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Who Delivers Where? The effect of obstetric risk on facility delivery in East Africa

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Abstract:	Objectives Skilled attendance at birth is key for the survival of pregnant women. This study investigates whether women at increased risk of maternal and newborn complications in four East African countries are more likely to deliver in a health facility than those at lower risk. Methods Demographic & Health Survey data for Kenya 2014, Rwanda 2014-15, Tanzania 2015-16 and Uganda 2011 were used to study women with a live birth in the three years preceding the survey. A three-level obstetric risk index was created using known risk factors. Generalised linear Poisson regression was used to investigate the association between obstetric risk and facility delivery. Results We analysed data from 13,119 women across the four countries of whom 42-45% were considered at medium risk and 12-17% at high risk, and the remainder were low risk. In Rwanda, 93% of all women delivered in facilities but this was lower (59-66%) in the other three countries. There was no association between a woman's obstetric risk level and her place of delivery in any country; increased wealth and education were, however, independently strongly associated with facility delivery. Conclusions In four East African countries women at higher obstetric risk were not more likely to deliver in a facility than those with lower risk. . This calls for a renewed focus on antenatal risk screening and improved communication on birth planning to ensure women with an increased chance of maternal and newborn complications are supported to deliver in facilities with skilled care.

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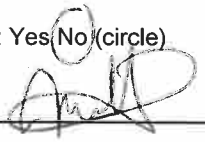

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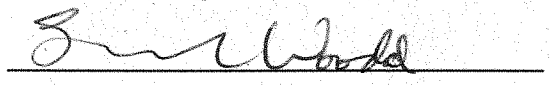

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ABSTRACT

Objectives

Skilled attendance at birth is key for the survival of pregnant women. This study investigates whether women at increased risk of maternal and newborn complications in four East African countries are more likely to deliver in a health facility than those at lower risk.

Methods

Demographic & Health Survey data for Kenya 2014, Rwanda 2014-15, Tanzania 2015-16 and Uganda 2011 were used to study women with a live birth in the three years preceding the survey. A three-level obstetric risk index was created using known risk factors. Generalised linear Poisson regression was used to investigate the association between obstetric risk and facility delivery.

Results

We analysed data from 13,119 women across the four countries of whom 42-45% were considered at medium risk and 12-17% at high risk, and the remainder were low risk. In Rwanda, 93% of all women delivered in facilities but this was lower (59-66%) in the other three countries. There was no association between a woman's obstetric risk level and her place of delivery in any country; increased wealth and education were, however, independently strongly associated with facility delivery.

Conclusions

In four East African countries women at higher obstetric risk were not more likely to deliver in a facility than those with lower risk. This calls for a renewed focus on antenatal risk screening and improved communication on birth planning to ensure women with an increased chance of maternal and newborn complications are supported to deliver in facilities with skilled care.

INTRODUCTION

In global and national efforts to improve maternal and newborn health, a key focus has been to increase skilled attendance at birth (1), primarily through increasing the proportion of women delivering in a healthcare facility(2). Facility delivery rates have increased in most countries over the last decade, but, as with other health outcomes, this gain has been inequitable (3) and affected by factors including distance to facility and fees (4). While maternal mortality has decreased since 1990, few countries reached the 75% reduction set for MDG5a. MDG4 has seen greater progress, with many countries achieving a 2/3rds reduction in child mortality, however, newborn mortality lags behind that of children over 1 month old and now contributes to almost 50% of all under 5 deaths(1). Even where regional or country-level progress is good, heterogeneity often exists, with poor socio-demographic factors, such as lack of education, associated with worse maternal outcomes(5). At the start of the Sustainable Development Goal (SDG) era, as we consider how to maintain and accelerate progress, one important focus must be on reaching the most vulnerable women: those at high risk of maternal and newborn complications who are not receiving adequate care.

Identifying women at higher risk is complex, and complications often occur in low-risk women; however certain well-known factors, many of which can be identified before labour, increase the chance of obstetric complications occurring: poor obstetric history (6-8), co-existing medical conditions(9-11) or factors related to the current pregnancy such as primi- or grand multi-parity and multiple pregnancy(12-14). Labour is a process which for many progresses safely with little or no intervention, but the development of obstetric complications in a minority of deliveries is unpredictable and can rapidly lead to severe morbidity or mortality for the mother or her baby. Good monitoring to detect problems early and prompt access to skilled personnel combined with appropriate resources to manage these problems are necessary to prevent adverse outcomes. Women at higher risk of developing complications should benefit from skilled birth attendance, and it is of particular importance that they access facility-based care where complications can be managed rapidly.

While previous studies have investigated some of the reasons women do and do not access health facility care at birth, to our knowledge none have explored the effect of obstetric risk factors on women's attendance. Therefore, we used survey data from four East African countries (Kenya, Tanzania, Rwanda, Uganda) to determine whether women at increased risk of obstetric complications were more likely to deliver in a facility. We also examined the effect of wealth and education on delivery location and whether these modified the effect of obstetric risk.

METHODS

Data used are from the most recent Demographic and Health Surveys (DHS) for the following countries and years: Kenya 2014, Rwanda 2014-15, Tanzania 2015-16 and Uganda 2011. These are nationally representative, cross-sectional, household surveys using standardised questionnaires and shown to produce high-quality data for low- and middle-income settings which are comparable across countries (15). Women aged 15-49 years were included in the surveys. Our sample was of women who had had their last live birth in the three years prior to the survey; who were regular household members rather than visitors; and who had data on weight and height. The latter were available for approximately half the total sample in Rwanda and Kenya, around 31% of the Uganda sample, and around 99% of the Tanzania sample.

The outcome was place of delivery for the index (most recent) birth. It was coded as a binary outcome: facility or non-facility delivery, with the latter including respondent's home, other home, traditional birth attendant's home, en route to provider, or 'other'. Facility birth was chosen in preference to skilled birth attendant (SBA) as it is less prone to misclassification by women and should provide the necessary equipment as well as the personnel to enable skilled attendance.

An obstetric risk index for each woman in our sample was created using variables derived from DHS survey responses, listed in Table 1 along with the maternal/newborn complications with which they are associated. The selected criteria closely match those for higher risk pregnancy in the clinical guidelines from Uganda and Kenya, including age, parity, nutritional status, poor obstetric history and multiple pregnancy, but are unable to capture information on medical conditions which are not recorded in the DHS (16, 17). We classified risk factors as medium if they were moderately associated with elevated obstetric risk such as parity, short height, poor nutritional status, short birth interval, no antenatal care and history of caesarean section or stillbirth with a subsequent vaginal delivery and live birth. Factors were classified as high risk if they were considered to be strongly associated with a risk of complications for mother or baby, such as caesarean section or stillbirth in the previous pregnancy, or of importance for some other reason as indicated in the table, based on epidemiological evidence and clinical consensus. Mothers' weight and height, used to assess malnutrition and obesity, were measured during the survey interview up to 3 years after the index birth; we assumed that women had the same risk from these parameters prior to the index birth. The combination of these factors determined a woman's risk at one of three levels: low, where no risk factors were observed; medium, where only one of the medium risk factors was observed; and high, where one or more high risk factors or two or more medium risk factors were observed.

Socio-economic position, assessed using mothers' education or household wealth, is known to be strongly associated with delivery location (18) and was considered a potential confounder or effect modifier of any association with obstetric risk. It could be an effect modifier if for example high risk impoverished women were more likely to deliver in a facility, while wealthier women usually do so in the first place. Mothers' highest educational level was recoded as 'no education'; 'primary'; and 'secondary or higher'. For all countries we used the already-existing wealth index within the DHS which had been created with urban-rural weightings. The weighted index aims to reduce urban-bias and better distinguish the poorest from the other poor households (19).

ANALYSIS STRATEGY

All data management and analysis was undertaken in Stata SE 14.0, using *svyset* commands to account for the sampling strategy using individual sample weights and clustering. Percentages of women at each obstetric risk level, educational level and wealth quintile were estimated. We used generalised linear Poisson models to investigate the crude and adjusted effect of obstetric risk index, wealth and education on facility delivery. This model was chosen to estimate risk ratios because our outcome , facility delivery, is common (>10% incidence) and, as incidence increases, there is a growing disparity between odds ratios and risk ratios (20, 21). Models with interaction terms explored whether wealth or education modified the association between obstetric risk and facility delivery. To understand obstetric risk better, we examined the association between each individual risk factor and delivery location, plus the relationship between wealth and obstetric risk, using weighted percentages and chi-squared tests.

Table 1: Medium and high risk factors included in obstetric risk index

LIST A: MEDIUM RISK FACTORS

RISK FACTOR	Associated obstetric complications
First birth	Maternal dystocia (12)
Shortness (less than 145 cm used to be consistent with standards used by DHS)	Maternal dystocia; miscarriage; stillbirth; fistula (12, 22-24)
Past Caesarean in last 5 years, but has had vaginal delivery since and prior to focus birth	Scar rupture; placental complications; stillbirth; and increased morbidity and mortality for mother and infant (6, 8, 25)
Grand multiparity (focus birth is at least number six in live birth order)	placental complications; foetal malpresentation; postpartum haemorrhage (14) still birth, newborn mortality(26)
Malnutrition (BMI <18.5)	low birth weight; intrauterine growth restriction; premature labour (27-29)
Obesity (woman's BMI is >30)	Stillbirth; post-partum haemorrhage; pre-term delivery; emergency Caesarean; macrosomia; hypertension; pre-eclampsia; diabetes mellitus (30-36)
Past stillbirth in last 5 years, but last birth prior to focus birth was live birth	Stillbirth, , newborn mortality, intrapartum asphyxia, placental abruption, pre-term delivery (7, 26, 37)
Birth interval prior to focus birth was 12 months or less	Stillbirth, newborn mortality, pre-term birth, low birth weight, small size for gestational age, decreased gestational age associated with short birth interval (26, 38-40)
Sibling prior to focus birth died aged 1-12 months	Post-neonatal death (41)
Woman has had no ante-natal care in focus pregnancy	No identification of and intervention in hypertension, anaemia, infections and pre-eclampsia (42)

LIST B: HIGH RISK FACTORS

RISK FACTOR	**Associated obstetric complications**	**Reason for high risk level**
Focus birth is twins or triplets	Hypertension, pre-eclampsia, pre-term labour, dystocia, placental abruption, perinatal mortality and morbidity, uterine atony and postpartum haemorrhage (13, 26)	Multiple potential complications with emergency risk to the second twin. Should be encouraged to deliver in a facility offering CEmONC
Stillbirth was last delivery prior to focus birth	Stillbirth, newborn mortality, intrapartum asphyxia, placental abruption, pre-term delivery (7, 8, 26, 37)	Multiple potential complications including another stillbirth. Loss of the previous pregnancy can increase the importance of a successful outcome for mother and birth attendants
Last delivery prior to focus birth was Caesarean section	Scar rupture, placental complications, and increased morbidity and mortality for mother and infant have been associated with recent Caesarean section (6, 25)	Multiple potential complications with increased risk of requiring another caesarean section therefore needs good access to CEmONC. There has been no successful trial of scar.
Sibling prior to focus birth died in first month of life	Associations have been found between sibling neonatal outcomes including stillbirth and newborn mortality (26, 43-45)	Loss of the previous newborn can increase the importance of a successful outcome for mother and birth attendants.
Focus birth is to woman aged under 16	stillbirth, pre-term labour, low birthweight, neonatal mortality, small-for-gestational age infants (46-48)	Multiple potential complications including neonatal mortality
Focus birth is first child born to woman aged 35+	Miscarriage, gestational diabetes, placenta previa, placental abruption, Caesarean delivery, macrosomia, pre-term delivery, low birth weight, neonatal mortality, multiple gestation, hypertension, foetal death, operative vaginal delivery, post-partum haemorrhage, stillbirth (49-51)	Multiple potential complications. Woman has 2 risk factors; age and primiparity

RESULTS

Our initial sample was the women with their most recent live birth in the three years preceding the survey who were regular household members (not visitors) and who had anthropometric data: 13,360. Of these, 193 were missing data on delivery location and are not included in the remainder of the results and a further 47 lacked data on at least one component of the risk score leaving 13,119 women with complete data for the analysis (Rwanda 2158; Kenya 4733; Tanzania 5033; Uganda 1195). All numbers given are weighted unless otherwise stated.

The proportion of women considered at medium obstetric risk was similar (42-45%) in each country. High obstetric risk was rarer, ranging from 12% (95%CI 11%-14%) in Rwanda to 17% (95%CI 14%-20%) in Uganda. Most women had only primary education; Kenyan women were the highest educated with 35% receiving secondary or higher education (95%CI 33-37%) compared to only 14-24% in the other three countries (Table 2). The overall proportion of women delivering in facilities was 59-66% in Kenya, Tanzania and Uganda but much higher in Rwanda at 93% (95%CI 91-94%) (Table 3).

A key finding is that obstetric risk level had no effect on whether a woman delivered in a facility in any of the four countries, after adjusting for wealth and education (Table 3).

Most women were considered at risk because of their parity: over 40% of women in each country were either primi- or grand multi-parous. Poor nutritional status also occurred frequently in Kenya, Tanzania and Uganda where malnutrition or obesity affected 17% (95%CI 16%-19%); 14% (95% CI 13%-16%); and 13% (95%CI 11%-15%) of women in each country respectively (disaggregated data shown in Table 4). The risk of not having antenatal care did not exceed 4% in any of the countries. Other risk factors each occurred in 5% or less of women (Table 4).

Wealth and highest level of education showed strong, independent associations with delivery location (Table 3). The effect of socioeconomic status was greatest in Kenya and smallest in Rwanda. Wealth did not modify the effect of obstetric risk on facility delivery in any of the countries. While facility deliveries clearly increased with increasing wealth, the relationship with obstetric risk is similar in all quintiles (Fig. 1 and Appendix Table A). There is statistical evidence that education modified the association between obstetric risk and delivery location in Kenya and Tanzania (Appendix Table A). Among the most educated Tanzanian women, those at high risk were more likely to deliver in a facility than women at low risk (RR 1.12 95% CI 1.05-1.20). However, in Kenya, there is no consistent pattern.

Obstetric risk level did not vary by wealth in Rwanda or Uganda (Figure 2 and Appendix Table B). In Kenya and Tanzania, there is evidence of a difference in risk levels by wealth but patterns are inconsistent: high obstetric risk was commonest among the richest women in Tanzania but among the poorest in Kenya (Fig.2 and Appendix Table B).

Individual risk factors showed a more complex relationship with wealth. Primiparous women were overall more likely to be wealthy and to deliver in a facility, whereas grand multiparity was associated with being poor and giving birth outside a health facility, although in Rwanda this relationship was less pronounced (Fig 3 and Appendix Table C). The same pattern is seen for under- and over-nutrition; malnourished women were poorer and less likely to deliver in a facility, while the opposite was seen for obese women (Table 4 and Appendix Table C).

Having a caesarean section in the birth prior to the index birth showed the strongest association with facility delivery and occurred more often among women of higher socio-economic status. However, it was a risk factor for only 1-5% of women studied. A similar pattern was seen for primiparous women aged over 35 years, but there were too few in the sample to draw any conclusions. Women not attending antenatal care were less likely to have a facility delivery everywhere except Uganda, but the relationship between no antenatal care and wealth was inconsistent. Other factors showed little or no consistent association with either wealth or facility delivery.

Table 2: Distribution of women's obstetric risk, wealth and education in four East African Countries

		RWANDA 2011-2015	KENYA 2011-2014	TANZANIA 2012-2016	UGANDA 2008-2011
		Weighted n (%) Total Weighted N=2158*	Weighted n (%) Total Weighted N=4746*	Weighted n (%) Total Weighted N=5048*	Weighted n (%) Total Weighted N=1215*
Obstetric risk levels	**Low**	988 (46)	1967 (41)	1997 (40)	477 (39)
	Medium	903 (42)	2005 (42)	2266 (45)	514 (42)
	High	267 (12)	762 (16)	770 (15)	204 (17)
	Missing	0 (0)	13 (0.3)	15 (0.3)	19 (2)
Wealth quintiles	**Poorest**	534 (25)	1074 (23)	1183 (23)	266 (22)
	Poorer	468 (22)	950 (20)	1057 (21)	258 (21)
	Middle	401 (19)	865 (18)	945 (19)	232 (19)
	Richer	373 (17)	884 (19)	978 (19)	229 (19)
	Richest	383 (18)	974 (21)	884 (18)	230 (19)
Education levels	**No education**	289 (13)	527 (11)	975 (19)	149 (12)
	Primary	1556 (72)	2564 (54)	3251 (64)	778 (64)
	Secondary or higher	313 (14)	1655 (35)	822 (16)	287 (24)

*Totals include those for whom information on delivery place was available

TABLE 3: Association between women's obstetric risk, wealth or education and having a facility delivery in four East African countries

