Access barriers and facility delivery inequalities in Zambia: A multilevel analysis of individual heterogeneity and discriminatory accuracy (MAIHDA).

Keywords: Zambia; Health inequities; Multilevel analysis; Discriminatory accuracy; Access to care; Maternal health

Abstract

Low and middle income countries' progress in reducing intra-country inequalities in maternal healthcare access has lagged behind progress made in other primary healthcare areas and maternal health interventions intended to be pro-poor have had mixed effects on equity. Additional evidence is needed to inform policy-makers on the health system factors shaping disparities in maternal healthcare access, going beyond individual-level determinants.

This study draws on established "relational" healthcare access models to define accessibility as the extent to which the health system is fit for purpose given the population's needs and capacities. It is the first study to apply an innovative method from social epidemiology, Multilevel Analysis of Individual Heterogeneity and Discriminatory Accuracy (MAIHDA), to the study of healthcare access barriers. Findings provide reliable estimates of the predicted probability of facility delivery for 24 barrier combinations, demonstrate very good levels of discriminatory accuracy for the proposed model, and show that geographic, availability, and quality of care barriers are particularly effective in predicting who is likely to access a facility delivery.

This approach to the study of healthcare access can significantly improve our ability to put the most disadvantaged first, both by providing actionable information on the most salient barriers and by intentionally reframing the problem away from individual-level determinants of healthcare access.

1. Introduction

Skilled birth attendance is crucial to preventing maternal and neonatal mortality (Miller et al., 2016). However, inequalities in access to skilled birth attendance and facility delivery in Low and Middle Income Countries (LMICs) remain larger than inequalities in other primary healthcare areas (Boerma et al., 2018). A large minority of countries (15/42) experienced greater improvements in coverage of skilled birth attendance in the richest quintile compared to the poorest quintile between 1995 and 2004 (vs. 23 pro-poor change, 2 decreases in average coverage, and 2 no change) (Hosseinpoor et al., 2015). Designing effective interventions to reduce inequalities in maternal healthcare access in LMICs is not straightforward. A 2014 review of interventions to reduce maternal and child health inequalities in LMICs found great variation: interventions can increase, decrease or fail to impact health or healthcare inequalities defined according to wealth, education, ethnicity, gender, and other dimensions (Yuan et al., 2014).

There is currently insufficient information on the mechanisms underlying maternal healthcare inequalities. We know which types of women are less likely to access a health facility delivery (according to age, wealth, education, rural-urban residence, parity), but we have much less quantitative evidence on how the health system contributes to low access for these groups (Gabrysch and Campbell, 2009; Moyer and Mustafa, 2013; Stephenson and Tsui, 2002). Many studies conduct data-driven analyses that rely only on large-scale household surveys (e.g.: MICS and DHS) (Dzakpasu et al., 2014; Gabrysch and Campbell, 2009; Moyer and Mustafa, 2013). These datasets survey individuals and households, but do not adequately measure health system barriers. Because such an approach erases health system characteristics as potential variables, it can implicitly "blame the victim" while absolving the state from reforming health services and financing (Desai, 2000; Gabrysch and Campbell, 2009). This is particularly the case when authors fail to interpret individuals' demographic characteristics as social determinants of health rooted in broader patterns of power and injustice (Marmot et al., 2008).

Many recently published quantitative studies on healthcare access inequalities still rely exclusively on individual-level determinants (Amo-adjei et al., 2018; Asrese and Adamek, 2017; Goli et al., 2017; Målqvist et al., 2017; Nghargbu and Olaniyan, 2017), while others have attempted to innovate. For example, one study analysed maternal healthcare access in Ghana through DHS variables that measure the types of problems women report when accessing healthcare for themselves when they are sick (Moyer et al., 2013). However, these variables are not specific to maternal healthcare (and may in fact exclude maternal healthcare if women do not consider childbirth as a sickness), may be subject to social desirability bias, and may be more negatively reported by women who have actually sought care. Other researchers have investigated the role of supply barriers through their own surveys, or by using baseline surveys from evaluation research (Hounton et al., 2008; Karanja et al., 2018; Kruk et al., 2015; Negero et al., 2018; Silal et al., 2012). These often have the disadvantage of small samples and/or narrow spatial coverage, which can result in insufficient variation in supply barriers (Gabrysch and Campbell, 2009).

By contrast, linking DHS data to health facility lists through Geographic Information Systems (GIS) enables the inclusion of externally measured supply barrier variables while still having wide geographic reach (Gabrysch et al., 2011). These approaches are still relatively rare. As of 2011, only 3% of articles examining the determinants of facility delivery in Sub-Saharan Africa included any GIS information (Moyer and Mustafa, 2013). While the use of GIS in MNH is rapidly growing (Ebener et al., 2015; Makanga et al., 2016; Matthews et al., 2019), many studies focus on distance in isolation from other health system barriers.

Set in Zambia, a lower-middle-income country, this study investigates which barriers (if any) impede women's access to maternal healthcare by proposing and evaluating a healthcare accessibility model. This study makes three key innovations to better tailor the evidence to equity concerns. Firstly, the model is rooted in a "relational" concept of healthcare access, which locates accessibility in the interplay between population needs and health system capabilities. Secondly, the model draws on both population and health system data in order to operationalise this relational concept, using GIS methods. Thirdly, this study is the first to apply a Multi-level Analysis of Individual Heterogeneity and Discriminatory Accuracy (MAIHDA) analysis to the study of healthcare access barriers rather than social determinants. MAIHDA, a method newly developed in the field of intersectional social epidemiology, is used to determine how accurately combinations of barrier can predict who will access a facility delivery.

