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Bottlenecks in the provision of antenatal care: rural settled and mobile pastoralist communities in Chad

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Summary

OBJECTIVE To assess antenatal care (ANC) coverage and analyse constraining factors for service delivery to rural settled and mobile populations in two districts in Chad.

METHOD Data from cross-sectional household and health facility surveys in the two Chadian rural health districts were analysed. First, contact coverage of ANC services in the study area was estimated from household data as the proportion of women who visited health facilities to obtain ANC during their last pregnancy. Second, bottlenecks in the provision of this service were explored by calibrating a multiplicative model of ANC contact coverage to household and health facility data. The model allowed quantification of the magnitude by which coverage decreased as it progressed through the health system. Sensitivity analysis was applied to account for uncertainty around the estimated coverage factors.

RESULTS Direct estimates revealed that ANC contact coverage decreased as the number of required visits increased: 79% of rural settled mothers and 46% of mobile pastoralist mothers visited a health facility to obtain ANC at least once (ANC 1). Among mobile pastoralists, only 20% of pregnant women attended ANC at least three times compared to 63% of rural settled women. Availability, accessibility, affordability and acceptability contributed to reductions in service coverage in both populations. For mobile pastoralists, acceptability was clearly the most important factor. ANC 1 contact coverage resulting from the model is 50% for rural settled and 30% for mobile pastoralists.

CONCLUSION Antenatal care coverage was low in rural districts of Chad, particularly for mobile pastoralists. Acceptability largely explained the prevailing difference between the two population groups.

keywords antenatal care, contact coverage, equity, maternal health, rural settled communities, mobile pastoralists, Chad

Introduction

Maternal health is a global concern for securing future economic and social development: worldwide, around 210 million women become pregnant annually. In 2015, 216 women per 100 000 live births died of maternal causes [1]. Through the prioritisation of maternal health in the Millennium Development Goals, the international community made important strides towards reducing maternal morbidity and mortality. The global mortality ratio nearly halved between 1990 and 2015, and important increases in maternal health coverage among poor and rural mothers were achieved [2]. Despite this progress, inequalities and large disparities in the burden of maternal morbidity and mortality persist within and between populations. A comprehensive multicountry analysis of health service utilisation revealed that inequalities along the socio-economic gradient are particularly high for skilled care at delivery and antenatal care (ANC) as compared to other health interventions [3]. There is considerable divergence in the magnitude of maternal mortality which is concentrated in vulnerable populations, particularly in sub-Saharan Africa [4]. A women's lifetime risk of dying as a result of pregnancy and childbirth is more than 100 times higher in sub-Saharan Africa than in high-income countries [1].

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In Chad, over 78% of the total population live in rural areas which are characterised by insufficiently equipped health centres. General health care is difficult to provide because of long distances, poor infrastructure, lack of electricity and clean water and most prominently the lack of qualified medical and nursing staff. Chad represents a particular case of inequality: maternal mortality rate is one of the highest in the world at 1099 per 100 000 live births, with only 30% of women being assisted by qualified personnel while giving birth in 2010 [5]. This figure is likely even lower in remote areas, especially for mobile pastoralists (3.5% of the population, which is presumably underestimated due to methodological shortcomings of censuses in mobile communities) who are particularly affected by low access to and provision of health services [6]. An extreme example among mobile pastoralist communities is immunisation, where vaccination coverage among livestock was significantly higher than for children [7, 8].

Effective maternal health service interventions such as ANC are associated with improved maternal and neonatal health outcomes [4]. Progress in provision of these services must meet a variety of demand- and supply-side requirements to finally reach the target population and generate the expected health gains, causing a cascade between the potential and effective health service coverage [9]. Bottlenecks to achieve effective coverage are generally defined as those requirements that cause the main difficulties for service provision. Identifying and evaluating the bottleneck constraints in health service delivery is paramount for setting intervention priorities.