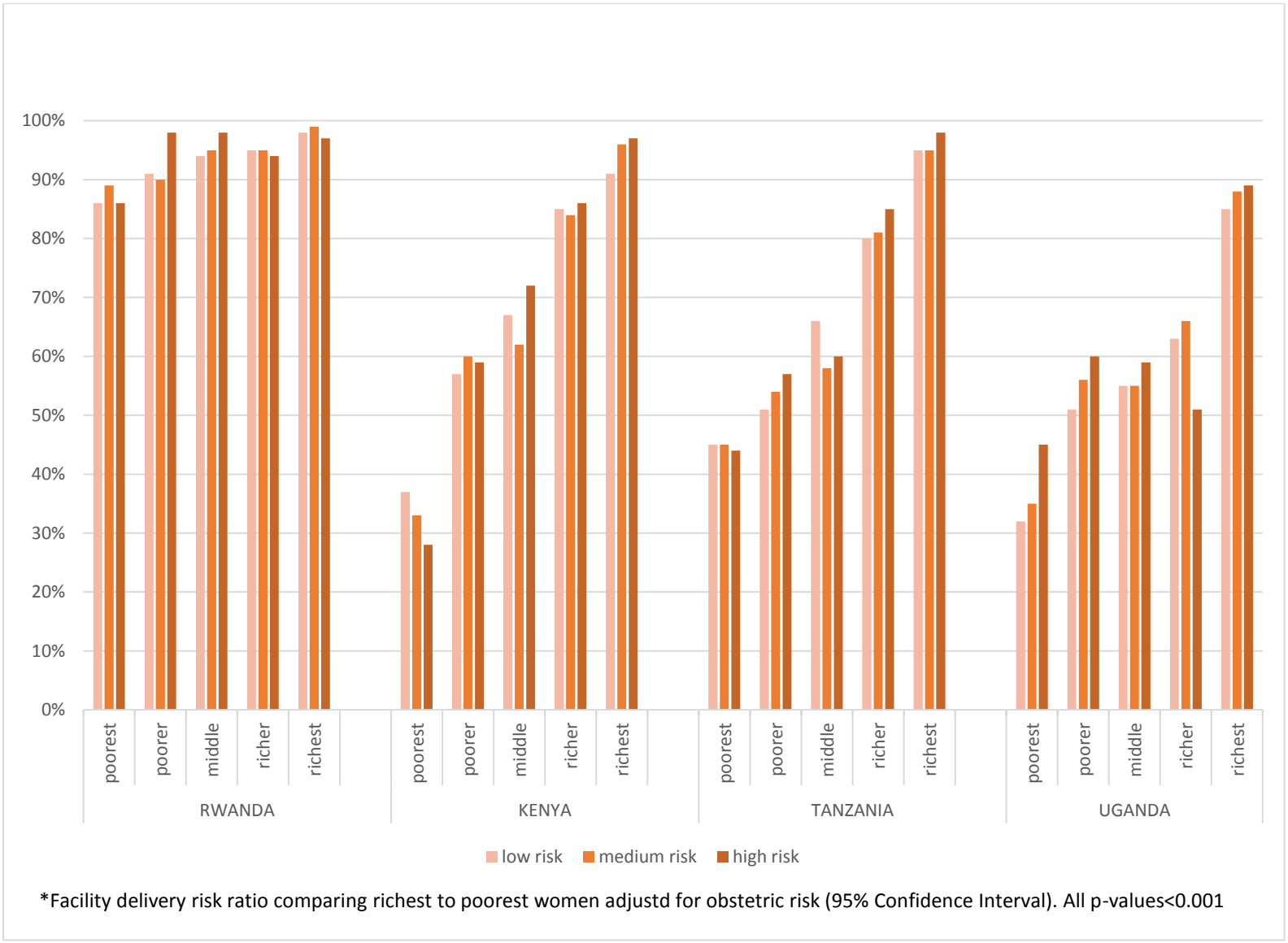
	RWANDA N=2158				KENYA N=4733				TANZANIA N=5033				UGANDA N=1195			
	Weighted % facility delivery	**RR (95% CI)**	**Adjusted RR* (95% CI)**	**p-value Wald test**	**Weighted % facility delivery**	**RR (95% CI)**	**Adjusted RR* (95% CI)**	**p-value Wald test**	**Weighted % facility delivery**	**RR (95% CI)**	**Adjusted RR* (95% CI)**	**p-value Wald test**	**Weighted % facility delivery**	**RR (95% CI)**	**Adjusted RR* (95% CI)**	**p-value Wald test**
Total	93%				66%				66%				59%			
Obstetric Risk index				0.6356				0.7800				0.3745				0.3095
Low	92%	1.00	1.00		67%	1.00	1.00		65%	1.00	1.00		58%	1.00	1.00	
Medium	93%	1.02 (0.99-1.04)	1.01 (0.98-1.04)		66%	0.99 (0.94-1.04)	0.98 (0.94-1.04)		65%	0.99 (0.94-1.05)	0.98 (0.93-1.03)		59%	1.02 (0.90-1.15)	1.07 (0.96-1.21)	
High	94%	1.02 (0.98-1.06)	1.02 (0.98-1.06)		64%	0.96 (0.89-1.03)	1.00 (0.94-1.07)		71%	1.09 (1.02-1.17)	1.01 (0.95-1.07)		58%	1.00 (0.87-1.17)	1.11 (0.95-1.28)	
Wealth				0.0001				<0.0001				<0.0001				<0.0001
Poorest	87%	1.00	1.00		33%	1.00	1.00		45%	1.00	1.00		36%	1.00	1.00	
Poorer	91%	1.04 (0.99-1.10)	1.04 (0.99-1.09)		59%	1.77 (1.58-1.99)	1.49 (1.32-1.68)		53%	1.19 (1.05-1.34)	1.16 (1.03-1.31)		55%	1.54 (1.21-1.94)	1.47 (1.16-1.88)	
Middle	95%	1.08 (1.03-1.13)	1.07 (1.02-1.12)		66%	1.99 (1.77-2.23)	1.64 (1.45-1.85)		62%	1.39 (1.23-1.57)	1.32 (1.17-1.49)		56%	1.57 (1.23-2.01)	1.48 (1.15-1.91)	
Richer	95%	1.08 (1.04-1.13)	1.07 (1.02-1.11)		85%	2.55 (2.29-2.84)	2.05 (1.82-2.30)		81%	1.82 (1.62-2.05)	1.69 (1.51-1.89)		63%	1.76 (1.41-2.21)	1.64 (1.30-2.06)	
Richest	98%	1.12 (1.08-1.17)	1.09 (1.05-1.14)		94%	2.83 (2.55-3.14)	2.19 (1.95-2.45)		95%	2.13 (1.91-2.39)	1.88 (1.69-2.10)		87%	2.42 (1.97-2.98)	2.14 (1.70-2.68)	
Education				0.0003				<0.0001				<0.0001				0.0067
None	85%	1.00	1.00		27%	1.00	1.00		46%	1.00	1.00		41%	1.00	1.00	
Any Primary	93%	1.09 (1.02-1.17)	1.08 (1.01-1.16)		61%	2.22 (1.87-2.64)	1.67 (1.40-1.98)		65%	1.43 (1.29-1.59)	1.24 (1.13-1.37)		55%	1.35 (1.07-1.69)	1.24 (0.99-1.55)	
Secondary or higher	99%	1.16 (1.08-1.25)	1.11 (1.04-1.19)		87%	3.19 (2.69-3.78)	1.97 (1.65-2.34)		90%	1.97 (1.77-2.20)	1.39 (1.26-1.53)		78%	1.94 (1.54-2.43)	1.43 (1.12-1.83)	

*adjusted for all other variables in the table

Table 4: Association between women's individual obstetric risk factors and having a facility delivery in Four East African countries

	RWANDA N=2158			KENYA N=4733			TANZANIA N=5033			UGANDA N=1195		
MEDIUM RISK FACTORS	**weighted n (% of all women)**	**% facility delivery**	**facility delivery RR (95%CI)**	**weighted n (% of all women)**	**% facility delivery**	**facility delivery RR (95%CI)**	**weighted n (% of all women)**	**% facility delivery**	**facility delivery RR (95%CI)**	**weighted n (% of all women)**	**% facility delivery**	**facility delivery RR (95%CI)**
Focus birth was first-born	588 (27)	98	1.07 (1.05-1.10)	1160 (25)	83	1.37 (1.31-1.44)	1301 (26)	79	1.30 (1.24-1.36)	172 (14)	72	1.30 (1.15-1.45)
Height <145cm	56 (3)	95	1.03 (0.97-1.09)	43 (0.9)	70	1.05 (0.82-1.35)	88 (2)	75	1.14 (0.99-1.32)	14 (1)	45	0.77 (0.41-1.45)
Previous Caesarean but vaginal delivery before focus birth	0 (0)	N/A	N/A	3 (0.1)	36	0.54 (0.16-1.87)	0.3 (0.01)	100	1.52 (1.46-1.59)	3 (0.2)	85	1.46 (0.95-2.25)
Grand multiparous (>=6 live births)	292 (14)	86	0.92 (0.87-0.96)	749 (16)	39	0.54 (0.49-0.61)	1025 (20)	48	0.68 (0.62-0.74)	383 (32)	51	0.83 (0.73-0.95)
Malnourished (BMI < 18.5)	96 (4)	87	0.93 (0.86-1.01)	420 (9)	46	0.68 (0.60-0.76)	357 (7)	59	0.89 (0.80-0.99)	114 (10)	58	0.99 (0.82-1.19)
Obese (BMI >= 30)	96 (4)	94	1.01 (0.96-1.08)	406 (9)	88	1.37 (1.29-1.44)	365 (7)	93	1.46 (1.38-1.55)	33 (3)	71	1.23 (0.94-1.62)
Previous stillbirth, but subsequent live birth prior to focus birth	4 (0.2)	100	1.08 (1.06-1.09)	5 (0.1)	47	0.70 (0.27-1.86)	18 (0.4)	62	0.95 (0.62-1.46)	1 (0.1)	100	1.72 (1.62-1.83)
Short preceding birth interval (<=12months)	22 (1)	82	0.87 (0.70-1.12)	39 (0.8)	52	0.78 (0.56-1.08)	42 (0.8)	53	0.81 (0.61-1.07)	16 (1)	44	0.76 (0.41-1.40)
Previous baby died aged 1-12 months	22 (1)	95	1.03 (0.94-1.13)	71 (2)	58	0.87 (0.65-1.15)	92 (2)	59	0.90 (0.73-1.11)	35 (3)	54	0.93 (0.63-1.36)
Woman has had no antenatal care	20 (1)	57	0.61 (0.39-0.95)	173 (4)	16	0.23 (0.15-0.35)	113 (2)	27	0.40 (0.26-0.60)	36 (3)	39	0.66 (0.39-1.12)
HIGH RISK FACTORS												
Focus birth twins/triplets	28 (1)	100	1.08 (1.06-1.09)	83 (2)	73	1.10 (0.91-1.31)	87 (2)	70	1.06 (0.89-1.26)	21 (2)	60	1.03 (0.69-1.53)
Last delivery before focus birth was stillbirth	8 (0.4)	100	1.08 (1.06-1.09)	30 (0.6)	78	1.18 (0.97-1.44)	53 (1)	70	1.07 (0.85-1.35)	8 (1)	65	1.12 (0.61-2.04)
Last delivery before focus birth was Caesarean	98 (5)	100	1.08 (1.06-1.10)	118 (3)	92	1.40 (1.30-1.51)	81 (2)	95	1.45 (1.36-1.56)	33 (3)	72	1.25 (0.99-1.57)
Previous baby died in first 30 days of life	36 (2)	91	0.98 (0.87-1.09)	102 (2)	74	1.12 (0.94-1.33)	104 (2)	70	1.06 (0.92-1.23)	36 (3)	56	0.96 (0.66-1.40)
Woman was under 16 at time of focus birth	4 (0.2)	100	1.08 (1.06-1.09)	40 (0.8)	65	0.98 (0.77-1.25)	41 (0.8)	56	0.85 (0.61-1.17)	4 (0.3)	51	0.88 (0.40-1.96)
Focus birth was first born to a woman aged 35+	4 (0.2)	100	1.08 (1.06-1.09)	2 (0.04)	100	1.51 (1.47-1.55)	8 (0.2)	100	1.52 (1.46-1.59)	0	0	

Figure 1: Weighted percentage of women attending for facility delivery in four East African countries by wealth quintile and obstetric risk



*Facility delivery risk ratio comparing richest to poorest women adjustd for obstetric risk (95% Confidence Interval). All p-values<0.001

Figure 2: Weighted percentage of women at each obstetric risk level by wealth quintile for four East African countries

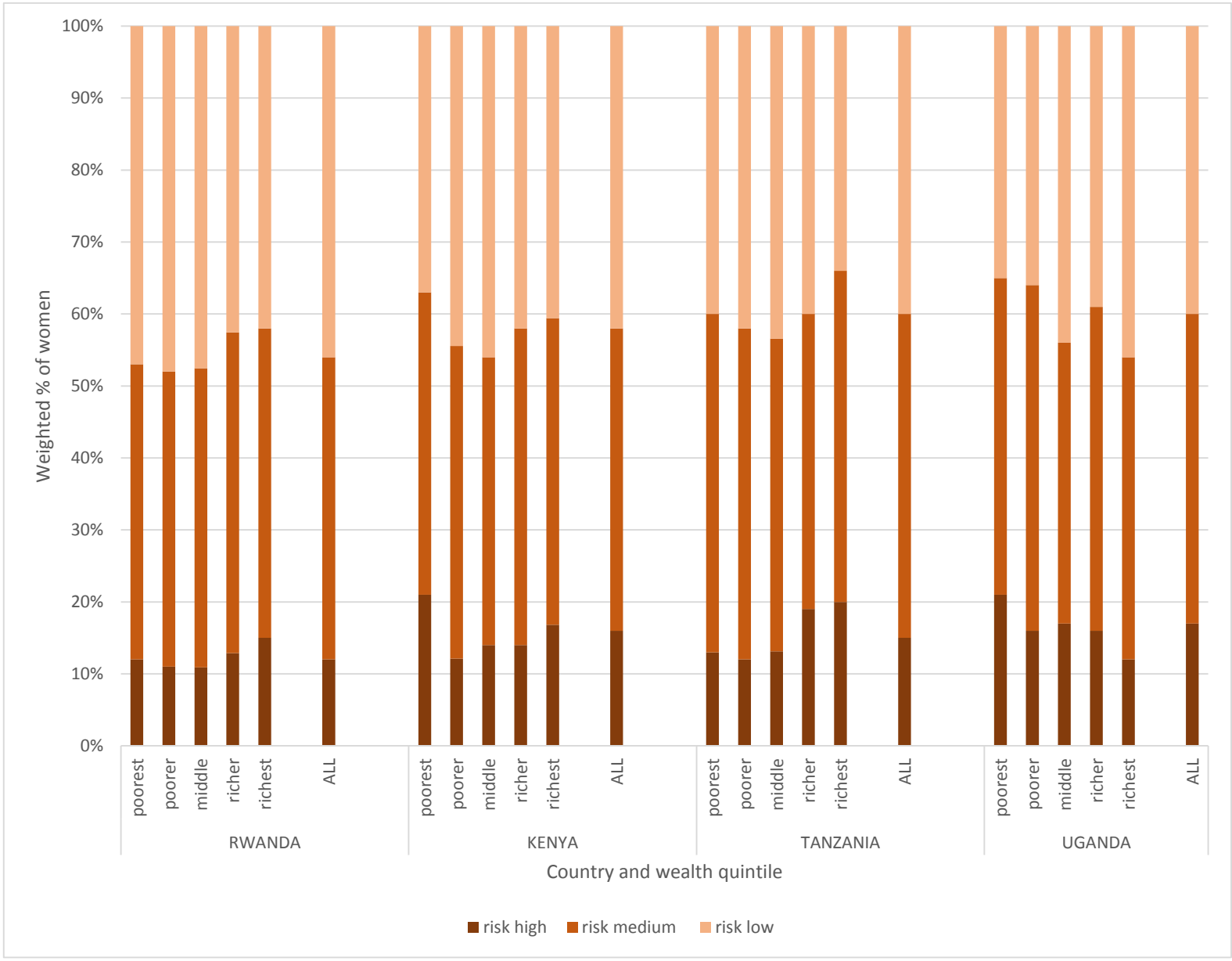
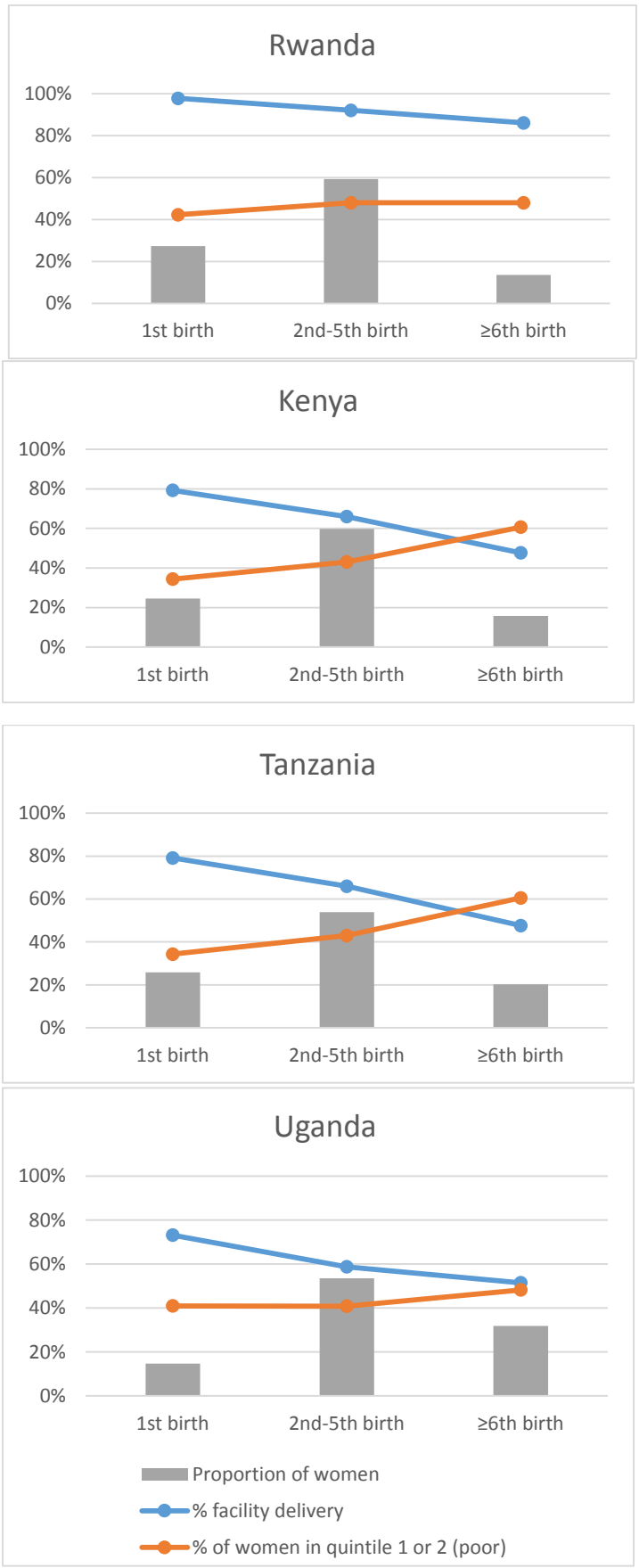


Figure 3: Trend in women's wealth and facility delivery by parity in four East African countries



DISCUSSION

Overall obstetric risk, as defined in our study, was not associated with delivery location. This is concerning as it suggests that women with a higher risk of developing maternal or newborn complications are as likely to deliver at home or in a facility as women without specific risk factors. Possible explanations relate to access, awareness of risk, and concerns about quality of care.

Geographical and financial barriers to facility care are known (52) and are supported by the large associations seen between wealth and facility delivery in our data. Preterm and short labours reduce the opportunity to overcome these barriers, and are more common with risk factors such as multiple gestation and grand multiparity. Other family members, who have not learnt about a woman's risk at antenatal appointments, may decide where she gives birth. For example, in Uganda, husbands are very important in both choosing and overcoming barriers to access facility delivery (53).

Women not receiving ANC might be unaware of their risk; advice given during ANC to deliver in a health facility has been shown to predict use of skilled facility delivery care (54, 55) and ANC was strongly associated with facility delivery in this study, except in Uganda. The large majority of women (96-99%) attended at least one antenatal appointment, however, from the DHS reports for these countries we know only around half of women attended the recommended four visits (56-59). Some risk factors, like multiple gestation, are harder to identify in low-resource settings without easy access to ultrasound scans. Certain at-risk women may not understand advice given, for example women who have delivered safely at home for previous births may not appreciate that their grand multi-parity now puts them at a higher risk (18). Some women will grasp the risk of complications occurring but doubt the quality of facility care or fear neglect and maltreatment (52, 55), especially if they experienced a stillbirth or newborn death in a previous pregnancy. For others, demands such as caring for older children may take priority over a stay in hospital.