2. Background

2.1. Conceptual framework and existing evidence

This study uses healthcare access barriers to understand why some women are unable to access a facility delivery. Specifically, I adopt a "relational" or "fit" approach to accessibility by conceptualising barriers to healthcare access as the interaction between health system characteristics and health users' characteristics and needs. This can be contrasted with "behavioural" models, which focus on the role of individuals' internal decision-making processes (Ricketts and Goldsmith, 2005). A relational framework is better suited to the analysis of inequities because it highlights the fact that the health system serves the needs of some citizens better than others. Drawing on established theoretical frameworks in healthcare access, I define seven access barriers: Availability, Geographic, Affordability, Administrative, Quality, Cognitive and Psycho-Social barriers (Bertrand et al., 1995; Penchansky and Thomas, 1981; UN, 2000). Table 1, adapted from Choi et al (2014), provides definitions for these barriers in the left-most column and demonstrates how they relate to three important relational models of healthcare access.

Table 1: Barriers as defined in established relational healthcare access frameworks

BARRIERS	Penchansky and Thomas (1981)	Bertrand et al (1995)	UN Right to health (2000)
Availability "The relationship of the volume and type of existing services to the clients' volume and types of needs" (P & T 1981)			
Geographic accessibility "The relationship between the location of supply and the location of clients, taking into account client transportation resources and travel time, distance and cost" (P & T 1981)			Accessibility (geographic)
Affordability "The relationship of prices of services to the clients' income, ability to pay, and health insurance" (P & T 1981)		Economic accessibility	Accessibility (economic)
Administrative accessibility "The relationship between the manner in which the supply resources are organised to accept clients and the clients' ability to accommodate to these factors, and the clients' perception of their appropriateness" (P&T 1981)	Accommodation		
Perceived quality of care Clients' perception of the extent to which they are likely to receive effective care once they access a facility	Acceptability (user attitudes towards providers' professional characteristics)	Quality of care	Quality of care
Cognitive accessibility "Extent to which potential clients are aware if the locations of service (…) points and of the services available at these locations" (B et al 1995). Also includes clients' awareness of the benefits of quality biomedical care			Accessibility (informational)
Psychosocial accessibility "Extent to which clients are constrained by psychological, attitudinal or social factors in seeking out (…) services" (B et al 1995). E.g.: shame; fear of disrespect from health workers and others; lack of agency; lack of self-entitlement; unacceptable care in the context of beliefs.	Acceptability (attitudes of users towards providers' personal characteristics)		Acceptability (culturally appropriate, respecting confidentiality)

Note: Shaded cells indicate that a theoretical framework includes that particular access barrier. The text within the cells is the name given by that theoretical framework to the access barrier if it differs from the barrier name in the left-most column. Barrier definitions are referenced where appropriate. Non-referenced barrier definitions were developed by the author.

2.2. Context

Zambia has a high Total Fertility Rate (TFR) of 5.3, lower levels of facility delivery than many countries in the Southern African region (64.2% in the period 2008-2014), but comparatively low levels of maternal mortality (224 deaths per 100,000 live births in 2015) WHO et al. 2015). Inequalities in access to facility delivery have been decreasing since 2002, though at a slower rate than inequalities in access to child healthcare (Assaf and Pullum, 2016). The absolute difference between facility delivery rates for the 20% richest and 20% poorest was still almost 50 percentage points between 2008 and 2013 (CSO et al 2014).

The Zambian Government has made it a priority to reduce these inequalities: equity of access to healthcare services was part of the mission statement and key principles of the past three National Health Strategic Plans (Republic of Zambia Ministry of Health, 2017, 2011, 2009). The Government of Zambia has implemented many health and health-related reforms over the past ten years with this goal in mind. These reforms have had mixed effects on equity. Removing user fees had no effect on inequalities of access, while unconditional cash transfers for families with children under five years old only increased access to facility delivery among women who lived in a village with a health facility (Handa et al., 2016; Lépine et al., 2017).

Many of the barriers listed in Section 2.1 have been shown to be relevant in the Zambian context (mostly in qualitative studies), though they have never been evaluated as a group of factors. Most studies emphasise geographic, affordability, and psychosocial barriers. Difficulty in reaching the nearest facility, due to distance and lack of transport, is a major barrier for many women (Gabrysch et al., 2011; Hjortsberg, 2003; Mutale et al., 2017, 2013, Sialubanje et al., 2014a, 2014b). Affordability remains an issue, despite the removal of user fees in 2006, due to the cost of transport and because women are required to bring various items to the delivery, such as a plastic sheet, a cord clamp, etc. (Mutale et al., 2013; Sialubanje et al., 2014a) [anonymised reference]. Psycho-social barriers are also important, including young women's inability to make their own decisions (Banda et al., 2016; Sialubanje et al., 2014a), the unacceptability of young or male nurse-midwives and being examined early in the pregnancy, as well as disrespectful care (Mutale et al., 2013; Sialubanje et al., 2014b).