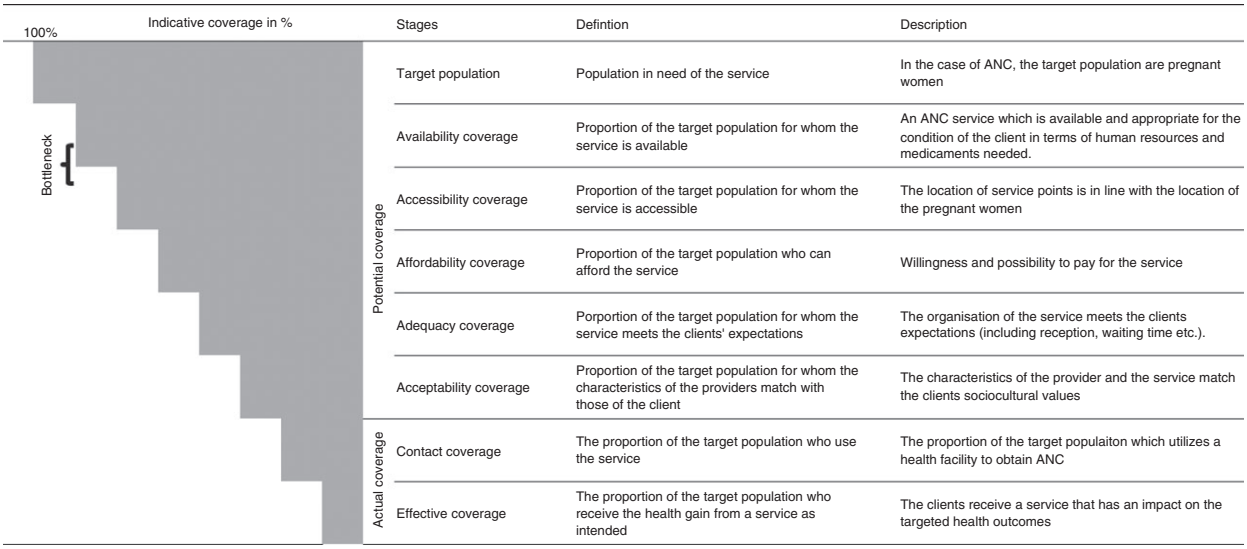
Tanahashi [10] proposes a concept for measuring health service coverage and evaluating gaps in health service delivery. Adapted versions of this framework are widely used in research and evidence-based planning [11] and also to address bottlenecks in maternal health interventions [12, 13]. However, at the district and subdistrict level in low-income countries, there remains a considerable lack of understanding on barriers to affordable health service delivery [14]. Little is known about specific requirements of socio-economically disadvantaged and vulnerable groups [15], including mobile pastoralists in sub-Saharan Africa due to limited data availability and absence of demographic surveillance for these communities [16]. Modern maternal health policies must ensure that the needs of disadvantaged and marginalised populations are included as benefits of the interventions to reduce the disproportionate burden of poor maternal health, in Chad and elsewhere, and close the gaps between population groups [17].

This study assesses maternal health service coverage and analyses constraining factors for health service delivery using the example of ANC in settled and mobile pastoralist communities in rural Chad. Data from cross-sectional household and health facility surveys in two Chadian rural health districts (Yao and Danamadji) were analysed. The main purpose of this research is to gain knowledge on the bottlenecks responsible for gaps in maternal health service delivery. Stratifying the analysis for population subgroups provides necessary information to develop population-specific measures for service provision in rural areas and allow equitable access to essential health care.

Methods

Operational definitions

The operational definitions used to evaluate ANC coverage and bottlenecks in this study build on the Tanahashi framework [10]. These coverage measures reflect service provision across conditional stages: potential coverage in terms of availability, accessibility and acceptability of the service, and actual coverage, comprised of contact and effective coverage. Contact coverage describes the proportion of the target population in contact with the services, and the final effective coverage reflects the proportion of target populations that receive the health gains from the intervention. To study ANC coverage in rural Chad, the Tanahashi framework was adapted to match health service provision in resource-poor settings based on an analytical approach developed for sub-Saharan African countries [18]. Potential coverage was extended to include affordability, adequacy and acceptability as additional stages in the coverage cascade. The process of actually obtaining the health service must, therefore, meet the following requirements: first, it must be available. Subsequently, the service can only be used if it is accessible and affordable for the population. The organisation of the service must further meet client expectations (adequacy) and the characteristics of providers must match with those of clients, including the social and cultural values (acceptability). This extended framework was validated in the Sahel region by applying it to assess the coverage of a rabies dog mass vaccination in Mali [11, 19]. In the current analysis, contact coverage estimated by the proportion of the target population (pregnant women) who utilised ANC at least one time at a health facility during the last pregnancy was used as main outcome to assess the actual coverage. Bottlenecks were defined by the decrease in coverage between one stage and the next. Figure 1 shows a stylised visualisation and description of the coverage framework depicting an exemplary bottleneck between availability and accessibility coverage.



Stages	Defintion	Description
Target population	Population in need of the service	In the case of ANC, the target population are pregnant women
Availability coverage	Proportion of the target population for whom the service is available	An ANC service which is available and appropriate for the condition of the client in terms of human resources and medicaments needed.
Accessibility coverage	Proportion of the target population for whom the service is accessible	The location of service points is in line with the location of the pregnant women
Affordability coverage	Proportion of the target population who can afford the service	Willingness and possibility to pay for the service
Adequacy coverage	Porportion of the target population for whom the service meets the clients' expectations	The organisation of the service meets the clients expectations (including reception, waiting time etc.).
Acceptability coverage	Proportion of the target population for whom the characteristics of the providers match with those of the client	The characteristics of the provider and the service match the clients sociocultural values
Contact coverage	The proportion of the target population who use the service	The proportion of the target populaiton which utilizes a health facility to obtain ANC
Effective coverage	The proportion of the target population who receive the health gain from a service as intended	The clients receive a service that has an impact on the targeted health outcomes

Figure 1 Coverage measures and bottlenecks in the provision of antenatal care (ANC) services.