Antenatal care, which is at least partially accessed by the large majority of women, provides a key opportunity to identify women at increased obstetric risk, explain the importance of skilled attendance and encourage birth planning. Risk identification is acknowledged in the new WHO recommendations on ANC as important to reduce maternal morbidity and mortality (60) and it is therefore surprising that none of the 49 recommendations specifically addresses risk identification or describes the constituents of a high-risk pregnancy. This reflects the change in emphasis that occurred in the early 2000s, away from a risk approach to considering every pregnancy to be at risk. However, we would argue alongside others (26), that it is important to identify pregnancies with higher risk for the mother and baby, inform women of this risk and encourage and enable them to deliver in a hospital with the capacity to manage complications and perform Caesarean sections (CEmONC).

Communication on birth preparedness and complication readiness, as described in the earlier WHO guidelines on health promotion for maternal and newborn health (61), is expected to occur at all ANC contacts so is only referred to in recommendations for community-based interventions and task shifting. All four countries in our analysis have introduced focussed ANC, including four antenatal visits, communication on birth preparedness and recommendations for all women to deliver with a skilled attendant. However, studies in Kenya, Uganda and Tanzania observed only 24-76% of women received birth preparedness advice and only 7% of Ugandan women were informed about danger signs (62, 63) indicating that the quality of ANC is poor and needs improvement. All women should be encouraged to deliver in a health facility(2), but particular attention should be given to women with any identified risk factors, many of whom should be recommended to deliver not only in a facility but in one offering comprehensive emergency obstetric care. Monitoring of ANC activities, both routinely and in surveys such as the Service Provision Assessment(64), should include indicators on risk assessment and communication.

Overall facility delivery rates varied widely between the countries studied, suggesting that differences in health policy, including fee exemption schemes, and health service delivery (access and quality) affected uptake of facility care. Population distribution might also be relevant: Kenya has remote areas, while Rwanda is smaller, making travel easier. User fees for maternity services were abolished in Tanzania and Uganda before the period studied, as well as in Kenyan health centres and dispensaries. However, neither Kenya, nor Uganda saw immediate improvements in

facility deliveries as a result (65, 66) and studies in Kenya and Tanzania show most women continued to pay a service fee, despite the policy (65, 67).

Rwanda notably has both a higher overall facility delivery rate and smaller differences between rich and poor than the other three countries. As well as developing a successful health insurance scheme (68), making maternity care more financially accessible, the country has also invested heavily in the development of their Community Health Worker (CHW) programme. CHWs provide community education, identify pregnant women and give ongoing encouragement to attend ANC and deliver in a facility(69). Between 2005 and 2010 a steep increase in facility deliveries was seen in Rwanda (70), coinciding with sustained capacity building of CHWs especially through training in Maternal and Child Health. However, almost 80% of these facility deliveries occur in low-level facilities not offering full basic emergency obstetric care (BEmOC), compared to Uganda and Kenya where over 40% of facility deliveries occur where comprehensive emergency care is provided (71).

Similar to other studies(3), we found women with a higher socio-economic status or educational level were much more likely to deliver in a facility. In Tanzania, education appeared to modify the effect of risk on delivery location with obstetric risk driving place of delivery only among better educated women. The difference in facility delivery rates between risk groups was small and these results were not replicated elsewhere so should be treated with caution. However, it is plausible that more educated women might better understand the complex concept of risk and subsequently deliver in a facility, and improving girls' education should be advocated for this and many other reasons.

Wealth did not modify the effect of obstetric risk on delivery location and there is no consistent association across countries between wealth and overall obstetric risk. This is probably explained by the clustering of individual components of obstetric risk into different wealth groups, especially those associated with parity and nutrition. The most common risk factors related to parity and our results confirm those of other studies which show higher risk is associated with both lower socioeconomic status and lower likelihood of facility delivery (18). Conversely, due to their smaller completed family size, richer women in the sample are more likely to be giving birth for the first time, putting them at increased risk of complications associated with first delivery, such as obstructed labour. However, they are more likely to deliver their baby in a health facility. Socio-economic status is therefore an integral part of the relationship between risk and facility delivery, affecting the most common factors that increase obstetric risk as well women's decisions about where they give birth.

LIMITATIONS TO OUR STUDY

We used a simple approach to measuring obstetric risk, taking the factors available in population-based surveys known to carry an increased risk of obstetric complications, and using the premise that once a woman had a risk factor she would benefit from delivering in a facility. We regarded certain factors, and the combination of 2 or more factors, as increasing a woman's risk further (grouped under the "high-risk" category). However, we did not weight the factors beyond this. This categorisation has not been done before and the association between this grouping of risk factors and actual health outcomes for women and newborns is unknown, although based on evidence supporting the individual factors.

Some important risk factors are not collected in the DHS and thus we could not include these in our categories, notably clinical risk factors such as diabetes and anaemia, previous poor obstetric history such as haemorrhage and pre-eclampsia, as well as clinical risk factors identified in the current pregnancy, such as pre-eclampsia or placenta praevia. Therefore, women whom we categorised as low risk may have been identified with such risk factors in the pre-pregnancy or antenatal period, weakening any potential association between obstetric risk and delivery location. Furthermore, while some obstetric risk factors are identifiable prior to delivery, predicting antenatally which women will develop complications at birth is difficult (72-74). Consequently, the priority in low-resource settings where emergency transport is unavailable is still to ensure that all women have access to high-quality delivery care in a health facility.

The DHS relies on self-reported data and there could be differences between individuals' recall and characterisation of risk factors. Self-reported aspects of risk like stillbirth may suffer from under-reporting for personal reasons, but it

is unclear if this would vary by socioeconomic background, or in which direction. The validity of self-reported data for factors such as previous caesarean section is known to be high (75). The use of the DHS' wealth quintiles is imperfect as they are relative measures of within-country wealth, and not comparable between countries. The wealth indices are, however, weighted to mitigate urban/rural disparities.

The DHS only provides detailed data about live births, as reported by the mother. Therefore, our sample excludes women who died or who had a stillbirth in the index pregnancy – two important potential consequences of obstetric complications. Some early neonatal deaths may also have been misclassified as stillbirths and not included in our sample of live births.

Women's weight was measured at the time of the survey and we assumed that they were in the same weight category (malnourished, low-risk or obese) at the time of their index pregnancy, whereas this might have changed following delivery. However, the similarity in the main results across countries, despite differences in the contribution of weight to medium risk scores (8-18%) suggests any potential misclassification is unlikely to be causing major bias. Data on previous caesarean sections and stillbirths is only available for the 5 years preceding the survey: therefore earlier events are not captured in our risk factors, and we may have misclassified medium or high-risk women as having a lower obstetric risk.

CONCLUSION

The troubling key message from our results is that many women who can be easily identified before delivery as being at increased potential risk of maternal and newborn complications are not delivering within a health facility. Many of these complications require urgent care unavailable at home, such as caesarean section. Instead, it appears to be a woman's socio-economic status that determines her likelihood of a facility delivery. One straightforward way to improve this situation could be a renewed focus within ANC on screening for obstetric risk and improving communication around birth planning to reduce context-specific barriers to facility delivery. Further research into the quality of ANC communication, the effect of increased awareness of risk on women's decision-making, and the specific barriers faced by high-risk women will help to highlight the key areas for intervention and to strengthen service quality. In country, greater attention could also be given to service innovations such as maternity waiting homes which lessen the inequities related to transport and geographical accessibility of facility care. Lessons can also be learned from the comparative equity and high proportion of facility deliveries seen in Rwanda, exploring the role of community-based interventions to improve birth preparedness and strengthening the call for available and affordable high-quality services for all women.

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Table

Appendix

Table A: Tests for interaction between obstetric risk and wealth or education

		RWANDA		**KENYA**		**TANZANIA**		**UGANDA**	
Wealth quintiles	**Obstetric risk**	facility delivery RR compared to low risk (95% CI)	p-value for interaction	facility delivery RR compared to low risk (95% CI)	p-value for interaction	facility delivery RR compared to low risk (95% CI)	p-value for interaction	facility delivery RR compared to low risk (95% CI)	p-value for interaction
Poorest	Medium	1.04 (0.96-1.11)	0.13	0.89 (0.72-1.10)	0.25	1.01 (0.86-1.18)	0.62	1.08 (0.73-1.61)	0.79
	High	0.99 (0.88-1.11)		0.75 (0.55-1.01)		0.97 (0.77-1.23)		1.40 (0.88-2.20)	
Poorer	Medium	0.99 (0.91-1.08)		1.05 (0.93-1.18)		1.05 (0.90-1.22)		1.11 (0.83-1.49)	
	High	1.08 (1.02-1.14)		1.02 (0.84-1.24)		1.12 (0.91-1.38)		1.18 (0.83-1.69)	
Middle	Medium	1.02 (0.97-1.07)		0.92 (0.80-1.06)		0.88 (0.77-1.00)		0.99 (0.73-1.35)	
	High	1.04 (0.98-1.11)		1.07 (0.90-1.26)		0.91 (0.75-1.09)		1.07 (0.73-1.57)	
Richer	Medium	1.00 (0.95-1.06)		0.98 (0.90-1.06)		1.02 (0.93-1.12)		1.04 (0.80-1.34)	
	High	0.99 (0.91-1.08)		1.01 (0.89-1.14)		1.07 (0.95-1.20)		0.81 (0.53-1.23)	
Richest	Medium	1.01 (0.99-1.04)		1.06 (1.00-1.12)		1.00 (0.96-1.04)		1.04 (0.92-1.17)	
	High	0.99 (0.95-1.04)		1.07 (1.00-1.14)		1.03 (1.00-1.07)		1.05 (0.92-1.21)	
Education		**RWANDA**		**KENYA**		**TANZANIA**		**UGANDA**	
No education	Medium	0.96 (0.86-1.07)	0.77	0.84 (0.60-1.20)	0.03	1.00 (0.84-1.18)	0.001	0.72 (0.45-1.13)	0.16
	High	1.02 (0.89-1.16)		0.56 (0.36-0.86)		0.78 (0.59-1.02)		0.76 (0.45-1.35)	
Any Primary	Medium	1.02 (0.99-1.06)		0.94 (0.86-1.02)		0.92 (0.87-0.99)		1.04 (0.87-1.25)	
	High	1.02 (0.97-1.07)		1.00 (0.90-1.11)		1.08 (1.00-1.17)		1.11 (0.91-1.35)	
Secondary or higher	Medium	1.00 (0.97-1.03)		1.03 (0.98-1.09)		1.07 (1.00-1.15)		1.25 (1.08-1.46)	
	High	1.01 (0.99-1.03)		1.05 (0.97-1.13)		1.12 (1.05-1.20)		1.03 (0.78-1.35)	

Table B: Weighted number (percentage) of women at each obstetric risk level by wealth quintile for four East African countries

	RWANDA N= 2158				**KENYA N=4733**				**TANZANIA N=5033**				**UGANDA N= 1195**			
	OBSTETRIC RISK				**OBSTETRIC RISK**				**OBSTETRIC RISK**				**OBSTETRIC RISK**			
	Low	Med	High	Overall	Low	Med	High	Overall	Low	Med	High	Overall	Low	Med	High	Overall
	Weighted n (%)			p-value*	Weighted n (%)			p-value*	Weighted n (%)			p-value*	Weighted n (%)			p-value*
Poorest	253 (47)	214 (40)	66 (12)	0.43	393 (37)	449 (42)	231 (22)	0.0009	468 (40)	560 (47)	154 (13)	0.0001	93 (35)	114 (43)	58 (22)	0.26
Poorer	225 (48)	191 (41)	51 (11)		421 (44)	411 (43)	118 (12)		444 (42)	486 (46)	125 (12)		93 (36)	120 (47)	43 (17)	
Middle	191 (48)	166 (41)	44 (11)		400 (46)	343 (40)	121 (14)		396 (42)	413 (44)	134 (14)		102 (44)	89 (39)	40 (17)	
Richer	158 (42)	167 (45)	48 (13)		364 (41)	388 (44)	126 (14)		387 (40)	400 (41)	184 (19)		87 (39)	101 (45)	36 (16)	
Richest	160 (42)	165 (43)	58 (15)		390 (40)	414 (43)	165 (17)		303 (34)	408 (46)	173 (20)		101 (46)	90 (41)	27 (12)	

*Pearson's chi-squared test

Table C: Association between individual risk factors and wealth in four East African Countries

RWANDA	**Weighted n (column %)**						
	POOREST n=550	**POORER n=476**	**MIDDLE n=405**	**RICHER n=376**	**RICHEST n=384**	**TOTAL N=2191**	Risk/wealth association
MEDIUM RISK FACTORS							p-value
Focus birth was first-born	135 (24.53)	118 (24.83)	111 (27.34)	109 (28.99)	121 (31.38)	593 (27.08)	0.18
Height <145cm	29 (5.25)	13 (2.70)	13 (3.12)	4 (1.16)	2 (0.61)	61 (2.79)	0.0003
Previous Caesarean but vaginal delivery before focus birth	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	
Grand multiparous (>=6 live births)	83 (15.04)	64 (13.55)	58 (14.43)	68 (18.06)	28 (7.18)	301 (13.74)	0.0008
Malnourished (BMI < 18.5)	37 (6.79)	25 (5.24)	22 (5.50)	8 (2.10)	6 (1.69)	99 (4.51)	0.0012
Obese (BMI > 30)	4 (0.70)	12 (2.58)	10 (2.38)	13 (3.43)	58 (15.07)	97 (4.41)	<0.0001
Previous stillbirth- but subsequent live birth prior to focus birth	1 (0.13)	0 (0)	1 (0.27)	1 (0.36)	0 (0.10)	4 (0.16)	0.55
Short preceding birth interval (<=12months)	7 (1.26)	6 (1.34)	4 (0.98)	1 (0.38)	3 (0.82)	22 (1.00)	0.68
Previous baby died aged 1-12 months	7 (1.31)	7 (1.50)	4 (0.94)	2 (0.55)	2 (0.41)	22 (0.99)	0.42
Woman has had no antenatal care	7 (1.30)	4 (0.76)	2 (0.52)	1 (0.28)	8 (1.97)	22 (0.98)	0.15
HIGH RISK FACTORS							
Focus birth twins/triplets	8 (1.39)	11 (2.22)	5 (1.13)	3 (0.88)	2 (0.45)	28 (1.27)	0.22
Last delivery before focus birth was stillbirth	0 (0)	1 (0.22)	3 (0.71)	2 (0.55)	2 (0.58)	8 (0.37)	0.40
Last delivery before focus birth was Caesarean	14 (2.62)	19 (3.96)	16 (3.89)	22 (5.78)	27 (7.09)	98 (4.47)	0.02
Previous baby died in first 30 days of life	14 (2.55)	9 (1.81)	3 (0.73)	6 (1.71)	4 (1.12)	36 (1.66)	0.23
Woman was under 16 at time of focus birth	1 (0.24)	0 (0)	0 (0)	0 (0)	3 (0.81)	4 (0.20)	0.11
Focus birth was first born to a woman aged 35+	2 (0.28)	1 (0.21)	0 (0)	2 (0.47)	0 (0)	4 (0.20)	0.51

KENYA	Weighted n (column %)						
	POOREST n=1092	POORER n=961	MIDDLE n=872	RICHER n=895	RICHEST n=980	TOTAL N=4799*	Risk/wealth association
MEDIUM RISK FACTORS							p-value
Focus birth was first-born	162 (14.82)	192 (20.00)	191 (21.86)	286 (31.90)	335 (34.22)	1165 (24.29)	<0.0001
Height <145cm	20 (1.85)	9 (0.94)	4 (0.48)	2 (0.23)	8 (0.79)	43 (0.90)	0.06
Previous Caesarean but vaginal delivery before focus birth	0 (0.01)	1 (0.11)	1 (0.10)	0 (0)	1 (0.10)	3 (0.06)	0.56
Grand multiparous (>=6 live births)	316 (28.93)	203 (21.12)	153 (17.52)	56 (6.27)	32 (3.30)	760 (15.84)	<0.0001
Malnourished (BMI < 18.5)	207 (18.99)	82 (8.57)	62 (7.16)	50 (5.59)	25 (2.56)	427 (8.9)	<0.0001
Obese (BMI > 30)	16 (1.44)	36 (3.75)	41 (4.67)	104 (11.62)	211 (21.52)	407 (8.49)	<0.0001
Previous stillbirth- but subsequent live birth prior to focus birth	2 (0.15)	1 (0.12)	3 (0.36)	0 (0)	0 (0)	6 (0.12)	0.40
Short preceding birth interval (<=12months)	16 (1.51)	6 (0.59)	14 (1.66)	3 (0.31)	1 (0.12)	41 (0.84)	0.0001
Previous baby died aged 1-12 months	23 (2.09)	17 (1.79)	12 (1.33)	13 (1.45)	9 (0.96)	74 (1.54)	0.66
Woman has had no antenatal care (Total N = 4786)	98 (8.98)	35 (3.59)	24 (2.73)	15 (1.73)	5 (0.50)	177 (3.69)	<0.0001
HIGH RISK FACTORS							
Focus birth twins/triplets	19 (1.73)	7 (0.74)	26 (2.96)	10 (1.07)	22 (2.29)	84 (1.75)	0.12
Last delivery before focus birth was stillbirth	7 (0.60)	10 (1.00)	6 (0.70)	2 (0.23)	5 (0.53)	30 (0.62)	0.52
Last delivery before focus birth was Caesarean	21 (1.90)	9 (0.98)	20 (2.34)	20 (2.28)	47 (4.83)	118 (2.46)	0.0016
Previous baby died in first 30 days of life	17 (1.52)	17 (1.82)	14 (1.57)	32 (3.63)	22 (2.25)	102 (2.13)	0.21
Woman was under 16 at time of focus birth	9 (0.83)	17 (1.80)	9 (1.02)	5 (0.50)	0 (0)	40 (0.83)	0.0181
Focus birth was first born to a woman aged 35+	0 (0)	1 (0.13)	0 (0)	0 (0.05)	0 (0.04)	2 (0.04)	0.61