Qualitative studies have reported perceived quality of care and availability barriers. Insufficient skilled health workers and drug stock-outs discourage women from seeking a facility delivery

(Mutale et al., 2017, 2013; Sialubanje et al., 2014a). Only one administrative barrier has been documented in the literature to date, the requirement to bring the father of the baby when registering the pregnancy in order to access antenatal, perinatal and postnatal care (Sialubanje et al., 2014b; REDACTED, 2019a). Regarding cognitive barriers, Sialubanje et al (2014a) found that women were aware of the risks inherent in childbirth and knew that the formal care sector could address complications should they arise. However multi-parous mothers are less likely to view facility delivery as necessary in light of their previous childbirth experience, which is a misconception as complications can arise regardless of parity (Banda et al., 2016; Isaac Banda, Charles Michelo, 2012; Mulenga et al., 2018; Scott et al., 2018; Sialubanje et al., 2015, 2014a).

3. Methods

This study uses a combination of innovative approaches, including GIS methods to link a population-level dataset to a facility-level dataset, key informant interviews to select variables for analysis, and an analytical approach recently developed in intersectional social epidemiology: Multi-level Analysis of Individual Heterogeneity and Discriminatory Accuracy (MAIHDA).

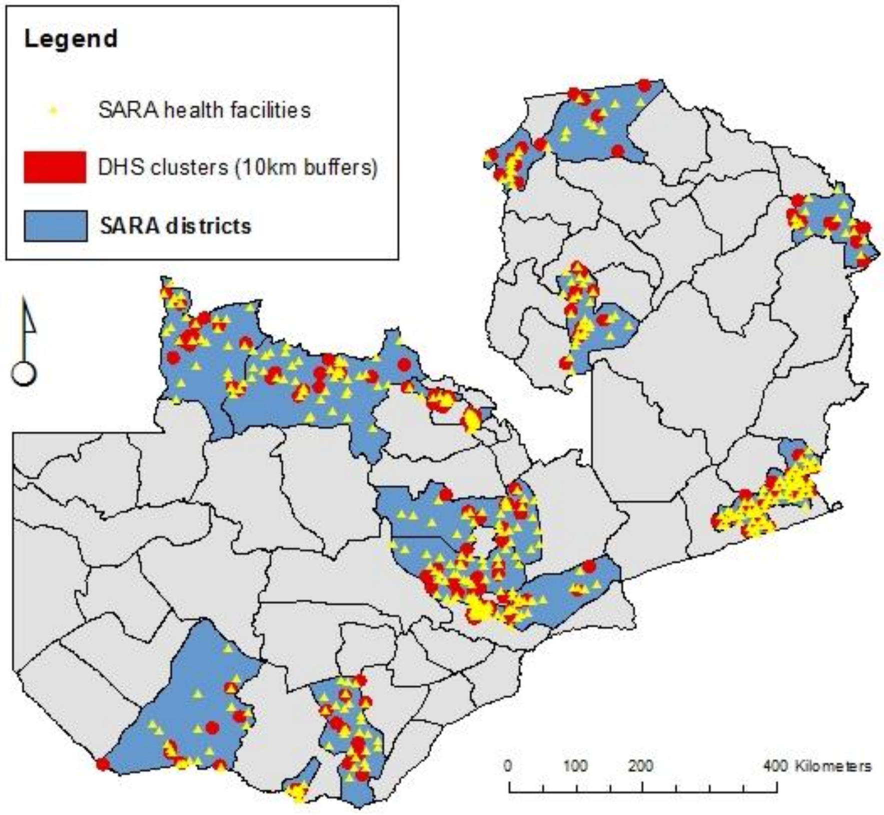
3.1. Data

This study draws on two datasets, one at the population-level and one at the health facility-level, linking them using GIS (Figure 1): the nationally representative 2013-14 Demographic Health Survey (DHS) and the 2010 Service Availability and Readiness Assessment (SARA), which collected information on all facilities located in 17 of Zambia's districts (out of 72).

The 2013-14 DHS is a cross-sectional population survey on reproductive, maternal and child healthcare access and outcomes, representative at the national and provincial levels. Data is geo-referenced according to the central location of the sampling cluster, an enumeration area with an average size of 130 households. The DHS randomly displaces the geo-location of these clusters for confidentiality purposes, by 0-2km for urban clusters, and 0-5km (of which 1% up to 10km) for rural clusters (CSO et al 2014). The sample for this study is at the birth-level. It includes live births occurring in the five years prior to interview (i.e. those for which place of birth information was recorded), if the child's mother resided within one of the 17 SARA districts, and if the sampling cluster had a valid geo-reference. Births to mothers who migrated since the birth and non-singleton births were excluded. The final sample is comprised of 253 clusters and 3,470 live births.

The 2010 SARA collected information on health facilities' staffing levels, drugs and equipment, from all facilities in 17 out of Zambia's 72 districts, and geo-referenced the health facility's location. Districts were selected evenly, but not randomly, from across Zambia's 9 provinces, in order to purposefully include malaria sentinel districts and Global Fund evaluation districts, and to include an even mix of predominantly rural and predominantly urban districts. Facilities which were revealed to be located outside of the SARA districts' shapefiles by GIS analysis (Hijmans, 2015), or without a valid geo-reference, were excluded. A total of 596 health facilities are included in the analysis. The SARA was preferred to the Zambia 2012 health facility list, which covers all health facilities in the country, as the latter lacked sufficient information on quality of care and staffing.

