Conclusions

This study shows that there is no 'one size fits all' approach for indirect measurement of abortion. While some methods, such as the classification method, may work well in some contexts, they may be completely unsuitable in others.

The revised residual method bears a lot of uncertainty if used to study levels of abortion. Moreover, the model sometimes produces negative abortion rates, particularly among the youngest and the oldest age groups, where pregnancies are less common.

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