*Total includes those who have any of the risk factors

TANZANIA	Weighted n (column %)						
	POOREST n=1214	POORER n=1082	MIDDLE n=972	RICHER n=985	RICHEST n=888	TOTAL N=5140*	Risk/wealth association
MEDIUM RISK FACTORS							p-value
Focus birth was first-born	231 (19.00)	223 (20.65)	233 (23.94)	295 (29.99)	330 (37.18)	1312 (25.53)	<0.0001
Height <145cm	18 (1.48)	21 (1.90)	16 (1.62)	22 (2.26)	12 (1.35)	89 (1.72)	0.65
Previous Caesarean but vaginal delivery before focus birth	0 (0)	0 (0)	0 (0)	0 (0)	0 (0.04)	0 (0.01)	0.91
Grand multiparous (>=6 live births)	360 (29.67)	279 (25.83)	239 (24.58)	137 (13.91)	37 (4.14)	1052 (20.47)	<0.0001
Malnourished (BMI < 18.5)	120 (9.84)	83 (7.68)	63 (6.52)	68 (6.90)	34 (3.80)	368 (7.15)	0.0008
Obese (BMI > 30)	11 (0.89)	22 (1.99)	32 (3.31)	94 (9.54)	213 (23.93)	371 (7.22)	<0.0001
Previous stillbirth- but subsequent live birth prior to focus birth	7 (0.55)	7 (0.64)	0 (0)	3 (0.31)	1 (0.17)	18 (0.35)	0.23
Short preceding birth interval (<=12months)	10 (0.83)	14 (1.34)	8 (0.87)	6 (0.63)	3 (0.34)	42 (0.82)	0.37
Previous baby died aged 1-12 months	23 (1.86)	28 (2.61)	13 (1.34)	19 (1.96)	12 (1.34)	95 (1.85)	0.35
Woman has had no antenatal care (Total N=5125)	44 (3.66)	20 (1.86)	16 (1.65)	16 (1.64)	17 (1.93)	114 (2.22)	0.0754
HIGH RISK FACTORS							
Focus birth twins/triplets	15 (1.21)	11 (1.03)	18 (1.85)	26 (2.64)	17 (1.94)	87 (1.69)	0.1035
Last delivery before focus birth was stillbirth	7 (0.58)	6 (0.54)	16 (1.69)	15 (1.55)	8 (0.89)	53 (1.02)	0.0754
Last delivery before focus birth was Caesarean	11 (0.95)	7 (0.65)	12 (1.28)	13 (1.37)	36 (4.11)	81 (1.58)	<0.0001
Previous baby died in first 30 days of life	21 (1.73)	17 (1.59)	10 (1.04)	30 (3.07)	29 (3.28)	108 (2.09)	0.0039
Woman was under 16 at time of focus birth	13 (1.10)	7 (0.65)	6 (0.63)	11 (1.12)	3 (0.38)	41 (0.80)	0.38
Focus birth was first born to a woman aged 35+	0 (0)	2 (0.20)	0 (0)	1 (0.12)	5 (0.53)	8 (0.16)	0.25

*Total includes those who have any of the risk factors

UGANDA	Weighted n (column %)						
	POOREST n=274	POORER n=262	MIDDLE n=233	RICHER n=230	RICHEST n=231	TOTAL N=1230*	Risk/wealth association
MEDIUM RISK FACTORS							p-value
Focus birth was first-born	32 (11.51)	45 (17.16)	25 (10.94)	34 (14.74)	47 (20.39)	183 (14.88)	0.05
Height <145cm	6 (2.02)	3 (1.22)	3 (1.47)	3 (1.34)	2 (0.65)	17 (1.36)	0.80
Previous Caesarean but vaginal delivery before focus birth	0 (0.14)	0 (0)	0 (0)	2 (0.93)	0 (0)	3 (0.21)	0.27
Grand multiparous (>=6 live births)	102 (37.18)	87 (33.32)	81 (34.73)	81 (35.37)	38 (16.48)	389 (31.67)	<0.01
Malnourished (BMI < 18.5)	43 (15.56)	34 (13.13)	18 (7.78)	13 (5.71)	9 (4.01)	118 (9.56)	<0.01
Obese (BMI > 30)	2 (0.60)	1 (0.40)	5 (2.12)	6 (2.46)	24 (10.27)	37 (3.01)	<0.01
Previous stillbirth- but subsequent live birth prior to focus birth	0 (0)	1 (0.55)	0 (0)	0 (0)	0 (0)	1 (0.12)	0.47
Short preceding birth interval (<=12months)	1 (0.52)	4 (1.70)	3 (1.11)	4 (1.60)	6 (2.60)	18 (1.48)	0.48
Previous baby died aged 1-12 months	15 (5.60)	7 (2.83)	5 (2.31)	5 (2.08)	3 (1.12)	35 (2.89)	0.09
Woman has had no antenatal care (Total N=1211)	16 (5.73)	4 (1.68)	9 (3.70)	3 (1.50)	4 (1.72)	36 (2.96)	0.08
HIGH RISK FACTORS							
Focus birth twins/triplets	3 (1.26)	6 (2.43)	3 (1.48)	4 (1.84)	4 (1.59)	21 (1.72)	0.90
Last delivery before focus birth was stillbirth	2 (0.78)	2 (0.58)	3 (1.37)	1 (0.47)	0 (0.16)	8 (0.68)	0.61
Last delivery before focus birth was Caesarean (Total N=1229)	5 (1.85)	5 (1.85)	6 (2.65)	6 (2.48)	13 (5.49)	34 (2.80)	0.17
Previous baby died in first 30 days of life	10 (3.54)	10 (3.74)	7 (3.10)	8 (3.47)	2 (0.76)	36 (2.96)	0.43
Woman was under 16 at time of focus birth	1 (0.31)	2 (0.72)	0 (0.12)	0 (0)	1 (0.31)	4 (0.31)	0.32
Focus birth was first born to a woman aged 35+	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	N/A

*Total includes those who have any of the risk factors

Comments from email received at 16.23 March 7th, 2017:

Reviewers' comments:

Reviewer #1: This papers investigates whether mothers at risk, thus those most vulnerable to complications, are delivering in a facility. This raises the neglected topic on obstetric risk and whether the policies and health systems in poor rural settings are able to support women at increased risk. I like to congratulate the authors to reviving the risk thinking of the 1990s which got neglected in programming for maternal and newborn health in the past years summarised with the slogan "every pregnancy faces risks" .
The study methodology is sound, the statistical analyses appropriate.
However, I have a few concerns but these should not prevent the paper to be published. I clearly see a large value in the paper as it is. However, I like to mention some concerns:

First, the authors use DHS data which refer to deliveries of around 2007 to 2010. In view of the rapid economic development in SSA and the rapid changes in facility delivery seen in the past few years, I wonder whether these data are not too old to make meaningful conclusions?
Moreover, new DHS data are available from three countries, Kenya 2014, Rwanda 2014/15 and Tanzania 2015/16, while the report from Uganda is not yet published.

Thank you for this comment – the older datasets were originally chosen to match with another analysis conducted by our team. However, we agree that the newer data is more appropriate and have now analysed the new surveys for Kenya, Rwanda and Tanzania and report these results in place of the old ones. The main results of the study remain unchanged.

Second, I wonder whether one should lump the high risk groups together. All of them are very different, and I assume that the antenatal care policies in the four countries also differ. I do not think the message gets stronger when constructing the indicator high risk, instead I think it might be good to have 2 tracers for the analysis, maybe previous Caesarean section and twin delivery?

Thank you for this comment. The associations between each individual risk factor and facility delivery are presented in Table 4 and summarised in the results section, also taking note of their associations with wealth. Particular attention is given to Caesarean section in the previous delivery. However, the proportion of women with any one of these factors is very small which limits the conclusions that can be made. For example, only 1-2% of women have multiple pregnancy. While the risk-factors are different, they all increase the chance of obstetric or neonatal complications. The creation of a composite high-risk variable which combines previous caesarean, twin pregnancy and other factors provides more power to assess the relationship with place of delivery.

Thirdly, I miss that the authors put the results in country perspectives such as the structure and content of antenatal care, the messages given to women, the options to detect risk factors (I assume that twin deliveries are missed in many cases) and the overall health system structure. For example, Kenia has a much more centralised system, where delivery care is organised in less facilities. I contrast, in Tanzania and Rwanda delivery facilities are very close.

Thank you for these suggestions. We have now added to the paragraph on ANC in the discussion section to include a discussion of the new WHO recommendations and some studies showing what is happening in practice in the countries studied.

Identification of women at risk and effective communication with them are acknowledged in the new WHO recommendations on ANC as important to reduce maternal morbidity and mortality (62). It is

therefore surprising that of the 49 recommendations, none specifically addresses risk identification or describes the constituents of a high-risk pregnancy. This reflects the change in emphasis that occurred in the early 2000s, away from a risk approach to considering every pregnancy to be at risk. However, we would argue, as others have before (26), that it is important to identify pregnancies with higher risk for the mother and baby, inform women of this risk and encourage and enable them to deliver in a hospital with the capacity to manage complications and perform Caesarean sections (CEmONC).
Communication on birth preparedness and complication readiness, as described in the earlier WHO guidelines on health promotion for maternal and newborn health (63), is expected to occur at all ANC contacts so is only referred to in recommendations for community-based interventions and task shifting. All four countries in our analysis have introduced focussed ANC, including four antenatal visits, communication on birth preparedness and recommendations for all women to deliver with a skilled attendant. However, studies in Kenya, Uganda and Tanzania observed only 24-76% of women received birth preparedness advice and only 7% of Ugandan women were informed about danger signs (64, 65) indicating that the quality of ANC is poor and needs to be improved.

We have also added a sentence on the level of health facility where deliveries take place

However, it should also be noted that [in Rwanda] *almost 80% of these facility deliveries occur in low-level facilities that do not offer full basic emergency care, compared to Uganda and Kenya where over 40% of facility deliveries occur where comprehensive emergency care is provided.*

Fourthly, I miss a more in-depth review/discussion of what might be the reasons for missing these women at risk. A lot is mentioned such as barriers to assess facility deliveries, but the discussion is general, not in relation to the risk factors. I assume such evidence is largely missing. However, there are many researchers in the four countries who could give more insights and speculate what the reasons are specifically for the risk factors you did examine. For example, I believe that twins are not really detected during ANC, and mother will be surprised by early contractions at home, and cannot make it anymore to the facilities.
In contrast, the risk factor previous CS is known (unless there is misclassification and some women reported previous episiotomies). Women are typically referred to a hospital, and not any facility for delivery. Thus much larger distances have to be overcome and I expect differences for this indicator in relation to socio-economic status.

Thank you for this helpful comment. We have expanded the early discussion of barriers to access to explore how these might relate to some of the particular risk factors in question. This is mainly speculation based on the authors' understanding of the context but we hope it strengthens the argument. Women with CS in the previous pregnancy have high rates of facility delivery, so in many cases have overcome the barrier of distance, however, as discussed, they are also wealthier. The Updated paragraphs are as follows:

There are many possible explanations for this finding related to access, awareness of risk, and concerns about quality of care.
Geographical and financial barriers to facility care have been previously described (52) and are supported by the large associations seen between wealth and facility delivery in our data. Preterm and short labours reduce the opportunity to overcome these barriers, and are more common with risk factors such as multiple gestation and grand multiparity. Other family members, who have not learnt about a woman's risk at antenatal appointments, may decide where she gives birth. For example, in Uganda, husbands are very important in both choosing and overcoming barriers to access facility delivery (53).

Women who do not receive ANC might be unaware of their risk; advice given during ANC to deliver in a health facility has been shown to predict use of skilled facility delivery care (54, 55) and ANC was strongly associated with facility delivery in this study, with the exception of Uganda. The large majority of women (96-99%) attended at least one antenatal appointment, however, from the DHS reports for these countries we know only around half of women attended the recommended four visits (56-59). Some risk factors, such as multiple gestation, are more difficult to identify in low-resource settings without easy access to ultrasound scans. Certain at-risk women may not understand the information they are given, for example women who have delivered safely at home for previous births may not appreciate that their grand multi-parity now puts them at a higher risk (18). Some women will grasp the risk of complications occurring but doubt the quality of facility care or fear neglect and maltreatment (52, 55), especially if they experienced a stillbirth or newborn death in a previous pregnancy. For others, demands such as caring for older children may take priority over a stay in hospital.

A few minor comments
I recommend to add the time period to which the numbers in the table belong to (years 2007-2010 or so)
This is now included in Table 2
Discussion: I recommend to include and refer to the policy documents/guidelines in the countries to review the risk factors.
Reference to Uganda and Kenya guidelines which list obstetric risk factors is now made in the Methods section as they support the choice of criteria. High-risk criteria could not be found in any guidelines from Tanzania and Rwanda

The selected criteria closely match those for high-risk pregnancy in the clinical guidelines from Uganda and Kenya, including age, parity, nutritional status, poor obstetric history and multiple pregnancy, but are unable to capture information on medical conditions which are not recorded in the DHS (16, 17).

I recommend to include a discussion around the argument which led to the re-focused ANC programmes giving more emphasis on providing services (syphilis screening Malaria prophylaxis etc) than risk detection. We probably need to new slogan: "Every pregnancy faces risk, but some mother and babies are more at risk" or so ???
As described above, we now discuss the new ANC recommendations and argue for more attention to be given to detecting high-risk pregnancies.

Under limitations of the study I would like to reject that risk factors would not be differentially reported by women of different socio-economic status. Also, the problem around data on Caesarean sections are known and the authors could go there more in-depth.

Thank you – we are now more cautious about this statement in relation to reporting risks such as previous stillbirth. While older versions of the DHS may have led to confusion with episiotomies, the current questionnaire is much clearer and validation studies have shown very high sensitivity and specificity of self-report. The sentences have been updated as follows;

Self-reported aspects of risk such as stillbirth may suffer from under-reporting for personal reasons, but it is unclear if this would vary by socioeconomic background, or in which direction. The validity of self-reported data for factors such as previous caesarean section is known to be high (74).

I do not think that the conclusions at present give the way forward. How can community-based initiatives help to detect pregnancy risks if already facility based ANC probably fails? And sure, we do not know where the problem is: 1) risk detection, 2) communication of risk/birth preparedness at ANC 3) taking the decision to go to a facility 4) being able to do so (twins might led to premature labor where there is little chance to reach any facility).

Thank you for these comments and questions. We have added a stronger emphasis on risk identification and communication in ANC, the need for further research to identify where the problem may be and have been more specific about the role of community-based interventions in birth preparedness (rather than detecting risk). The paragraph already considers the need to reduce geographical and financial barriers and improve quality of care.

One straightforward way to improve this situation could be a renewed focus within ANC on screening for obstetric risk and improving communication around birth planning to reduce context-specific barriers to facility delivery. Further research into the quality of ANC communication, the effect of increased awareness of risk on women's decision-making, and the specific barriers faced by high-risk women will help to highlight the key areas for intervention and to strengthen service quality. In country, greater attention could also be given to service innovations such as maternity waiting homes that can help to overcome some of the inequities related to transport and geographical accessibility of facility care. Lessons can also be learned from the comparative equity and high proportion of facility deliveries seen in Rwanda, exploring the role of community-based interventions to improve birth preparedness and strengthening the call for available and affordable high-quality services for all women.

I feel the ANC package needs to be looked at, and in this respect I also miss a reference to the new guidance from WHO.

Please see new paragraph above

Thank you for giving me the chance to read this very interesting paper

Thank you for your useful and insightful comments

Reviewer #2: This paper examines the association between level of obstetric risk and delivery in a facility in four East African countries. It is timely given that the new SDG framework includes specific targets for ending preventable maternal deaths, and access to skilled delivery care is essential for achieving these targets. The paper is very well written, the methodology is sound, the presentation of the results is clear and the discussion section does a thorough job of interpreting the results and presenting plausible explanations for the findings in each of the four countries. The limitations section is also well done. The authors do show that there is no strong relationship between obstetric risk and facility delivery (with a small exception in Rwanda), which does suggest that we are failing to convey the message to even women at high risk the importance of a facility delivery in these four settings, and are not sufficiently addressing barriers to such care.

However, there are a few minor issues that could be addressed to strengthen the study, including presenting ideas for future research in each of the countries to explore context specific reasons for low coverage levels of institutional deliveries (aside from Rwanda) and emphasizing the importance of all women, not just those identified at higher risk, having access to skilled care and a functional referral system given that most complications are unpredictable

Here are some specific comments by study section:

1. Introduction.

- The authors seem to conflate skilled attendance at birth with institutional delivery, although they note later on that one reason why women may not opt to deliver in a facility is because of reports of poor quality of care (which can include that the providers are not always skilled at the facility, and may lack needed equipment, running water, etc, and there may not be respectful care either). I think they could make a clearer argument for why they are focusing on institutional delivery and not skilled attendant at birth, or looking at SBA in combination with the referral system.

Thank you for this comment. We agree that a clearer argument is necessary and have added an extra sentence to the methods to explain the choice of outcome.

Facility birth was chosen in preference to skilled birth attendant (SBA) as it is less prone to misclassification by women and should provide the necessary equipment as well as the personnel to enable skilled attendance.

- The authors state that it is the women at highest obstetric risk that are falling through the cracks (in their effort to position this paper and the study hypothesis within the context of the SDGs). However, this doesn't seem to really be the case since women in all wealth quintiles and education levels were found to have a similar % of women in the highest risk category (although the set of risk factors may have differed between these groups of women). The study findings seem instead to echo other research that show it is poor and less educated women that are falling the farthest behind in terms of access to institutional delivery and are the ones in need of most targeted attention. I think the authors could still make the argument that it is important to look at the relationship between level of risk and likelihood to access facility delivery as a measure of how well we are 1) informing women, especially those at high risk, of the importance of skilled delivery care and access to a functional referral system, and 2) how well we are addressing other barriers to care like lack of transport, poor quality, cultural factors, etc.

Many thanks for this comment. We agree that poor and less educated women are the ones falling behind in terms of accessing skilled care at birth. In the introduction we were trying to argue that the most vulnerable women are those who are both at high risk and not accessing care. We have changed the sentence at the end of the first paragraph to clarify this.

At the start of the Sustainable Development Goal (SDG) era, as we consider how to maintain and accelerate progress, one important focus must be on reaching the most vulnerable women: those at high risk of maternal and newborn complications who are not receiving adequate care.

The issues around informing women and addressing other barriers are picked up in the discussion

- The authors' stated prediction is predicated upon high risk women receiving counseling about their warning signs and the importance of facility delivery. But, we are not given any information on coverage levels of ANC4 or whether women recognized that they were at high risk (the classification system is one that was developed by the authors so it's not clear to me if the women would have identified themselves as at low, medium or high risk). So, it could be that women in these contexts are also not receiving adequate ANC or any kind of counseling on risk factors and danger signs.

We agree that the hypothesis that women at risk are more likely to attend for facility delivery depends on many other factors such as women knowing and understanding their risk, as well as them overcoming all the other barriers to facility care. We have decided to remove the prediction

from the introduction and have added more to the results and discussion on coverage and content of ANC as mentioned above.

- It's not clear why there is mention of progress towards MDG4, there is no other reference to child or neonatal mortality and this seems a non-necessary statement unless the authors want to make a better link between the maternal and newborn health outcomes that can be improved with skilled attendance at birth.