Figure 1: Health facilities and DHS clusters in SARA districts, Zambia.



Note: Produced by the author using ArcGIS 10

3.2. Variables

While each of the barriers is a multi-dimensional and complex concept, I selected one variable per barrier to avoid an exponential number of barrier combinations. In order to maximise legitimacy, contextual relevance, and accuracy of measurement, variable selection was informed by 12 key informant interviews (KII), as well as a Zambia-focused literature review. KIIs were held in Lusaka in July-August 2017 with respondents from academic, government, international aid, and medical backgrounds, selected purposively for their knowledge of healthcare access in Zambia. Ethical clearance was obtained from [anonymised ethics bureau] and [anonymised ethics bureau]. KIIs focused on the validation of the overall access barrier framework, the selection of the variables from a shortlist provided by the author, additional variable suggestions, and discussion of the strengths and weaknesses of potential variables. The respondents were asked to assess potential variables according to their conceptual closeness to a given barrier and to the availability of high-quality secondary data measuring this variable in the Zambian context. One barrier, administrative accessibility, could not be measured in this study, due to the lack of a suitable data source.

Whether a birth occurred in a health facility, or "facility delivery" for short, is the outcome variable for all analyses, and is sourced from DHS data. This variable measures delivery at any facility, including private and public facilities, from health posts to hospitals. Facility delivery is very closely related to being assisted by a skilled provider at birth: 95% of births in a health facility were delivered by a skilled birth attendant (SBA) (i.e. doctor, clinical officer, or nurse/midwife), compared to only 0.7% of births occurring elsewhere (CSO et al 2014).

The affordability barrier is defined as whether the mother's household was in the two poorest wealth quintiles at the time of interview, using DHS data. Wealth quintiles were calculated by the author using principle component analysis of housing infrastructure and household assets, using separate indices for rural vs. urban residents (Filmer and Pritchett, 2001). This variable does not directly measure the relationship between healthcare costs and households' income, neither of which were captured by available data. However, households in the two lowest wealth quintiles are more likely to struggle to afford the cost of a facility delivery. This cost was recently estimated as $20 (lower-bound) despite the absence of formal user fees, relative to an average annual income of $250 for rural residents (Chiu et al., 2019).

The cognitive and psychosocial barriers are defined according to birth order, using DHS data. Birth orders above one are coded as facing a cognitive barrier. Key informant interviews confirmed conclusions from the Zambian literature that multi-parous mothers are less likely to view facility delivery as necessary because of their previous childbirth experience, even though complications can arise regardless of parity. Birth orders of six and above are coded as facing a psycho-social barrier in addition to the cognitive barrier. Key informants reported that women with six or more births are more likely to receive disrespectful care from nurses or midwives, which was confirmed in interviews conducted with mothers in Mansa district in 2018 [anonymised reference]. These variables only proxy for one of the many reasons why women might suffer from cognitive or psycho-social barriers, while the extent to which these characteristics result in access barriers is shaped by health workers' attitudes, for which data is not available.

The geographic barrier is defined as whether the mother's DHS sampling cluster at the time of interview was within 10km of any health facility in the SARA census, measured as a straight-line distance. The last three National Health Strategic Plans (going back to 2006) all make explicit reference to the importance of increasing the percentage of the population living within 5km of a health facility. However, because of the random displacement of DHS sampling clusters, I follow best practice and use a distance of 10km for all geographically-defined barriers in order to minimise the possibility of misclassification (Burgert and Prosnitz, 2014; Wang et al., 2015). I use straight-line distance rather than networked distance due to the noise introduced by other factors such as cluster displacement and the lack of data on means of transport to reach the health facility. I control for the cluster's slope to partially account for the terrain and include year-month fixed effects to account for seasonality of travel time (DHS Program, 2017; Makanga et al., 2016).

The availability barrier is defined as whether the mother's DHS sampling cluster was within 10km of any health facility with a midwife, with staffing measured using SARA data. Key informants agreed that having a sufficient number of skilled staff was important (although not sufficient) to meet the population's need for skilled childbirth care. The importance of the health workforce for the availability of maternity care has also been emphasised in the global literature (Downe et al., 2014). KIs reported that doctors, clinical officers, medical licentiates, midwives and nurses with midwifery training were considered skilled birth attendants in Zambia. Because the SARA did not record the number of staff working in maternity care specifically, and higher-level facilities include many health workers that do not provide maternity care, I operationalised this variable to focus on midwives specifically (as opposed to any SBA). By construction, any person facing the geographic barrier also faces the availability barrier.

The perceived quality of care barrier is defined as whether the mother's DHS sampling cluster at the time of interview was within 10km of any health facility with the capacity to provide Comprehensive Emergency Obstetric and Neonatal Care (CEMONC). A CEMONC facility is able to respond to all obstetric complications, including those requiring caesarean section and blood transfusion, and is thus able to provide the highest quality obstetric care (Freedman et al., 2007). CEMONCs were identified in the SARA data according to whether the facility's manager reported that the facility provided all eight CEMONC signal functions (WHO et al., 2009), although this is likely to overestimate the quality of care provided in practice. A CEMONC-level facility is more likely to be perceived to provide quality care (Gabrysch et al., 2011; Kruk et al., 2009). By construction, any person facing the availability barrier also faces the quality barrier.