Many thanks for raising this point. Our intention was to consider the risk to the mother and her baby, and the risk factors included in the study can lead to poor outcomes for newborns as well as mothers – as illustrated in Table 1. We have made this more explicit in the text by referring to "*maternal and newborn complications*" in a number of places.

2. Methods
This section is really excellent. It would be good for the authors to explain that it is also advantageous to use the DHS for comparability across the countries, which is a key component of this study. I do think the authors should also note how old the data is. I think there are newer DHS for Kenya and Rwanda (2014-2015), and with the recall period being the last 3 to 5 years, these findings for Kenya in particular are quite old and may not reflect more current patterns of institutional delivery.

Thank you for these positive comments. As described above, we have carried out the analysis on the new DHS datasets and this is presented in the revised version of the paper. We have revised the second sentence of the Methods section to include the comparability of the DHS data.

These are nationally representative, cross-sectional, household surveys using standardised questionnaires and shown to produce high-quality data for low- and middle-income settings which are comparable across countries

3. Results
Figure 3 is not called out anywhere in the text, unless figure 4 is supposed to be figure 3? And, I find figure 3 very hard to interpret. What do the two series represent?

Many apologies for the poor labelling and referencing of figure 3. This has now been corrected and we hope the figure is much clearer.

4. Discussion and conclusion.

- It could be argued that women with higher obstetric risk are as likely to have a home OR A FACILITY delivery as women at lower risk. The way this sentence is written is misleading to support the authors' stated premise.
Agreed – we have changed the sentence
This is concerning as it suggests that women with a higher risk of developing maternal or newborn complications are as likely to deliver at home or in a facility as women without specific risk factors

- The authors do a great job of presenting all the possible reasons for why women may not have accessed an institutional birth regardless of their risk level.
- However, with no information on patterns of ANC use or access to other forms of counseling, it's difficult to determine what women knew about their level of risk and the importance of delivering in a facility.

Thank you for this comment. As described above, we have now tried to show how some of the risk factors particularly relate to certain barriers to access. We have also included information on ANC attendance and discussed the content of ANC observed in other studies.

- I think the authors miss an opportunity to stress the need for future research in each of these countries to get a better understanding of how awareness of risk affects women's decision making on accessing care, and on the other more structural factors that may impede women's ability to access a facility delivery even if they and their partners are informed about the importance of it (i.e., transportation, user fees, inability to go unescorted to a facility, poor quality of care, etc.)

Thank you for highlighting the need for further research. We have added a sentence to the conclusion.

One straightforward way to improve this situation could be a renewed focus within ANC on screening for obstetric risk and improving communication around birth planning to reduce context-specific barriers to facility delivery. Further research into the quality of ANC communication, the effect of increased awareness of risk on women's decision-making, and the specific barriers faced by high-risk women will help to highlight the key areas for intervention and to strengthen service quality.

- I think although the authors should stress that women in high risk groups are a priority for counseling on the need for delivering in a facility, that this should not preclude or overshadow the importance of counseling all women on the importance of skilled delivery care and making a birth plan in case of complications given that complications are often unpredictable and happen even in women with no known risk factors.

Thank you for this suggestion. We hope the additions to the discussion on ANC give suitable attention to birth preparedness and complication readiness for all women.

And, the authors should build upon the findings that showed the relationship between education level and wealth - they mention short term strategies that are specific to the health system, but what about longer term approaches that would improve women's social status in these countries?

Thank you – we very much appreciate this comment and agree that reducing inequalities in gender and wealth are essential for many developments to take place. However, we believe that such expansive recommendations are not really appropriate following this analysis of cross-sectional survey data, especially where wealth and education were not the primary exposures examined.

Who Delivers Where? The effect of obstetric risk on facility delivery in East Africa

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ABSTRACT

Objectives

Skilled attendance at birth is key for the survival of women with potential higher risk of obstetric complications. This study investigates whether women at increased obstetric risk in four East African countries are more likely to deliver in a health facility than those at low risk.

Methods

Demographic & Health Survey data for Kenya 2008-9, Rwanda 2010, Tanzania 2010 and Uganda 2011 were used to study women with a live birth in the three years preceding the survey. A three-level obstetric risk index was created using known risk factors available in the data set. Generalised linear Poisson regression was used to investigate the association between obstetric risk and facility delivery and to test whether wealth or education modified any association.

Results

In Kenya, Tanzania and Uganda there was no association between a woman's obstetric risk level and her place of delivery. In Rwanda there was a small increase in facility delivery among women at medium risk compared to those at low risk, adjusting for wealth and education (adjusted RR 1.06 95% CI 1.03-1.10), but not among those at high risk. Increased wealth and education were associated with facility delivery but neither factor interacted with obstetric risk.

Conclusions

Being at greater risk of obstetric complications according to our risk index does not make a woman likelier to deliver in a facility. Although obstetric risk is experienced by women of all socio-economic backgrounds, only the more privileged tend to deliver in an institution and are therefore safer.

INTRODUCTION

In global and national efforts to improve maternal and newborn health, a key focus, and one of the former Millennium Development Goal (MDG) indicators, has been to increase skilled attendance at birth (1), primarily through increasing the proportion of women delivering in a healthcare facility(2). An increase in facility delivery rates has been seen in most countries, but, as with other health outcomes, there is an inequitable distribution (3) affected by factors including distance to facility and fees (4). While maternal mortality has decreased since 1990, few countries reached the 75% reduction set for MDG5a. Greater progress has been seen for MDG4, with many countries achieving a 2/3 reduction in child mortality, however, newborn mortality lags behind that of children over 1 month old and now contributes to almost 50% of all under 5 deaths(1). Even where regional or country-level progress is good, heterogeneity often exists, with poor socio-demographic factors, such as lack of education, associated with worse maternal outcomes(5). At the start of the Sustainable Development Goal (SDG) era, as we consider how to sustain and accelerate progress, one important focus must be on reaching the most vulnerable women: those most at risk of obstetric complications currently falling through the gaps.

Identifying the women most at risk is complex, and complications often occur in low-risk women; however certain well-known factors increase the chance of obstetric complications occurring: poor obstetric history (6-8), co-existing medical conditions(9-11) or factors related to the existing pregnancy such as primi- or grand multi-parity and multiple pregnancy(12-14). Labour is a process which for many can progress safely with very little or no intervention, but the development of obstetric complications in a minority of deliveries is unpredictable and can rapidly lead to severe morbidity or mortality. Good monitoring, to detect problems early, and prompt access to skilled personnel combined with the appropriate resources to manage these problems is necessary to prevent this occurring. Therefore, the women at highest risk of developing obstetric complications are the ones who will benefit most from skilled attendance at a health facility, and it is of particular importance that they access care. Some risk factors can be identified before labour and women can be alerted to their increased risk, therefore, we predict that a higher proportion of facility deliveries will occur among these women.

While previous studies have investigated some of the reasons that women do and do not access health facility care at birth, to our knowledge none have explored the effect of obstetric risk factors on women's attendance. Therefore, we used survey data from four East African countries (Kenya, Tanzania, Rwanda, Uganda) to determine whether women at increased risk of obstetric complications were more likely to deliver in a facility. We also examined the effect of wealth and education on delivery location and whether these modified the effect of obstetric risk.

METHODS

Data used are from Demographic and Health Surveys (DHS) for the following countries and years: Kenya 2008-9, Rwanda 2010, Tanzania 2010 and Uganda 2011. These are nationally representative, cross-sectional, household surveys using standardised questionnaires and shown to produce high-quality data for low- and middle-income settings (15). The focus birth is the most recent live birth for each woman who had a child in the three years prior to the survey. Women aged 15-49 years were included in the surveys.

The outcome was place of delivery for the index (most recent) birth. It was coded as a binary outcome; facility or non-facility delivery, with the latter including respondent's home, other home, traditional birth attendant's home, en route to provider, or 'other'.

An obstetric risk index for each woman in our sample was created using variables derived from DHS survey responses, listed in Table 1 along with the obstetric/delivery complications with which they are associated. We classified risk factors as medium if they were moderately associated with elevated obstetric risk such as parity, short height, poor nutritional status, short birth interval, no antenatal care and previous obstetric complications but not in the birth prior to the index birth. Factors were classified as high risk, if they were considered to be strongly associated with a risk of delivery complications or be of importance for some other reason as indicated in the table, based on epidemiological evidence and clinical consensus. Mothers' weight and height, used to assess malnutrition

and obesity, were measured during the survey interview up to 3 years after the index birth, with the assumption that women had the same risk prior to the birth. The combination of factors determined a woman's risk at one of three levels: low, where no risk factors were observed; medium, where only one of the medium risk factors was observed; and high, where one or more high risk factors or two or more medium risk factors were observed.

Socio-economic position, assessed using mothers' education or household wealth, is known to be strongly associated with delivery location (16) and was considered a potential confounder or effect modifier of any association with obstetric risk. It could be an effect modifier, if for example high risk impoverished women were suddenly more likely to deliver in a facility, while wealthier women usually do so in the first place. Mothers' highest educational level was recoded as 'no education'; 'primary (complete and incomplete)'; 'incomplete secondary'; 'complete secondary/higher education'. Wealth indices were derived using principal component analyses from variables representing household assets, using standardised DHS methodology (17). The first component was grouped into five quintiles (Qs) of households. For Uganda, Rwanda and Tanzania we used the already-existing wealth index within the DHS which had been created with urban-rural weightings. For Kenya the wealth index was not weighted by location so we created a comparable national-level composite wealth index using rural and urban weights (18). The weighted index aims to reduce urban-bias and better distinguish the poorest from the other poor households (19).

ANALYSIS STRATEGY

All data management and analysis was undertaken in Stata SE 14.0. We used *svyset* commands to take into account the sampling strategy using individual sample weights and clustering. The percentage of women at each obstetric risk level, educational level and wealth quintile were estimated. We used generalised linear Poisson models to investigate the crude and adjusted effect of obstetric risk index, wealth and education on facility delivery. This model was chosen to estimate risk ratios because our outcome , facility delivery, is common (>10% incidence) and as incidence increases there is a growing disparity between odds ratios and risk ratios (20, 21). Models with interaction terms were used to explore whether wealth or education modified the association between obstetric risk and facility delivery. To understand obstetric risk better, we examined the association between each individual risk factor and delivery location as well as the relationship between wealth and obstetric risk, using weighted percentages and chi-squared tests.

Table One: Medium and high risk factors included in obstetric risk index

LIST A: MEDIUM-RISK FACTORS

RISK FACTOR	**Associated obstetric complications**
First birth	Maternal dystocia (12)
Shortness (less than 145 cm used to be consistent with standards used by DHS)	Maternal dystocia; miscarriage; stillbirth; fistula (12, 22-24)
Past Caesarean in last 5 years, but has had vaginal delivery since and prior to focus birth	Scar rupture; placental complications; stillbirth; and increased morbidity and mortality for mother and infant (6, 8, 25)
Grand multiparity (focus birth is at least number six in live birth order)	placental complications; foetal malpresentation; postpartum haemorrhage (14)
Malnutrition (BMI <18.5)	low birth weight; intrauterine growth restriction; premature labour (26-28)
Obesity (woman's BMI is >30)	Stillbirth; post-partum haemorrhage; pre-term delivery; emergency Caesarean; macrosomia; hypertension; pre-eclampsia; diabetes mellitus (29-35)
Past stillbirth in last 5 years, but last birth prior to focus birth was live birth	Stillbirth, intrapartum asphyxia, placental abruption, pre-term delivery (7, 36)
Birth interval prior to focus birth was 12 months or less	Pre-term birth, low birth weight, small size for gestational age, decreased gestational age (37-39)
Sibling prior to focus birth died aged 1-12 months	Post-neonatal death (40)
Woman has had no ante-natal care in focus pregnancy	No identification of and intervention in hypertension, anaemia, infections and pre-eclampsia (41)

LIST B: HIGH-RISK FACTORS

RISK FACTOR	**Associated obstetric complications**	**Reason for high risk level**
Focus birth is twins or triplets	Hypertension, pre-eclampsia, pre-term labour, dystocia, placental abruption, perinatal mortality and morbidity, uterine atony and postpartum haemorrhage (13)	Multiple potential complications with potential emergency risk to the second twin. Should be encouraged to deliver in a facility offering CEmONC
Stillbirth was last delivery prior to focus birth	Stillbirth, intrapartum asphyxia, placental abruption, pre-term delivery (7, 8, 36)	Multiple potential complications including another stillbirth. Loss of the previous pregnancy can increase the importance of a successful outcome for mother and birth attendants
Last delivery prior to focus birth was Caesarean section	Scar rupture, placental complications, and increased morbidity and mortality for mother and infant have been associated with recent Caesarean section (6, 25)	Multiple potential complications with increased risk of requiring another caesarean section therefore needs good access to CEmONC. There has been no successful trial of scar.
Sibling prior to focus birth died in first month of life	Associations have been found between sibling neonatal outcomes (42-44)	Loss of the previous newborn can increase the importance of a successful outcome for mother and birth attendants.
Focus birth is to woman aged under 16	stillbirth, pre-term labour, low birthweight, neonatal mortality, small-for-gestational age infants (45-47)	Multiple potential complications including neonatal mortality
Focus birth is first child born to woman aged 35+	Miscarriage, gestational diabetes, placenta previa, placental abruption, Caesarean delivery, macrosomia, pre-term delivery, low birth weight, neonatal mortality, multiple gestation, hypertension, foetal death, operative vaginal delivery, post-partum haemorrhage, stillbirth (48-50)	Multiple potential complications. Woman has 2 risk factors; age and primiparity

RESULTS

In the rest of this article, all numbers given are weighted unless otherwise stated. A total of 15,566 women across the four countries had a live birth in the 3 years preceding the survey and had information on delivery location. As seen in Table Two, obstetric risk category could not be created for 114 (0.7%) of them, mainly due to missing information on antenatal attendance, and thus 15,454 were included in the analysis sample (Rwanda 4514; Kenya 3001; Tanzania 4084; Uganda 3856). The proportion of women considered at medium obstetric risk was similar (40-43%) in each country. High obstetric risk was less common, ranging from 11% (95%CI 10%-12%) in Rwanda to 19% (95%CI 17%-20%) in Kenya. The majority of women had only primary education; Tanzanian and Rwandan women were the least educated with only 7% (95%CI 6%-8%) and 9% (95%CI 8%-10%) having any secondary schooling respectively, compared to 24% in Uganda (95%CI 21%-26%) and 25% in Kenya (95%CI 22%-28%). Table Three shows the overall proportion of women delivering in facilities varied greatly between countries, from only 45% (95%CI 41%-49%) of women in Kenya up to 79% (95%CI 77%-80%) in Rwanda (Table 3).

Obstetric risk level had no effect on whether a woman delivered in a facility in Kenya, Tanzania or Uganda. In Rwanda there is good evidence that after adjusting for wealth and education, obstetric risk was associated with delivery location (p=0.002). However, the effect was small and mainly seen among those at medium risk of whom 81% delivered in a facility compared to 76% of those with low risk (adjusted RR 1.06 95% CI 1.03-1.10). There was no evidence that women in Rwanda with high risk were more likely to deliver in a facility than those at low risk (RR 1.03 95% CI 0.97-1.08).

When we look at the individual factors that make up obstetric risk levels, it is clear that most women were considered at risk because of their parity: over 40% of women in each country were either primi- or grand multi-parous. Poor nutritional status also occurred frequently in Kenya and Tanzania where malnutrition or obesity affected 16% (95%CI 14%-18%) and 13% (95% CI 12%-14%) of women in each country respectively. In Kenya 7.4% (95%CI 6%-9%) of women did not have antenatal care, but this risk was less common in the other countries. Other risk factors each occurred in less than 4% of women (Table 4).

Wealth and highest level of education showed strong, independent associations with where a woman gave birth (Table 3). The effect of both wealth and education was greatest in Kenya and smallest in Rwanda. There is no evidence that wealth or education modified the effect of obstetric risk on facility delivery in any of the countries (Appendix Table A), irrespective of cell sizes. While facility deliveries clearly increased with increasing wealth and education, the relationship with obstetric risk is similar in all socio-economic groups (Fig. 1 and Appendix Fig. A).

Obstetric risk level did not vary according to wealth in Rwanda or Tanzania (Figure 2 and Appendix Table B). In Kenya and Uganda there is evidence for small differences in risk according to a woman's socio-economic status. In Kenya, high obstetric risk is more common among the poorest women and less common among the richest. Conversely in Uganda, low obstetric risk is more common among the richest women than those of other wealth levels. (Fig.2 and Appendix Table B).

Individual risk factors showed a more complex relationship with wealth. Primiparous women were overall more likely to be wealthy and to deliver in a facility, whereas grand multiparity was associated with being poor and giving birth outside a health facility (Fig 4). The same pattern is seen for under- and over-nutrition in Kenya and Tanzania, and to a lesser extent in the other two countries (Table 4 and Appendix Table C); those suffering from malnutrition were poorer and less likely to deliver in a facility, while the opposite was seen for obese women.

Having a caesarean section in the birth prior to the index birth showed the strongest association with facility delivery and occurred more often among women of higher socio-economic status, however, it was a factor for only 1-3% of women in the study. A similar pattern was seen for primiparous women aged over 35 years, but there were too few in the study population to be able to draw any conclusions. Women who did not attend antenatal care were less likely to attend a facility for their delivery and more likely to be poor. Other factors showed little or no consistent association with either wealth or facility delivery.

DISCUSSION

Overall obstetric risk, as defined in our study, was not meaningfully associated with delivery location. This is concerning as it suggests that women with a higher risk of developing obstetric complications are as likely to deliver at home, without direct access to care, as women without specific risk factors. There are many possible explanations for this finding. Even when women desire a facility delivery, geographical and financial barriers can exist, or the decision may not be theirs to make. Husbands, mothers and mothers-in-law may choose where a woman gives birth, and are less likely to accompany her to antenatal appointments and learn about the woman's risk (51-53). If women do not receive antenatal care then they might be unaware of their risk. Advice given during ANC to deliver in a health facility has been shown to predict use of skilled facility delivery care (54, 55). However, some women may not understand or believe the information they are given, for example women who have delivered safely at home for previous births may not appreciate that their grand multi-parity now puts them at a higher risk (16). Some women will appreciate the chance of complications occurring but doubt the quality of facility care or fear neglect and maltreatment (53, 55). For others, demands such as caring for older children may take priority over a stay in hospital.

While it does not address all the barriers mentioned above, antenatal care does provide a key opportunity to identify obstetric risk, educate women and encourage facility delivery. Analyses from Kenya and Tanzania suggest that a woman's knowledge of safe birth and pregnancy risk factors increase her chances of utilising maternal healthcare (54, 56). When problems arose, Tanzanian women were more likely to say they wanted to give birth in a facility (57), demonstrating an appreciation of the need for skilled care. All women should be encouraged to deliver in a health facility(2), but particular attention should be given to women with any identified risk factors, many of whom should be recommended to deliver not only in a facility but in one offering comprehensive emergency obstetric care. Monitoring of ANC activities, both routinely and in surveys such as the Service Provision Assessment(58), needs to include this aspect of communication.

Overall facility delivery rates varied widely between the countries studied, suggesting that differences in health policy and health service delivery affected uptake of facility care. (Population distribution might also be relevant, for example Kenya has desert areas while Rwanda is a small country, making travel easier.) User fees for maternity services were abolished in Tanzania and Uganda before the period studied, as well as in Kenyan health centres and dispensaries. However, neither Kenya, nor Uganda saw immediate improvements in facility deliveries as a result of this change (59, 60) and studies in Kenya and Tanzania show the majority of women continued to pay a service fee, despite the policy (59, 61).

Rwanda stands out as having both a higher overall facility delivery rate and smaller differences between rich and poor than the other three countries. As well as developing a highly successful health insurance scheme (62), making maternity care more financially accessible, the country has also invested heavily in the development of their Community Health Worker (CHW) programme. CHWs provide education at the community level, identify pregnant women and give ongoing encouragement to attend ANC and deliver in a facility(63). Between 2005 and 2010 a steep increase in facility deliveries was seen in Rwanda (64), coinciding with sustained capacity building of CHWs especially through training in Maternal and Child Health.

Similar to other studies(3), we found women with a higher socio-economic status were much more likely to deliver in a facility. However, wealth did not modify the effect of obstetric risk on delivery location and there is no consistent association across countries between wealth and overall obstetric risk. This is likely to be explained by the clustering of individual components of obstetric risk into different wealth groups, especially those associated with parity and nutrition. The most common obstetric risk factors related to parity. Our results confirm those of other studies which show higher parity is not only an obstetric risk factor, associated with post-partum haemorrhage and foetal mal-presentation, but is also associated with both lower socioeconomic status and lower likelihood of facility delivery (16). Conversely, due to their smaller family size, richer women are more likely to be giving birth for the first time, putting them at increased risk of complications from obstructed labour. However, they are more likely to deliver their baby in a health facility. Socio-economic status is therefore an integral part of the relationship between risk and

facility delivery, having a large effect on the most common factors that increase obstetric risk as well on women's response to that risk in terms of where they give birth.

LIMITATIONS TO OUR STUDY

We used a simple approach to measuring obstetric risk, taking the factors available in population-based surveys known to carry an increased risk of obstetric complications, and using the premise that once a woman had a risk factor she would be more likely to benefit from delivering in a facility and should be given that option. We did regard certain factors, and the combination of 2 or more factors, as increasing a woman's risk further (grouped under the "high-risk" category). However, we did not attempt to weight the factors beyond this. This categorisation has not been done before and the association between these categories and actual health outcomes for women and newborns is unknown.

Some important risk factors are not collected in the DHS and we were unable to include these in our categories, notably clinical risk factors such as diabetes and anaemia, previous poor obstetric history such as haemorrhage and pre-eclampsia, as well as clinical risk factors identified in the current pregnancy, such as pre-eclampsia or placenta praevia. Therefore, women whom we categorised as low-risk may have been identified with risk-factors in the pre-pregnancy or antenatal period, weakening any potential association between obstetric risk and delivery location. Furthermore, while some risk factors for obstetric risk are identifiable prior to delivery, the potential to predict antenatally which women will develop complications is low (65-67). Consequently, the priority in low-resource settings where emergency transport is unavailable is still to ensure that all women have access to high-quality delivery care in a health facility.

The DHS relies on self-reported data and there could be differences between individuals' recall and characterisation of risk factors. Self-reported aspects of risk such as previous caesarean section or stillbirth may suffer from under-reporting for personal reasons, but should not be differentially reported between women of varying socioeconomic backgrounds. The use of the DHS' wealth quintiles is imperfect as they are relative measures of wealth within countries constructed systematically, but they are not directly comparable between countries. We have, however, used wealth index weighted by urban/rural status so that disparities between urban and rural households are mitigated.

The DHS only provides detailed data about live births, as reported by the mother. Therefore our analysis is missing information for women who died or who had a still-birth in the focus pregnancy – two important potential consequences of obstetric complications. Some early neonatal deaths may also have been misclassified as stillbirths and not included in our sample of live births.

Women's weight was measured at the time of the survey and we assumed that they were in the same weight category (malnourished, low risk or obese) at the time of their pregnancy whereas weight gain or loss could have occurred following delivery. Possible misclassification is of most concern in Kenya and Tanzania where 19% and 15% respectively of women were categorised as at medium risk based on their weight compared to less than 4% in Rwanda and Uganda. However, the similarity in overall results seen in all four countries suggests any potential misclassification is unlikely to be causing bias. Data on previous caesarean sections and stillbirths is only available for the 5 years preceding the survey, therefore earlier events are not captured in our risk factors, and we may have misclassified medium or high-risk women as having a lower obstetric risk. However, for the variables which used death of a sibling to predict obstetric complications, we only used information relating to the immediately preceding sibling.

CONCLUSION

The troubling message from our results is that many women who can be easily identified before delivery as being at increased risk of obstetric complications are not delivering within a health facility. Although there is still room for improvement in availability and quality of obstetric care services in health facilities in the four countries studied, many of the potential complications identified would require urgent care which is not feasible to provide at home, such as caesarean section. Instead, it is a woman's socio-economic status and education that determines her chance

of a facility delivery. Perhaps the most straightforward way of tackling this situation would be to exploit the educational component of ANC, particularly where it relates to screening for obstetric risk and encouragement to deliver in a facility. In country, greater attention could also be given to service innovations such as maternity waiting homes that can help to overcome some of the inequities related to transport and geographical accessibility of facility care. Lessons can also be learned from the comparative equity and high proportion of facility deliveries seen in Rwanda, exploring the role of community-based interventions for maternal and newborn health and strengthening the call for available and affordable high-quality services for all women.

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http://dhsprogram.com/Data/

Who Delivers Where? The effect of obstetric risk on facility delivery in East Africa

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ABSTRACT

Objectives

Skilled attendance at birth is key for the survival of pregnant women. ~~with potential higher risk of obstetric complications.~~ This study investigates whether women at increased risk of maternal and newborn complications~~obstetric risk~~ in four East African countries are more likely to deliver in a health facility than those at lower~~low~~ risk.

Methods

Demographic & Health Survey data for Kenya 2014~~2008-9~~, Rwanda 2014-15~~2010~~, Tanzania 2015-16~~2010~~ and Uganda 2011 were used to study women with a live birth in the three years preceding the survey. A three-level obstetric risk index was created using known risk factors. ~~available in the data set.~~ Generalised linear Poisson regression was used to investigate the association between obstetric risk and facility delivery ~~and to test whether wealth or education modified any association~~.

Results

We analysed data from 13,119 women across the four countries of whom 42-45% were considered at medium risk ~~In Kenya, Tanzania~~ and 12-17% at high risk, and the remainder were low risk. In Rwanda, 93% of all women delivered in facilities but this was lower (59-66%) in the other three countries. There~~Uganda there~~ was no association between a woman's obstetric risk level and her place of delivery in any country; increased~~. In Rwanda there was a small increase in facility delivery among women at medium risk compared to those at low risk, adjusting for wealth and education (adjusted RR 1.06 95% CI 1.03-1.10), but not among those at high risk. Increased~~ wealth and education were, however, independently strongly associated with facility delivery ~~but neither factor interacted with obstetric risk~~.

Conclusions

In four East African countries women ~~Being~~ at higher ~~greater risk of~~ obstetric ~~complications according to our~~ risk were~~index does~~ not more likely~~make a woman likelier~~ to deliver in a facility than those with lower risk. This calls for a renewed focus on antenatal. ~~Although obstetric~~ risk screening and improved communication on birth planning to ensure women with an increased chance of maternal and newborn complications are supported~~is experienced by women of all socio-economic backgrounds, only the more privileged tend~~ to deliver in facilities with skilled care~~an institution and are therefore safer~~.

INTRODUCTION

In global and national efforts to improve maternal and newborn health, a key focus~~, and one of the former Millennium Development Goal (MDG) indicators,~~ has been to increase skilled attendance at birth (1), primarily through increasing the proportion of women delivering in a healthcare facility(2). Facility ~~An increase in facility~~ delivery rates have increased~~has been seen~~ in most countries over the last decade, but, as with other health outcomes, this gain has been ~~there is an~~ inequitable ~~distribution~~ (3) and affected by factors including distance to facility and fees (4).~~(4).~~ While maternal mortality has decreased since 1990, few countries reached the 75% reduction set for MDG5a. MDG4 has seen greater~~Greater~~ progress ~~has been seen for MDG4~~, with many countries achieving a 2/3rds~~3~~ reduction in child mortality, however, newborn mortality lags behind that of children over 1 month old and now contributes to almost 50% of all under 5 deaths(1). Even where regional or country-level progress is good, heterogeneity often exists, with poor socio-demographic factors, such as lack of education, associated with worse maternal outcomes(5). At the start of the Sustainable Development Goal (SDG) era, as we consider how to maintain~~sustain~~ and accelerate progress, one important focus must be on reaching the most vulnerable women: those ~~most~~ at high risk of maternal and newborn~~obstetric~~ complications who are not receiving adequate care.~~currently falling through the gaps.~~

Identifying ~~the~~ women ~~most~~ at higher risk is complex, and complications often occur in low-risk women; however certain well-known factors, many of which can be identified before labour, increase the chance of obstetric complications occurring: poor obstetric history (6-8), co-existing medical conditions(9-11) or factors related to the current~~existing~~ pregnancy such as primi- or grand multi-parity and multiple pregnancy(12-14). Labour is a process which for many progresses~~can progress~~ safely with ~~very~~ little or no intervention, but the development of obstetric complications in a minority of deliveries is unpredictable and can rapidly lead to severe morbidity or mortality for the mother or her baby.~~.~~ Good monitoring~~,~~ to detect problems early~~,~~ and prompt access to skilled personnel combined with ~~the~~ appropriate resources to manage these problems are~~is~~ necessary to prevent adverse outcomes. Women~~this occurring. Therefore, the women~~ at higher~~highest~~ risk of developing ~~obstetric~~ complications should~~are the ones who will~~ benefit ~~most~~ from skilled birth attendance ~~at a health facility~~, and it is of particular importance that they access facility-based care where complications~~care. Some risk factors~~ can be managed rapidly.~~identified before labour and women can be alerted to their increased risk, therefore, we predict that a higher proportion of facility deliveries will occur among these women.~~

While previous studies have investigated some of the reasons ~~that~~ women do and do not access health facility care at birth, to our knowledge none have explored the effect of obstetric risk factors on women's attendance. Therefore, we used survey data from four East African countries (Kenya, Tanzania, Rwanda, Uganda) to determine whether women at increased risk of obstetric complications were more likely to deliver in a facility. We also examined the effect of wealth and education on delivery location and whether these modified the effect of obstetric risk.

METHODS

Data used are from the most recent Demographic and Health Surveys (DHS) for the following countries and years: Kenya 2014~~2008-9~~, Rwanda 2014-15~~2010~~, Tanzania 2015-16~~2010~~ and Uganda 2011. These are nationally representative, cross-sectional, household surveys using standardised questionnaires and shown to produce high-quality data for low- and middle-income settings which are comparable across countries (15). Women aged 15-49 years were included in the surveys. Our sample was of women who had had their last live birth in the three years prior to the survey; who were regular household members rather than visitors; and who had data on weight and height. The latter were available for approximately half the total sample in Rwanda and Kenya, around 31% of the Uganda sample, and around 99% of the Tanzania sample.~~ The focus birth is the most recent live birth for each woman who had a child in the three years prior to the survey. Women aged 15-49 years were included in the surveys.~~

The outcome was place of delivery for the index (most recent) birth. It was coded as a binary outcome: facility or non-facility delivery, with the latter including respondent's home, other home, traditional birth attendant's home, en route to provider, or 'other'. Facility birth was chosen in preference to skilled birth attendant (SBA) as it is less prone to misclassification by women and should provide the necessary equipment as well as the personnel to enable skilled attendance.

An obstetric risk index for each woman in our sample was created using variables derived from DHS survey responses, listed in Table 1 along with the maternal/newborn complications with which they are associated. The selected criteria closely match those for higher risk pregnancy in the clinical guidelines from Uganda and Kenya, including age, parity, nutritional status, poor obstetric history and multiple pregnancy, but are unable to capture information on medical conditions which are not recorded in the DHS (16, 17). We classified risk factors as medium if they were moderately associated with elevated obstetric risk such as parity, short height, poor nutritional status, short birth interval, no antenatal care and history of caesarean section or stillbirth with a subsequent vaginal delivery and live birth. Factors were classified as high risk if they were considered to be strongly associated with a risk of complications for mother or baby, such as caesarean section or stillbirth in the previous pregnancy, or of importance for some other reason as indicated in the table, based on epidemiological evidence and clinical consensus. Mothers' weight and height, used to assess malnutrition and obesity, were measured during the survey interview up to 3 years after the index birth; we assumed that women had the same risk from these parameters prior to the index birth. The combination of these factors determined a woman's risk at one of three levels: low, where no risk factors were observed; medium, where only one of the medium risk factors was observed; and high, where one or more high risk factors or two or more medium risk factors were observed.

Socio-economic position, assessed using mothers' education or household wealth, is known to be strongly associated with delivery location (18) and was considered a potential confounder or effect modifier of any association with obstetric risk. It could be an effect modifier, if for example high risk impoverished women were more likely to deliver in a facility, while wealthier women usually do so in the first place. Mothers' highest educational level was recoded as 'no education'; 'primary'; and 'incomplete)'; 'incomplete secondary'; 'complete secondary or higher'. For all countries we used the already-existing wealth index within the DHS which had been created with urban-rural weightings. For Kenya the wealth index was not weighted by location so we created a comparable national-level composite wealth index using rural and urban weights (18). The weighted index aims to reduce urban-bias and better distinguish the poorest from the other poor households (19).

ANALYSIS STRATEGY

All data management and analysis was undertaken in Stata SE 14.0, using *svyset* commands to take into account for the sampling strategy using individual sample weights and clustering. Percentages of women at each obstetric risk level, educational level and wealth quintile were estimated. We used generalised linear Poisson models to investigate the crude and adjusted effect of obstetric risk index, wealth and education on facility delivery. This model was chosen to estimate risk ratios because our outcome , facility delivery, is common (>10% incidence) and, as incidence increases, there is a growing disparity between odds ratios and risk ratios (20, 21). Models with interaction terms explored whether wealth or education modified the association between obstetric risk and facility delivery. To understand obstetric risk better, we examined the association between each individual risk factor and delivery location, plus the relationship between wealth and obstetric risk, using weighted percentages and chi-squared tests.

Table 1~~One~~: Medium and high risk factors included in obstetric risk index

LIST A: MEDIUM -RISK FACTORS

RISK FACTOR	Associated obstetric complications
First birth	Maternal dystocia (12)
Shortness (less than 145 cm used to be consistent with standards used by DHS)	Maternal dystocia; miscarriage; stillbirth; fistula (12, 22-24)
Past Caesarean in last 5 years, but has had vaginal delivery since and prior to focus birth	Scar rupture; placental complications; stillbirth; and increased morbidity and mortality for mother and infant (6, 8, 25)
Grand multiparity (focus birth is at least number six in live birth order)	placental complications; foetal malpresentation; postpartum haemorrhage (14) still birth, newborn mortality(26)
Malnutrition (BMI <18.5)	low birth weight; intrauterine growth restriction; premature labour (26-28)
Obesity (woman's BMI is >30)	Stillbirth; post-partum haemorrhage; pre-term delivery; emergency Caesarean; macrosomia; hypertension; pre-eclampsia; diabetes mellitus (29-35)
Past stillbirth in last 5 years, but last birth prior to focus birth was live birth	Stillbirth, , newborn mortality, intrapartum asphyxia, placental abruption, pre-term delivery (7, 26, 37)~~Stillbirth, intrapartum asphyxia, placental abruption, pre-term delivery (7, 36)~~
Birth interval prior to focus birth was 12 months or less	Stillbirth, newborn mortality, pre~~Pre~~-term birth, low birth weight, small size for gestational age, decreased gestational age associated with short birth interval (37-39)
Sibling prior to focus birth died aged 1-12 months	Post-neonatal death (41) ~~Post-neonatal death (40)~~
Woman has had no ante-natal care in focus pregnancy	No identification of and intervention in hypertension, anaemia, infections and pre-eclampsia (42)~~No identification of and~~

RISK FACTOR	Associated obstetric complications
	~~intervention in hypertension, anaemia, infections and pre-eclampsia (41)~~

LIST B: HIGH -RISK FACTORS

RISK FACTOR	**Associated obstetric complications**	**Reason for high risk level**
Focus birth is twins or triplets	Hypertension, pre-eclampsia, pre-term labour, dystocia, placental abruption, perinatal mortality and morbidity, uterine atony and postpartum haemorrhage (13, 26)~~(13)~~	Multiple potential complications with ~~potential~~ emergency risk to the second twin. Should be encouraged to deliver in a facility offering CEmONC
Stillbirth was last delivery prior to focus birth	Stillbirth, newborn mortality, intrapartum asphyxia, placental abruption, pre-term delivery (~~7~~7, ~~8~~8, 26, 37~~36~~)	Multiple potential complications including another stillbirth. Loss of the previous pregnancy can increase the importance of a successful outcome for mother and birth attendants
Last delivery prior to focus birth was Caesarean section	Scar rupture, placental complications, and increased morbidity and mortality for mother and infant have been associated with recent Caesarean section (6, 25)	Multiple potential complications with increased risk of requiring another caesarean section therefore needs good access to CEmONC. There has been no successful trial of scar.
Sibling prior to focus birth died in first month of life	Associations have been found between sibling neonatal outcomes including stillbirth and newborn mortality (42-44)	Loss of the previous newborn can increase the importance of a successful outcome for mother and birth attendants.
Focus birth is to woman aged under 16	stillbirth, pre-term labour, low birthweight, neonatal mortality, small-for-gestational age infants (45-47)	Multiple potential complications including neonatal mortality
Focus birth is first child born to woman aged 35+	Miscarriage, gestational diabetes, placenta previa, placental abruption, Caesarean delivery, macrosomia, pre-term delivery, low birth weight, neonatal mortality, multiple gestation, hypertension, foetal death, operative vaginal delivery, post-partum haemorrhage, stillbirth (48-50)	Multiple potential complications. Woman has 2 risk factors; age and primiparity

RESULTS

Our initial sample wasIn the rest of this article, all numbers given are weighted unless otherwise stated. A total of 15,566 women with their most recent across the four countries had a live birth in the three3 years preceding the survey who were regular household members (not visitors) and who had anthropometric data: 13,360. Of these, 193 were missing datahad information on delivery location and are not . As seen in Table Two, obstetric risk category could not be created for 114 (0.7%) of them, mainly due to missing information on antenatal attendance, and thus 15,454 were included in the remainder of the results and a further 47 lacked data on at least one component of the risk score leaving 13,119 women with complete data for the analysis sample (Rwanda 21584514; Kenya 47333001; Tanzania 50334084; Uganda 1195). All numbers given are weighted unless otherwise stated.