Table 2: Descriptive statistics, Zambia DHS (2013-14) & SARA (2010)

	Study sample size (N missing)	**Study sample Unweighted**	**Original dataset Weighted**
		% of births	**% of births (DHS)**
Facility delivery	3,081 (488)	63.2%	67.6%
Affordability barrier *Two poorest wealth quintiles*	3,569 (0)	48.0%	47.8%
Cognitive barrier *Birth order 1 +*	3,569 (0)	81.5%	74.7%
Psycho-social barrier *Birth order 6 +*	3,569 (0)	25.4%	16.3%
		% of births	**% of facilities (SARA)**
Geographic barrier *No health facility within 5km*	3,569 (0)	34.5%	
No health facility within 10km	3,569 (0)	20.7%	
Availability barrier *No midwife*			55.9%
No midwife within 5km	3,481 (88)	48.6%	
No midwife within 10km	3,473 (96)	38.6%	
Quality of care barrier *Not CEMONC*			95.1%
No CEMONC within 5km	3,481 (88)	72.9%	
No CEMONC within 10km	3,473 (96)	56.4%	

3.3. Analytical strategy

This study applies an innovative method from intersectional social epidemiology: Multi-level Analysis of Individual Heterogeneity and Discriminatory Accuracy (MAIHDA) (Evans et al., 2017; Merlo, 2017). This approach is well suited to producing policy-relevant evidence for reducing health inequalities. Firstly, in contrast to a traditional risk factor approach, where the emphasis is on the average difference between women who do and do not face a specific barrier, a discriminatory accuracy approach identifies the extent to which births facing the same set of barriers are similar to each other in terms of accessing health facility delivery, and the extent to which they are different from births facing other sets of barriers. This approach highlights the importance of these barriers relative to individual heterogeneity or other mechanisms not included in the model (Austin and Merlo, 2017; Merlo, 2017; Wemrell et al., 2017). Secondly, MAIDHA focuses on barrier combinations instead of examining the independent effect of each individual barrier. This approach better reflects the fact that healthcare-seeking pregnant women may face multiple barriers simultaneously. While MAIDHA has been developed to test theories of intersectionality (Crenshaw, 1989; McCall, 2005; Nash, 2008), this study is not intersectional: it does not explicitly model overlapping axes of oppression or seek to measure the extent to which barriers have non-additive effects.

MAIHDA is implemented using a logistic random intercepts model (Equation 1), where births are nested within one of 24 possible barrier combinations (Table 3), and a random intercept is specified for each combination.

Equation 1: Logistic random intercept model $\mathrm{logit}(y_{ij}) = \propto + \mu_j$

y_{ij} is facility delivery for the i^{th} birth nested in the j^{th} barrier combination. α is the overall mean of facility delivery in the sample. The random intercepts μ are assumed to be normally distributed around mean α, with variance σ^2_μ (conditional on covariates where included), and to be independent from each other.

Using such a model, the predicted probability of a facility delivery can be estimated for each barrier combination from the resulting odds ratios. These probabilities are more reliably estimated in a multi-level model than a saturated fixed-effects model, since probabilities for rare combinations are estimated by borrowing information from the mean (Evans et al., 2017). The Intraclass Correlation Coefficient (ICC) (Equation 2) calculates the percentage of the total variance attributable to the barrier combinations rather than the individual-level variance (set at 3.29 in logistic models). The ICC measures the level of discriminatory accuracy, similar to the Area Under the Receiver operating characteristic curve (AUC) (Merlo, 2017). The higher the ICC, the better the barrier combinations are at distinguishing between who will and will not access a facility delivery. Where the models include a cross-classified random intercept at the sampling cluster level, the ICC's denominator additionally includes the variance of the clusters' random intercepts.

Equation 2: Intraclass Correlation $$\text{ICC} = \frac{\sigma^2{}_{\mu}}{\sigma^2{}_{\mu} + 3.29}$$

In subsequent models, I explore which barriers have stronger discriminatory accuracy by comparing the ICC of the barrier combinations' random intercepts in Equation 1 (model A) versus a model that also includes barrier dummies as main effects (model B). This is calculated using the Proportional Change in Variance (Equation 3) (Axelsson Fisk et al., 2018). Once the dummy for a given barrier is included as a main effect, the variance of the barriers' random intercepts no longer captures the variance of the additive effect of that barrier and is reduced. The larger the proportional difference between the random intercepts' variance in the two models, the more discriminatory accuracy that barrier has.