3856). The proportion of women considered at medium obstetric risk was similar (42-4540-43%) in each country. High obstetric risk was rarerless common, ranging from 1211% (95%CI 11%-1410% 12%) in Rwanda to 1719% (95%CI 1417%-20%) in Uganda. MostKenya. The majority of women had only primary education; KenyanTanzanian and Rwandan women were the highestleast educated with 35% receiving only 7% (95%CI 6% 8%) and 9% (95%CI 8% 10%) having any secondary or higher education (95%CI 33-37%)schooling respectively, compared to only 14-24% in the other three countries (Table 2). TheUganda (95%CI 21%-26%) and 25% in Kenya (95%CI 22%-28%). Table Three shows the overall proportion of women delivering in facilities was 59-66% in Kenya, Tanzania and Uganda but much highervaried greatly between countries, from only 45% (95%CI 41%-49%) of women in Kenya up to 79% (95%CI 77%-80%) in Rwanda at 93% (95%CI 91-94%) (Table 3).

A key finding is that obstetricObstetric risk level had no effect on whether a woman delivered in a facility in any of the four countries, Kenya, Tanzania or Uganda. In Rwanda there is good evidence that after adjusting for wealth and education (Table 3, obstetric risk was associated with delivery location (p=0.002). However, the effect was small and mainly seen among those at medium risk of whom 81% delivered in a facility compared to 76% of those with low risk (adjusted RR 1.06 95% CI 1.03-1.10). There was no evidence that women in Rwanda with high risk were more likely to deliver in a facility than those at low risk (RR 1.03 95% CI 0.97-1.08).

MostWhen we look at the individual factors that make up obstetric risk levels, it is clear that most women were considered at risk because of their parity: over 40% of women in each country were either primi- or grand multi-parous. Poor nutritional status also occurred frequently in Kenya, and Tanzania and Uganda where malnutrition or obesity affected 1716% (95%CI 16%-19%); 14% (95% CI 13%-16%);% 18%) and 13% (95%-CI 11%-1512% 14%) of women in each country respectively (disaggregated data shown in Table 4). The risk . In Kenya 7.4% (95%CI 6% 9%) of women did not havinghave antenatal care did not exceed 4% in any of , but this risk was less common in the other countries. Other risk factors each occurred in 5% or less than 4% of women (Table 4).

Wealth and highest level of education showed strong, independent associations with delivery locationwhere a woman gave birth (Table 3). The effect of socioeconomic status both wealth and education was greatest in Kenya and smallest in Rwanda. Wealth did not modify the There is no evidence that wealth or education modified the effect of obstetric risk on facility delivery in any of the countries. (Appendix Table A), irrespective of cell sizes. While facility deliveries clearly increased with increasing wealth and education, the relationship with obstetric risk is similar in all quintilessocio-economic groups (Fig. 1 and Appendix Table A). There is statistical evidence that education modified the association between obstetric risk and delivery location in Kenya and Tanzania (Appendix TableFig. A). Among the most educated Tanzanian women, those at high risk were more likely to deliver in a facility than women at low risk (RR 1.12 95% CI 1.05-1.20). However, in Kenya, there is no consistent pattern.

Obstetric risk level did not vary byaccording to wealth in Rwanda or UgandaTanzania (Figure 2 and Appendix Table B). In Kenya and Tanzania,Uganda there is evidence of for small differences in risk according to a difference in risk levels by wealth but patterns are inconsistent: high obstetric risk was commonestwoman's socio-economic status. In Kenya, high obstetric risk is more common among the poorest women and less common among the richest. Conversely in Uganda, low obstetric risk is more common among the richest women in Tanzania but among the poorest in Kenyathan those of other wealth levels. (Fig.2 and Appendix Table B).

Individual risk factors showed a more complex relationship with wealth. Primiparous women were overall more likely to be wealthy and to deliver in a facility, whereas grand multiparity was associated with being poor and giving birth outside a health facility, although in Rwanda this relationship was less pronounced (Fig 3 and Appendix Table C).~~4).~~ The same pattern is seen for under- and over-nutrition; malnourished women ~~in Kenya and Tanzania, and to a lesser extent in the other two countries (Table 4 and Appendix Table C); those suffering from malnutrition~~ were poorer and less likely to deliver in a facility, while the opposite was seen for obese women (Table 4 and Appendix Table C).~~.~~

Having a caesarean section in the birth prior to the index birth showed the strongest association with facility delivery and occurred more often among women of higher socio-economic status. However~~, however~~, it was a risk factor for only 1-5~~3~~% of women studied~~in the study~~. A similar pattern was seen for primiparous women aged over 35 years, but there were too few in the sample~~study population to be able~~ to draw any conclusions. Women ~~who did~~ not attending~~attend~~ antenatal care were less likely to have~~attend~~ a facility ~~for their~~ delivery everywhere except Uganda, but the relationship between no antenatal care and wealth was inconsistent~~more likely to be poor~~. Other factors showed little or no consistent association with either wealth or facility delivery.

Table 2: Distribution of women's obstetric risk, wealth and education in four East African Countries

		RWANDA 2011-2015	KENYA 2011-2014	TANZANIA 2012-2016	UGANDA 2008-2011
		Weighted n (%) Total Weighted N=2158*	Weighted n (%) Total Weighted N=4746*	Weighted n (%) Total Weighted N=5048*	Weighted n (%) Total Weighted N=1215*
Obstetric risk levels	Low	988 (46)	1967 (41)	1997 (40)	477 (39)
	Medium	903 (42)	2005 (42)	2266 (45)	514 (42)
	High	267 (12)	762 (16)	770 (15)	204 (17)
	Missing	0 (0)	13 (0.3)	15 (0.3)	19 (2)
Wealth quintiles	Poorest	534 (25)	1074 (23)	1183 (23)	266 (22)
	Poorer	468 (22)	950 (20)	1057 (21)	258 (21)
	Middle	401 (19)	865 (18)	945 (19)	232 (19)
	Richer	373 (17)	884 (19)	978 (19)	229 (19)
	Richest	383 (18)	974 (21)	884 (18)	230 (19)
Education levels	No education	289 (13)	527 (11)	975 (19)	149 (12)
	Primary	1556 (72)	2564 (54)	3251 (64)	778 (64)
	Secondary or higher	313 (14)	1655 (35)	822 (16)	287 (24)

*Totals include those for whom information on delivery place was available

TABLE 3: Association between women's obstetric risk, wealth or education and having a facility delivery in four East African countries

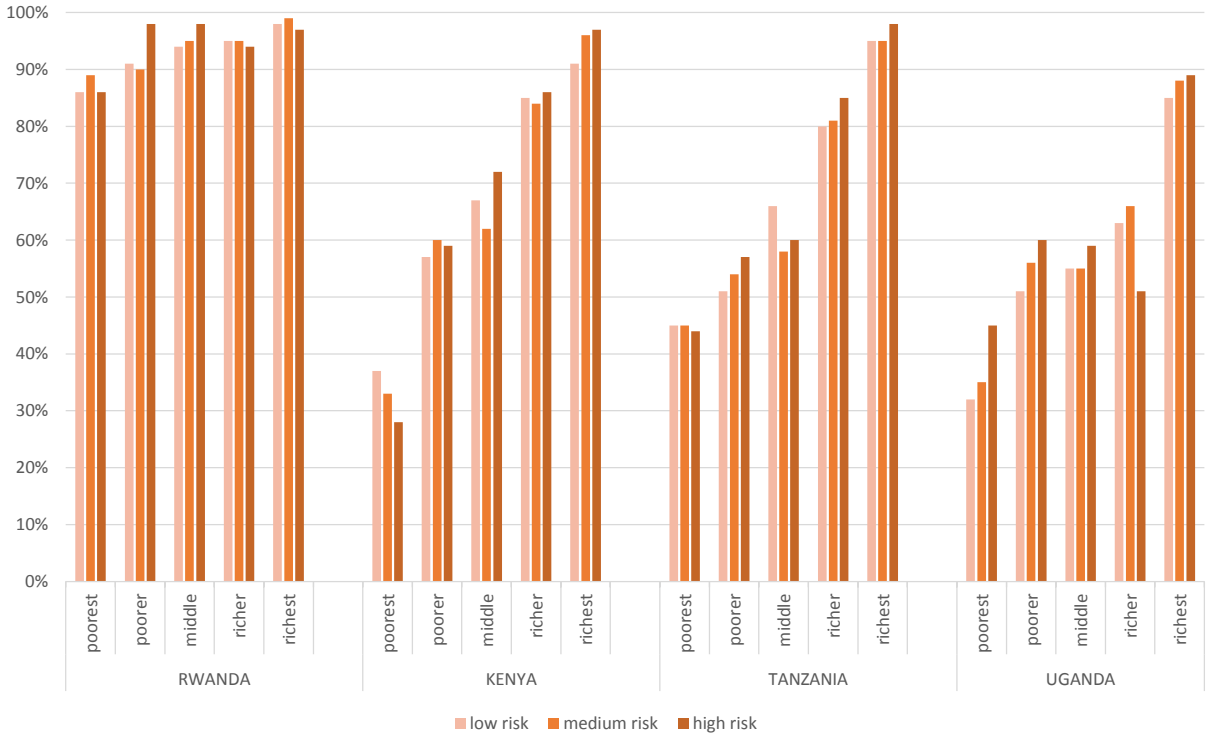
	RWANDA N=2158				KENYA N=4733				TANZANIA N=5033				UGANDA N=1195			
	Weighted % facility delivery	RR (95% CI)	Adjusted RR* (95% CI)	p-value Wald test	Weighted % facility delivery	RR (95% CI)	Adjusted RR* (95% CI)	p-value Wald test	Weighted % facility delivery	RR (95% CI)	Adjusted RR* (95% CI)	p-value Wald test	Weighted % facility delivery	RR (95% CI)	Adjusted RR* (95% CI)	p-value Wald test
Total	93%				66%				66%				59%			
Obstetric Risk index				0.6356				0.7800				0.3745				0.3095
Low	92%	1.00	1.00		67%	1.00	1.00		65%	1.00	1.00		58%	1.00	1.00	
Medium	93%	1.02 (0.99-1.04)	1.01 (0.98-1.04)		66%	0.99 (0.94-1.04)	0.98 (0.94-1.04)		65%	0.99 (0.94-1.05)	0.98 (0.93-1.03)		59%	1.02 (0.90-1.15)	1.07 (0.96-1.21)	
High	94%	1.02 (0.98-1.06)	1.02 (0.98-1.06)		64%	0.96 (0.89-1.03)	1.00 (0.94-1.07)		71%	1.09 (1.02-1.17)	1.01 (0.95-1.07)		58%	1.00 (0.87-1.17)	1.11 (0.95-1.28)	
Wealth				0.0001				<0.0001				<0.0001				<0.0001
Poorest	87%	1.00	1.00		33%	1.00	1.00		45%	1.00	1.00		36%	1.00	1.00	
Poorer	91%	1.04 (0.99-1.10)	1.04 (0.99-1.09)		59%	1.77 (1.58-1.99)	1.49 (1.32-1.68)		53%	1.19 (1.05-1.34)	1.16 (1.03-1.31)		55%	1.54 (1.21-1.94)	1.47 (1.16-1.88)	
Middle	95%	1.08 (1.03-1.13)	1.07 (1.02-1.12)		66%	1.99 (1.77-2.23)	1.64 (1.45-1.85)		62%	1.39 (1.23-1.57)	1.32 (1.17-1.49)		56%	1.57 (1.23-2.01)	1.48 (1.15-1.91)	
Richer	95%	1.08 (1.04-1.13)	1.07 (1.02-1.11)		85%	2.55 (2.29-2.84)	2.05 (1.82-2.30)		81%	1.82 (1.62-2.05)	1.69 (1.51-1.89)		63%	1.76 (1.41-2.21)	1.64 (1.30-2.06)	
Richest	98%	1.12 (1.08-1.17)	1.09 (1.05-1.14)		94%	2.83 (2.55-3.14)	2.19 (1.95-2.45)		95%	2.13 (1.91-2.39)	1.88 (1.69-2.10)		87%	2.42 (1.97-2.98)	2.14 (1.70-2.68)	
Education				0.0003				<0.0001				<0.0001				0.0067
None	85%	1.00	1.00		27%	1.00	1.00		46%	1.00	1.00		41%	1.00	1.00	
Any Primary	93%	1.09 (1.02-1.17)	1.08 (1.01-1.16)		61%	2.22 (1.87-2.64)	1.67 (1.40-1.98)		65%	1.43 (1.29-1.59)	1.24 (1.13-1.37)		55%	1.35 (1.07-1.69)	1.24 (0.99-1.55)	
Secondary or higher	99%	1.16 (1.08-1.25)	1.11 (1.04-1.19)		87%	3.19 (2.69-3.78)	1.97 (1.65-2.34)		90%	1.97 (1.77-2.20)	1.39 (1.26-1.53)		78%	1.94 (1.54-2.43)	1.43 (1.12-1.83)	

*adjusted for all other variables in the table

Table 4: Association between women's individual obstetric risk factors and having a facility delivery in Four East African countries

	RWANDA N=2158			KENYA N=4733			TANZANIA N=5033			UGANDA N=1195		
MEDIUM RISK FACTORS	**weighted n (% of all women)**	**% facility delivery**	**facility delivery RR (95%CI)**	**weighted n (% of all women)**	**% facility delivery**	**facility delivery RR (95%CI)**	**weighted n (% of all women)**	**% facility delivery**	**facility delivery RR (95%CI)**	**weighted n (% of all women)**	**% facility delivery**	**facility delivery RR (95%CI)**
Focus birth was first-born	588 (27)	98	1.07 (1.05-1.10)	1160 (25)	83	1.37 (1.31-1.44)	1301 (26)	79	1.30 (1.24-1.36)	172 (14)	72	1.30 (1.15-1.45)
Height <145cm	56 (3)	95	1.03 (0.97-1.09)	43 (0.9)	70	1.05 (0.82-1.35)	88 (2)	75	1.14 (0.99-1.32)	14 (1)	45	0.77 (0.41-1.45)
Previous Caesarean but vaginal delivery before focus birth	0 (0)	N/A	N/A	3 (0.1)	36	0.54 (0.16-1.87)	0.3 (0.01)	100	1.52 (1.46-1.59)	3 (0.2)	85	1.46 (0.95-2.25)
Grand multiparous (>=6 live births)	292 (14)	86	0.92 (0.87-0.96)	749 (16)	39	0.54 (0.49-0.61)	1025 (20)	48	0.68 (0.62-0.74)	383 (32)	51	0.83 (0.73-0.95)
Malnourished (BMI < 18.5)	96 (4)	87	0.93 (0.86-1.01)	420 (9)	46	0.68 (0.60-0.76)	357 (7)	59	0.89 (0.80-0.99)	114 (10)	58	0.99 (0.82-1.19)
Obese (BMI >= 30)	96 (4)	94	1.01 (0.96-1.08)	406 (9)	88	1.37 (1.29-1.44)	365 (7)	93	1.46 (1.38-1.55)	33 (3)	71	1.23 (0.94-1.62)
Previous stillbirth, but subsequent live birth prior to focus birth	4 (0.2)	100	1.08 (1.06-1.09)	5 (0.1)	47	0.70 (0.27-1.86)	18 (0.4)	62	0.95 (0.62-1.46)	1 (0.1)	100	1.72 (1.62-1.83)
Short preceding birth interval (<=12months)	22 (1)	82	0.87 (0.70-1.12)	39 (0.8)	52	0.78 (0.56-1.08)	42 (0.8)	53	0.81 (0.61-1.07)	16 (1)	44	0.76 (0.41-1.40)
Previous baby died aged 1-12 months	22 (1)	95	1.03 (0.94-1.13)	71 (2)	58	0.87 (0.65-1.15)	92 (2)	59	0.90 (0.73-1.11)	35 (3)	54	0.93 (0.63-1.36)
Woman has had no antenatal care	20 (1)	57	0.61 (0.39-0.95)	173 (4)	16	0.23 (0.15-0.35)	113 (2)	27	0.40 (0.26-0.60)	36 (3)	39	0.66 (0.39-1.12)
HIGH RISK FACTORS												
Focus birth twins/triplets	28 (1)	100	1.08 (1.06-1.09)	83 (2)	73	1.10 (0.91-1.31)	87 (2)	70	1.06 (0.89-1.26)	21 (2)	60	1.03 (0.69-1.53)
Last delivery before focus birth was stillbirth	8 (0.4)	100	1.08 (1.06-1.09)	30 (0.6)	78	1.18 (0.97-1.44)	53 (1)	70	1.07 (0.85-1.35)	8 (1)	65	1.12 (0.61-2.04)
Last delivery before focus birth was Caesarean	98 (5)	100	1.08 (1.06-1.10)	118 (3)	92	1.40 (1.30-1.51)	81 (2)	95	1.45 (1.36-1.56)	33 (3)	72	1.25 (0.99-1.57)
Previous baby died in first 30 days of life	36 (2)	91	0.98 (0.87-1.09)	102 (2)	74	1.12 (0.94-1.33)	104 (2)	70	1.06 (0.92-1.23)	36 (3)	56	0.96 (0.66-1.40)
Woman was under 16 at time of focus birth	4 (0.2)	100	1.08 (1.06-1.09)	40 (0.8)	65	0.98 (0.77-1.25)	41 (0.8)	56	0.85 (0.61-1.17)	4 (0.3)	51	0.88 (0.40-1.96)
Focus birth was first born to a woman aged 35+	4 (0.2)	100	1.08 (1.06-1.09)	2 (0.04)	100	1.51 (1.47-1.55)	8 (0.2)	100	1.52 (1.46-1.59)	0	0	

Figure 1: Weighted percentage of women attending for facility delivery in four East African countries by wealth quintile and obstetric risk



*Facility delivery risk ratio comparing richest to poorest women adjustd for obstetric risk (95% Confidence Interval). All p-values<0.001

Figure 2: Weighted percentage of women at each obstetric risk level by wealth quintile for four East African countries