Equation 3: Proportional Change in Variance $$\text{PCV} = \frac{\sigma^2_{\mu,A} - \sigma^2_{\mu,B}}{\sigma^2_{\mu,A}}$$

I estimate these models using Bayesian Markov Chain Monte Carlo (MCMC) methods, as recommended in the MAIHDA literature (Evans et al., 2017). Specifically, I use a Gibbs sampler, Rjags, from within RStudio v1.0.143. I use non-informative priors, 5,000 iteration burn-in and

100,000 saved posterior samples. No initialisation values were used, but chains with different random starting points gave similar results, and traceplots indicated good levels of convergence and mixing. The Raftery-Lewis diagnostic indicated an appropriate number of burn-in and saved samples in order to obtain the parameters of interest with a 0.005 margin of error at the 0.025 quartile with 95% accuracy. Point estimates are the average of the posterior samples for the parameter of interest, while credible intervals (CI) represent the smallest interval covering 95% of posterior samples for the parameter of interest. Predicted probabilities are estimated by calculating the logged odds for each barrier combination in each posterior sample using the parameters estimated in the Bayesian model described above, converting logged odds to probabilities, and averaging across posterior samples for each barrier combination in order to obtain the point estimate.

4. Limitations

This analysis presents a number of limitations. Firstly, some of the variables chosen to measure each barrier concept measure only one part of that concept, leaving other parts unaddressed. This is particularly true for the cognitive and psychosocial barriers, as these barriers operate on a range of dimensions, only one of which is included here. This limitation is the corollary of building a parsimonious model with a sufficient number of barrier combinations to allow the variance of the barrier random effects to be reliably estimated, while allowing for few enough combinations to predict probabilities for each combination accurately. This limitation was partly addressed by drawing on qualitative primary research to operationalise health barrier variables for the Zambian context, in order to maximise the legitimacy and contextual relevance of the variables chosen. However, other variables might also be valid measures of these barriers in Zambia.

The variance of the random effects may be capturing the influence of omitted variables correlated both with the barrier combinations and the outcome variable. Control variables and cluster-level random effects were included in the model in order to partially address this bias. The theoretical grounding of the model is another attempt to address this limitation, by guiding the inclusion of all major dimensions of accessibility in a single model. Only one major dimension could not be included due to lack of data: the administrative barrier.

DHS clusters are randomly displaced to maintain participant confidentiality. Some births will have been mistakenly classified as suffering from the geographic, availability or quality barriers when they did not, and vice-versa. The direction of this bias cannot be predicted. Likewise, it is unclear whether rural or urban clusters will be more affected. While the maximum limit for the displacement of rural clusters is larger, the density of the service environment is much lower. In order to address this issue, I define distance-related barriers at the 10km level (Burgert and Prosnitz, 2014; Wang et al., 2015).

5. **Results**

5.1. Predicted probability of facility delivery by barrier combination

91% of the sample suffers from at least one barrier, while 6% of the sample suffers from all six barriers (Table 4). There are wide disparities in the probability of accessing a facility delivery depending on the combination of barriers faced. Women facing all six barriers have a 41% chance of giving birth in a health facility, while women facing no barriers have a 94% chance of doing so. With some exceptions, combinations with fewer barriers have a higher predicted probability of facility delivery than combinations with a greater number of barriers. Relatedly, there are larger disparities in the probability of facility delivery between barrier combinations where the number of barriers is different, compared to disparities between barrier combinations with the same number of barriers but where the specific barriers faced are different.

Table 3: Predicted probability of facility delivery for women facing different barrier combinations, Zambia 2013-14 (10km; no controls; no adjustment for DHS sampling clusters)

#	Births N	Births %	Barriers N	poor	cogn	psyc	geog	avail	qual	Pred prob	CI
1	214	6%	6	yes	yes	yes	yes	yes	yes	0.41	0.34-0.48
2	271	8%	5	yes	yes	no	yes	yes	yes	0.42	0.35-0.48
3	90	3%	4	no	yes	no	yes	yes	yes	0.49	0.39-0.6
4	67	2%	5	no	yes	yes	yes	yes	yes	0.52	0.4-0.64
5	160	5%	5	yes	yes	yes	no	yes	yes	0.52	0.44-0.6
6	230	7%	4	yes	yes	no	no	yes	yes	0.60	0.53-0.66
7	75	2%	4	yes	no	no	yes	yes	yes	0.60	0.49-0.71
8	47	1%	4	no	yes	yes	no	yes	yes	0.64	0.49-0.78
9	105	3%	4	yes	yes	yes	no	no	yes	0.66	0.56-0.75
10	59	2%	3	yes	yes	yes	no	no	no	0.66	0.54-0.78
11	22	1%	3	no	no	no	yes	yes	yes	0.67	0.48-0.84
12	71	2%	3	no	yes	yes	no	no	yes	0.72	0.61-0.83
13	225	6%	3	yes	yes	no	no	no	yes	0.72	0.66-0.79
14	64	2%	3	yes	no	no	no	yes	yes	0.78	0.68-0.88
15	62	2%	2	yes	no	no	no	no	yes	0.82	0.72-0.91
16	154	4%	2	yes	yes	no	no	no	no	0.82	0.76-0.88
17	153	4%	2	no	yes	no	no	no	yes	0.83	0.77-0.89
18	29	1%	2	no	no	no	no	yes	yes	0.84	0.72-0.95
19	71	2%	3	no	yes	no	no	yes	yes	0.84	0.75-0.93
20	155	4%	2	no	yes	yes	no	no	no	0.86	0.8-0.91
21	37	1%	1	yes	no	no	no	no	no	0.90	0.8-0.98
22	758	22%	1	no	yes	no	no	no	no	0.93	0.91-0.95
23	299	9%	0	no	no	no	no	no	no	0.94	0.92-0.97
24	55	2%	1	no	no	no	no	no	yes	0.96	0.91-1

CI: 95% Bayesian Credible Intervals
Poor – affordability barrier; Cogn – cognitive barrier; Psych – psychosocial barrier; Geog – geographic barrier; Avail – availability barrier; Qual – quality barrier.

5.2. Discriminatory analysis

A quarter of the variance in facility delivery can be explained by the clustering of the outcome within barrier combinations defined at the 10km level, once control variables and sampling clusters are accounted for (Table 4). I report the results for the 5km-level model as a sensitivity check, though the literature recommends measuring distance-related variables at the 10km level (Burgert and Prosnitz, 2014; Wang et al., 2015).

The interpretation of the ICC as a measure of discriminatory accuracy relies on the assumption that the model includes any covariates correlated with the barrier combinations and the outcome. While this assumption is unlikely to hold, I mitigate this limitation by including covariates previously demonstrated to influence facility delivery (Gabrysch and Campbell, 2009). These include marital status (a dummy for being married), educational achievement (a dummy for having reached secondary school or above), and age at birth (continuous variable in years). I also include controls related to the distance barrier: how steep the terrain of the sampling cluster is, and seasonality of time of birth (fixed effects for month-year of birth). I exclude rural-urban residence as a control variable because controlling for it as an additive effect would diminish the geographic, availability and quality barriers' explanatory power, without adding any insight into why rural women are less likely to access care. Sensitivity analyses also include an additional cross-classified random intercept for the DHS sampling cluster, which controls for the fact that births within mothers and mothers within clusters are likely to be more similar to each other than to births from different mothers or in different clusters. Adding controls and sampling-cluster random intercepts reduces the ICC as expected, although not to a great extent (Table 4).

There are no established scales for what is considered a good ICC in terms of discriminatory accuracy. However Axelsson-Fisk et al (2018), drawing on cut-offs used in psychometric test reliability assessments, suggest that an ICC of 20-30 is "very good". While there remain large variations in facility delivery within barrier combinations, the barrier combinations defined by this study play an important role in identifying the mechanisms at play behind disparities in access to facility delivery.

Table 4: Intraclass correlations for barrier combinations, Zambia 2013-14

	No controls No cluster RE	**No controls With cluster RE**	**With controls With cluster RE**
10km variables			
ICC	27%	27%	25%
Variance barriers	1.20 (0.50-2.10)	1.59 (0.62-2.82)	1.56 (0.56-2.83)
Variance clusters	NA	1.10 (0.72-1.51)	1.30 (0.85-1.78)
5km variables			
ICC	26%	25%	22%
Variance barriers	1.13 (0.48-1.96)	1.50 (0.58-2.65)	1.36 (0.48-2.46)
Variance clusters	NA	1.22 (0.83-1.66)	1.43 (0.95-1.93)

Interpretation: The ICC indicates the proportion of the variance in facility delivery that can be explained by the variance between (vs. within) barrier combinations, controlling for confounders and clustering within DHS sample clusters.
(95% Bayesian Credible Intervals in parentheses)
Controls: mothers' age at birth, married, secondary school or higher, cluster slope, month-year fixed effects
Cluster RE: model also includes a cross-classified random intercept for DHS sampling clusters in addition to the barrier combinations' random intercepts.
5km variables: geographic, availability and quality barriers defined at the 5km level – other barriers defined as normal
10km variables: geographic, availability and quality barriers defined at the 10km level – other barriers defined as normal

5.3. Evaluating the relative importance of barriers

In this section, I investigate which barriers contribute particularly strongly to explaining disparities in facility delivery. Geographic, availability, and quality of care barriers display stronger discriminatory accuracy in predicting who will access a facility delivery and who will not (Table 5). The sequential inclusion of additive effects for the affordability, cognitive and psycho-social barriers reduces the variance of the barriers' random effects by 15% or less (models 2-4), compared to more than 47% for the affordability, cognitive and psychosocial barriers (models 5-7). This is confirmed by comparing the change in the variance when the first three barriers are included as main effects (a change of 27%) (model 8), relative to when the last three barriers are included (a change of 74%) (model 9).

These findings suggest that the geographic, availability, and quality of care barriers are more important in shaping access to facility delivery. However the results could also be affected by measurement limitations. While the cognitive, psychosocial and affordability barriers are also relational concepts, data constraints meant they were measured using individual characteristics that were discriminated against by the existing health system, rather than data on specific discriminating providers or facilities.

Table 5: Comparing the discriminatory accuracy of barriers using the proportional change in variance, Zambia 2013-14