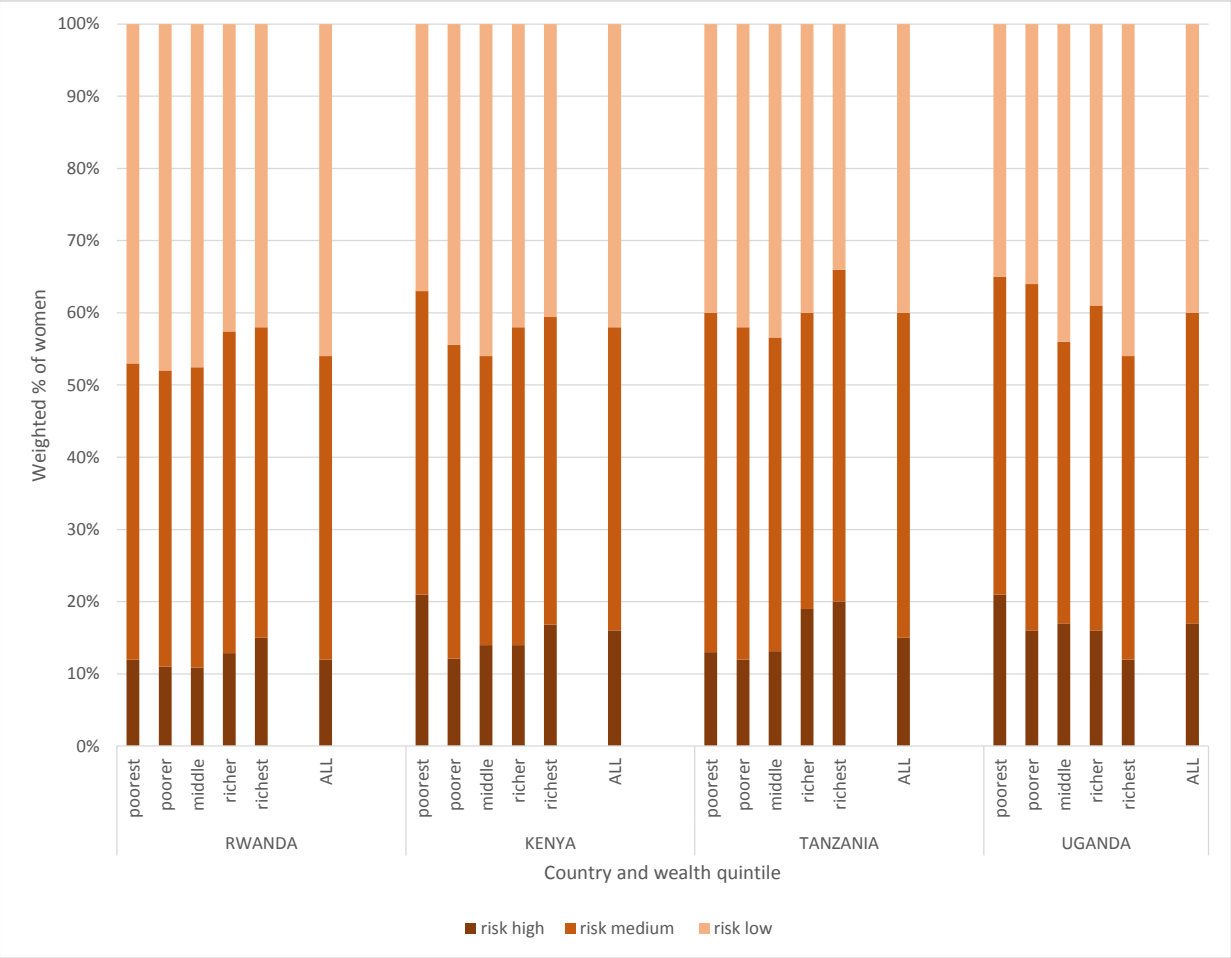
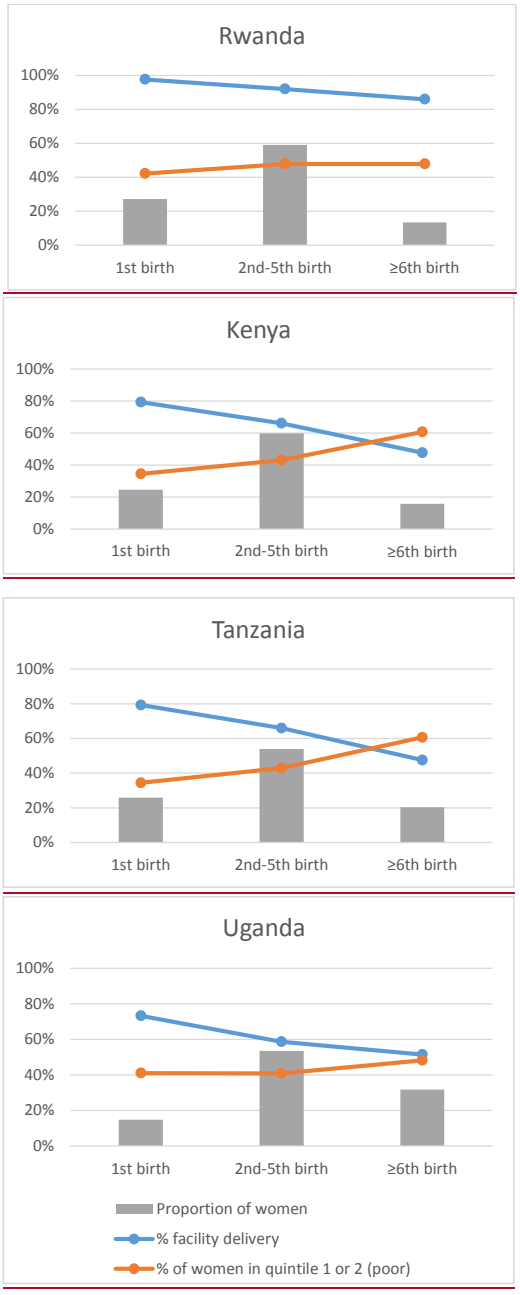


Figure 3: Trend in women's wealth and facility delivery by parity in four East African countries



DISCUSSION

Overall obstetric risk, as defined in our study, was not ~~meaningfully~~ associated with delivery location. This is concerning as it suggests that women with a higher risk of developing maternal or newborn~~obstetric~~ complications are as likely to deliver at home or in a facility ~~, without direct access to care,~~ as women without specific risk factors. Possible~~There are many possible~~ explanations relate to access, awareness of risk, and concerns about quality of care.

Geographical~~for this finding. Even when women desire a facility delivery, geographical~~ and financial barriers to facility care are known (52) and are supported by the large associations seen between wealth and facility delivery in our data. Preterm and short labours reduce the opportunity to overcome these barriers, and are more common with risk factors such as multiple gestation and grand multiparity. Other family members, who have not learnt about a woman's risk at antenatal appointments,~~can exist, or the decision~~ may decide~~not be theirs to make. Husbands, mothers and mothers-in-law may choose~~ where she~~a woman~~ gives birth. For example, in Uganda, husbands are very important in both choosing and overcoming barriers to access facility delivery (53).

Women~~, and are less likely to accompany her to antenatal appointments and learn about the woman's risk (51-53). If women do~~ not receiving ANC~~receive antenatal care then they~~ might be unaware of their risk; advice~~. Advice~~ given during ANC to deliver in a health facility has been shown to predict use of skilled facility delivery care (54, 55) and ANC was strongly associated with facility delivery in this study, except in Uganda. The large majority of women (96-99%) attended at least one antenatal appointment, however, from the DHS reports for these countries we know only around half of women attended the recommended four visits (56-59). Some risk factors, like multiple gestation, are harder to identify in low-resource settings without easy access to ultrasound scans. Certain at-risk women may not understand advice~~. However, some women may not understand or believe the information they are~~ given, for example women who have delivered safely at home for previous births may not appreciate that their grand multi-parity now puts them at a higher risk (18). Some women will grasp the risk~~(16). Some women will appreciate the chance~~ of complications occurring but doubt the quality of facility care or fear neglect and maltreatment (53, 55), especially if they experienced a stillbirth or newborn death in a previous pregnancy.~~.~~ For others, demands such as caring for older children may take priority over a stay in hospital.

Antenatal care, which is at least partially accessed by the large majority of women, provides a key opportunity to identify women at increased obstetric risk, explain the importance of skilled attendance and encourage birth planning. Risk identification is acknowledged in the new WHO recommendations on ANC as important to reduce maternal morbidity and mortality (60) and it is therefore surprising that none of the 49 recommendations specifically addresses risk identification or describes the constituents of a high-risk pregnancy. This reflects the change in emphasis that occurred in the early 2000s, away from a risk approach to considering every pregnancy to be at risk. However, we would argue alongside others (26), that it is important to identify pregnancies with higher risk for the mother and baby, inform women of this risk and encourage and enable them to deliver in a hospital with the capacity to manage complications and perform Caesarean sections (CEmONC).

Communication on birth preparedness and complication readiness, as described in the earlier WHO guidelines on health promotion for maternal and newborn health (61), is expected to occur at all ANC contacts so is only referred to in recommendations for community-based interventions and task shifting. All four countries in our analysis have introduced focussed ANC, including four antenatal visits, communication on birth preparedness and recommendations for all women to deliver with a skilled attendant. However, studies in Kenya, Uganda and Tanzania observed only 24-76% of women received birth preparedness advice and only 7% of Ugandan women were informed about danger signs (62, 63) indicating that the quality of ANC is poor and needs improvement. All women should be encouraged to deliver in a health facility(2), but particular attention should be given to women with any identified risk factors, many of whom should be recommended to deliver not only in a facility but in one offering comprehensive emergency obstetric care. Monitoring of ANC activities, both routinely and in surveys such as the Service Provision Assessment(64), should include indicators on risk assessment and communication.

~~While it does not address all the barriers mentioned above, antenatal care does provide a key opportunity to identify obstetric risk, educate women and encourage facility delivery. Analyses from Kenya and Tanzania suggest that a~~

~~woman's knowledge of safe birth and pregnancy risk factors increase her chances of utilising maternal healthcare (54, 56). When problems arose, Tanzanian women were more likely to say they wanted to give birth in a facility (57), demonstrating an appreciation of the need for skilled care. All women should be encouraged to deliver in a health facility(2), but particular attention should be given to women with any identified risk factors, many of whom should be recommended to deliver not only in a facility but in one offering comprehensive emergency obstetric care. Monitoring of ANC activities, both routinely and in surveys such as the Service Provision Assessment(58), needs to include this aspect of communication.~~

Overall facility delivery rates varied widely between the countries studied, suggesting that differences in health policy, including fee exemption schemes, and health service delivery (access and quality) affected uptake of facility care. ~~(~~Population distribution might also be relevant:~~, for example~~ Kenya has remote~~desert~~ areas, while Rwanda is smaller~~a small country~~, making travel easier.~~.)~~ User fees for maternity services were abolished in Tanzania and Uganda before the period studied, as well as in Kenyan health centres and dispensaries. However, neither Kenya, nor Uganda saw immediate improvements in facility deliveries as a result (65, 66)~~of this change (59, 60)~~ and studies in Kenya and Tanzania show most~~the majority of~~ women continued to pay a service fee, despite the policy (65, 67)~~(59, 61)~~.

Rwanda notably has both a higher overall facility delivery rate and smaller differences between rich and poor than the other three countries. As well as developing a successful health insurance scheme (68), making maternity care more financially accessible, the country has also invested heavily in the development of their Community Health Worker (CHW) programme. CHWs provide community education, identify pregnant women and give ongoing encouragement to attend ANC and deliver in a facility(69). Between 2005 and 2010 a steep increase in facility deliveries was seen in Rwanda (70), coinciding with sustained capacity building of CHWs especially through training in Maternal and Child Health. However, almost 80% of these facility deliveries occur in low-level facilities not offering full basic emergency obstetric care (BEmOC), compared to Uganda and Kenya where over 40% of facility deliveries occur where comprehensive emergency care is provided (71).

Similar to other studies(3), we found women with a higher socio-economic status or educational level were much more likely to deliver in a facility. In Tanzania, education appeared to modify the effect of risk on delivery location with obstetric risk driving place of delivery only among better educated women. The difference in facility delivery rates between risk groups was small and these results were not replicated elsewhere so should be treated with caution. However, it is plausible that more educated women might better understand the complex concept of risk and subsequently deliver in a facility, and improving girls' education should be advocated for this and many other reasons.

Wealth~~Rwanda stands out as having both a higher overall facility delivery rate and smaller differences between rich and poor than the other three countries. As well as developing a highly successful health insurance scheme (62), making maternity care more financially accessible, the country has also invested heavily in the development of their Community Health Worker (CHW) programme. CHWs provide education at the community level, identify pregnant women and give ongoing encouragement to attend ANC and deliver in a facility(63). Between 2005 and 2010 a steep increase in facility deliveries was seen in Rwanda (64), coinciding with sustained capacity building of CHWs especially through training in Maternal and Child Health.~~

~~Similar to other studies(3), we found women with a higher socio-economic status were much more likely to deliver in a facility. However, wealth~~ did not modify the effect of obstetric risk on delivery location and there is no consistent association across countries between wealth and overall obstetric risk. This is probably~~likely to be~~ explained by the clustering of individual components of obstetric risk into different wealth groups, especially those associated with parity and nutrition. The most common ~~obstetric~~ risk factors related to parity and our~~. Our~~ results confirm those of other studies which show higher ~~parity is not only an obstetric~~ risk is~~factor, associated with post-partum haemorrhage and foetal mal-presentation, but is also~~ associated with both lower socioeconomic status and lower likelihood of facility delivery (18). Conversely, due to their smaller completed family size, richer women in the sample~~(16). Conversely, due to their smaller family size, richer women~~ are more likely to be giving birth for the first

time, putting them at increased risk of complications associated with first delivery, such as~~from~~ obstructed labour. However, they are more likely to deliver their baby in a health facility. Socio-economic status is therefore an integral part of the relationship between risk and facility delivery, affecting~~having a large effect on~~ the most common factors that increase obstetric risk as well ~~on~~ women's decisions about~~response to that risk in terms of~~ where they give birth.

LIMITATIONS TO OUR STUDY

We used a simple approach to measuring obstetric risk, taking the factors available in population-based surveys known to carry an increased risk of obstetric complications, and using the premise that once a woman had a risk factor she would ~~be more likely to~~ benefit from delivering in a facility~~. and should be given that option.~~ We regarded~~did regard~~ certain factors, and the combination of 2 or more factors, as increasing a woman's risk further (grouped under the "high-risk" category). However, we did not ~~attempt to~~ weight the factors beyond this. This categorisation has not been done before and the association between this grouping of risk factors~~these categories~~ and actual health outcomes for women and newborns is unknown, although based on evidence supporting the individual factors.

Some important risk factors are not collected in the DHS and thus we could not~~were unable to~~ include these in our categories, notably clinical risk factors such as diabetes and anaemia, previous poor obstetric history such as haemorrhage and pre-eclampsia, as well as clinical risk factors identified in the current pregnancy, such as pre-eclampsia or placenta praevia. Therefore, women whom we categorised as low ~~-~~risk may have been identified with such risk ~~-~~factors in the pre-pregnancy or antenatal period, weakening any potential association between obstetric risk and delivery location. Furthermore, while some ~~risk factors for~~ obstetric risk factors are identifiable prior to delivery, predicting~~the potential to predict~~ antenatally which women will develop complications at birth is difficult~~low~~ (72-74)~~(65-67)~~. Consequently, the priority in low-resource settings where emergency transport is unavailable is still to ensure that all women have access to high-quality delivery care in a health facility.

The DHS relies on self-reported data and there could be differences between individuals' recall and characterisation of risk factors. Self-reported aspects of risk like~~such as previous caesarean section or~~ stillbirth may suffer from under-reporting for personal reasons, but it is unclear if this would vary by ~~should not be differentially reported between women of varying~~ socioeconomic background, or in which direction. The validity of self-reported data for factors such as previous caesarean section is known to be high (75).~~backgrounds.~~ The use of the DHS' wealth quintiles is imperfect as they are relative measures of ~~wealth~~ within-country wealth, and ~~countries constructed systematically, but they are~~ not ~~directly~~ comparable between countries. The wealth indices are~~We have~~, however, ~~used wealth index~~ weighted to mitigate~~by~~ urban/rural ~~status so that~~ disparities. ~~between urban and rural households are mitigated.~~

The DHS only provides detailed data about live births, as reported by the mother. Therefore, our sample excludes~~analysis is missing information for~~ women who died or who had a stillbirth~~still birth~~ in the index~~focus~~ pregnancy – two important potential consequences of obstetric complications. Some early neonatal deaths may also have been misclassified as stillbirths and not included in our sample of live births.

Women's weight was measured at the time of the survey and we assumed that they were in the same weight category (malnourished, low~~-~~risk or obese) at the time of their index pregnancy, whereas this might~~weight gain or loss could~~ have changed~~occurred~~ following delivery. ~~Possible misclassification is of most concern in Kenya and Tanzania where 19% and 15% respectively of women were categorised as at medium risk based on their weight compared to less than 4% in Rwanda and Uganda.~~ However, the similarity in the main~~overall~~ results across~~seen in all four~~ countries, despite differences in the contribution of weight to medium risk scores (8-18%) suggests any potential misclassification is unlikely to be causing major bias. Data on previous caesarean sections and stillbirths is only available for the 5 years preceding the survey~~;~~ therefore earlier events are not captured in our risk factors, and we may have misclassified medium or high-risk women as having a lower obstetric risk. ~~However, for the variables which used death of a sibling to predict obstetric complications, we only used information relating to the immediately preceding sibling.~~

CONCLUSION

The troubling key message from our results is that many women who can be easily identified before delivery as being at increased potential risk of maternal and newborn ~~obstetric~~ complications are not delivering within a health facility. Many of these ~~Although there is still room for improvement in availability and quality of obstetric care services in health facilities in the four countries studied, many of the potential~~ complications ~~identified would~~ require urgent care unavailable~~which is not feasible to provide~~ at home, such as caesarean section. Instead, it appears to be~~is~~ a woman's socio-economic status ~~and education~~ that determines her likelihood~~chance~~ of a facility delivery. One~~Perhaps the most~~ straightforward way to improve~~of tackling~~ this situation could be a renewed focus within ~~would be to exploit the educational component of~~ ANC on ~~, particularly where it relates to~~ screening for obstetric risk and improving communication around birth planning to reduce context-specific barriers~~encouragement~~ to ~~deliver in a~~ facility delivery. Further research into the quality of ANC communication, the effect of increased awareness of risk on women's decision-making, and the specific barriers faced by high-risk women will help to highlight the key areas for intervention and to strengthen service quality. In country, greater attention could also be given to service innovations such as maternity waiting homes which lessen~~that can help to overcome some of~~ the inequities related to transport and geographical accessibility of facility care. Lessons can also be learned from the comparative equity and high proportion of facility deliveries seen in Rwanda, exploring the role of community-based interventions to improve birth preparedness~~for maternal and newborn health~~ and strengthening the call for available and affordable high-quality services for all women.

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