Facility delivery	**(1) Original model**	**(2) Cognitive**	**(3) Psychosocial**	**(4) Affordability**	**(5) Geographic**	**(6) Availability**	**(7) Quality**	**(8) Cogn + Psych + Afford**	**(9) Geog + Avail + Qual**
ICC	25%	22%	25%	23%	14%	13%	15%	20%	8%
PCV	Reference model	15%	4%	12%	52%	54%	47%	27%	74%
Variance barriers	1.6	1.3	1.5	1.4	0.7	0.7	0.8	1.1	0.4
	(0.6;2.8)	(0.5;2.5)	(0.5;2.8)	(0.5;2.6)	(0.2;1.4)	(0.2;1.4)	(0.2;1.6)	(0.3;2.2)	(0.1;0.9)
Variance clusters	1.3	1.3	1.3	1.3	1.3	1.3	1.4	1.3	1.3
	(0.8;1.8)	(0.8;1.8)	(0.9;1.8)	(0.9;1.8)	(0.9;1.8)	(0.9;1.8)	(0.9;1.9)	(0.8;1.8)	(0.9;1.8)
Additive effects									
cognitive		-1.2						-1.1	
		(-2.3;-0.1)						(-2.2;0.1)	
psychosocial			-0.9					-0.3	
			(-2;0.3)					(-1.5;0.8)	
affordability				-0.8				-0.9	
				(-1.9;0.2)				(-1.8;0.1)	
geographic					-2.0				-1.2
					(-3;-1)				(-2.2;-0.2)
availability						-1.7			-0.6
						(-2.6;-0.9)			(-2.2;-0.2)
quality							-1.8		-1.0
							(-2.8;-0.8)		(-1.9;-0.1)
Constant	-8.7	0.5	-1.6	9.2	1.4	4.2	11.4	-0.9	4.2
	(-17.3;1.5)	(-8.6;10.8)	(-9.9;9.4)	(-6.4;21.8)	(-6.3;9.8)	(-8.2;20.1)	(-1.4;23.4)	(-13.8;7.8)	(-5.9;14.1)

Interpretation: Including a variable in the main part of the model in addition to the random part ensures that the REs' variance no longer accounts for the additive effect of that variable. This analysis shows the extent to which the ICC decreases with the inclusion of each barrier. A greater decrease in the ICC (and a correspondingly large PCV) indicates that the barrier contributes more strongly to the barrier model's collective discriminatory accuracy.

Notes: 95% Bayesian Credible Intervals in parentheses. Controls included in this analysis: mothers' age at birth, married, secondary school or higher, cluster slope, month-year fixed effects. The model also includes a cross-classified random intercept for DHS sampling clusters in addition to the barrier combination random intercept

6. Discussion

The number and combination of healthcare access barriers faced by women meaningfully predicts which women are most or least likely to give birth in a health facility in Zambia. Geographic, availability and quality of care barriers have particularly high discriminatory accuracy. The health system environment is highly associated with disparities in access to facility delivery. Under a causal interpretation, eliminating healthcare access barriers for all, particularly reducing distance to care, improving staffing, and improving quality of care, could reduce disparities in access to facility delivery.

This study's results are broadly consistent with Gabrysch et al (2011), who analyse the average and independent effect of distance and quality of care barriers (defined to include staffing) on facility delivery in Zambia in 2002-2007, controlling for household wealth and birth order, among other confounders. The authors conclude that under a causal interpretation, ensuring that all women live within 5km of a basic emergency obstetric care facility with appropriate staffing would reduce the proportion of home deliveries by a greater extent than if all households were in the richest wealth quintile.

While better evidence alone is highly unlikely to remedy inequities rooted in power differentials (Sriram et al., 2018), the innovative approach adopted in this study has many practical advantages in terms of generating policy-relevant information for reducing healthcare access disparities. It includes a theoretically-driven, comprehensive set of healthcare barriers; it teaches us about the distribution of outcomes within and between barrier combination groups; it analyses barrier combinations rather than the independent effect of each barrier; and it is able to contrast the relative importance of different barriers in terms of their discriminatory accuracy.

This study conceptualises and measures accessibility in a relational manner, placing moral responsibility for change with the health system rather than the individual. This approach is complementary to a social determinants of health perspective: while the health system cannot solve all health inequities, what *could* it do? This approach stands in contrast to studies that examine the role of individual-level behaviours in healthcare access and propose individual-level solutions. A recent example from the Zambian context is a study demonstrating an association between whether pregnant women saved to cover delivery costs, and the odds of facility delivery (Chiu et al., 2019). The authors' main recommendation is to implement awareness-raising initiatives about the importance of saving during pregnancy, as opposed to health system policies that would make accessing pregnancy less costly or redistributive social protection policies.

Gathering additional data on cognitive, psychosocial, affordability, and administrative accessibility would strengthen our ability to research the effect of these barriers. In the Zambian context, this could involve gathering data on how maternal health information is understood and interpreted by women and their families, staff attitudes, especially with respect to stigmatised women, and facility-level requirements that women buy materials for the delivery or bring their husband to register the pregnancy.

Further research with important implications for equity research could build on this model to explore the extent to which inequalities defined by demographic characteristics (e.g. high vs low education) are explained by these barriers, using pathway analysis or decomposition methods [anonymised reference]. MAIHDA could also be used to test intersectional health inequality hypotheses in LMIC settings. Intersectional approaches are potentially highly informative for health equity research and yet are least likely to be applied in LMIC contexts (Bauer, 2014; Larson et al., 2016).

7. Conclusion

A comprehensive barrier model, where accessibility is defined as the relationship between the health system and population needs, has very good discriminatory power in Zambia. Availability, geographic and quality of care barriers have greater discriminatory accuracy than affordability, cognitive and psycho-social barriers. This approach to the study of maternal healthcare inequalities could prove valuable for policy-makers seeking to put the needs of the most disadvantaged first, both by providing actionable information on salient barriers and by reframing the problem in a way that is less likely to “blame the victim”.

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