Study area and survey design

The study was conducted in the Yao (Batha region) and Danamadji (Moyen-Chari region) health districts. The first district is located in central Chad and the latter in southern Chad along the border with the Central African Republic. Together, the two districts cover 31 functional health zones, defined as geographical areas of responsibility of a health facility, which provide health services for approximately 270 000 inhabitants [20]. Each district has one district hospital acting as secondary referral centre. All other health facilities are primary health centres. Both districts are seasonally populated by a substantial number of mobile pastoralist communities (mainly camel and cattle breeders of the Arab and Fulani pastoralist ethnic groups), with transhumance routes and areas of concentration. Transhumance refers to the seasonal movement of pastoralist communities and their livestock which occurs typically during the rainy season. Major transhumance routes are flexible according to availability of pasture for the livestock, but generally are between zones of concentration. Concentration zones are the spaces – that are rather stable but also move over years – where mobile pastoralists stay closer together, which is during the dry season near water points. During these stays in the concentration zones, mobile communities are much more stable and clustered in smaller and larger camps composed of several families.

Data were collected as part of the Projet d'Appui aux Districts Sanitaires du Tchad, phase 1 (PADS) project, a collaborative health system intervention for improving maternal and new-born health in rural Chad between November 2014 and October 2018. Household and health facility baseline surveys were conducted in 2015 to monitor the effect and steer the PADS interventions. The two selected districts constitute the intervention area of this health implementation project.

The health facility survey was conducted in January 2015 in all 29 primary health centres of both districts to obtain information on the availability and quality of maternal health services.

The household survey was conducted in April and May 2015. Households with an adult mother of a child younger than 5 years were included. In total, 786 mothers from rural settled communities and 358 mothers from mobile pastoralist communities were randomly sampled. A stratified two-stage cluster sampling methodology was applied to achieve a representative sample of the two population groups in the study area. For rural settled populations, a two-stage cluster sampling methodology with probability of selection proportional to population was used. In the first stage, 47 villages were randomly selected using the official village list as a sampling frame. In the second stage, interviewers selected households after arrival at the centre of the cluster by spinning a pen to randomly determine the initial direction. The team then visited every second household along that trajectory and chose a predetermined number of households. Within each household, playing cards were used for random selection of study participants. For mobile pastoralist communities, a two-stage cluster sampling methodology

with a similar probability of selection was used. In the first stage, 120 nomadic camps were randomly selected from the sampling frame, developed beforehand through a participatory mapping approach involving local veterinary and health staff. In the second stage, interviewers randomly selected three households in each camp and the participating mothers using playing cards.

Survey design and sample size calculation were guided by a focus on collecting the minimal essential data required to obtain a given precision of ANC utilisation rates for each population group. The proportion of pregnant women that visited a health facility to obtain ANC at least three times (ANC 3) was used as a primary endpoint, assuming average prevalence of 25% as noted in the last Multi Indicator Cluster Survey in Chad. Calculation of the sample size was done using the formulas of Bennett *et al.* [21] to obtain an estimate of the standard error of +/−0.025. The intra-class correlation coefficient was taken as 0.1. The number of selected clusters was similarly distributed across the two districts as population size for rural settled communities was in the same range according to the last national census [20]. Based on the presence of a similar number of camps in the two study districts, the population size of mobile pastoralists was also assumed to be approximately equal.

A structured questionnaire was developed covering utilisation of maternal and infant health services and socio-demographic characteristics. The basic structure of this questionnaire was adapted from the Demographic and Health Survey (DHS) tools and a household questionnaires previously used in a mobile pastoralist context in Chad [22].

An electronic data collection system was established based on Open Data Kit (ODK). Data analysis was conducted in R statistical software.

Estimating contact coverage

The proportion of the target population (pregnant women) utilising a health facility to obtain ANC was used as main outcome to assess ANC contact coverage. Utilisation rates were estimated through reported service utilisation from the household survey. A generalised linear model with a binomial link function was used to account for the cluster structure of the sample integrating villages and camps as a random effect in the model specification. ANC 1, ANC 3 and ANC 4 utilisation rates as well as the proportion of mothers that delivered at home were estimated.

Multivariate regressions were applied to explore socio-economic factors that best predict these outcomes. To group respondents by socio-economic status, an asset index was created applying principal component analysis to participant responses on possession of assets [23]. This data reduction technique produces linear combinations of the variables (components) with the first component typically explaining a high proportion of the variation. Based on the asset index, households were then assigned to three socio-economic categories (the bottom 40%, the middle 40%, and the top 20%). Individual assets were reviewed by local health staff and validated through repeated pre-tests. Different assets were proposed for rural settled populations and mobile pastoralists to account for different life styles between the two subgroups.

Assessment of bottlenecks

Bottlenecks in ANC service provision were assessed using a multiplicative specification of the coverage factors. At least one ANC (ANC 1) was used as a main coverage measure. The model allowed quantification of the magnitude by which coverage decreased as it progressed through the health system. In algebraic terms, the contact coverage of ANC services is described as a product of the factors $\beta_{(i)}$ that relate to the five dimensions ($n = 5$) of potential coverage (availability, accessibility, affordability, adequacy and acceptability). Assuming the coverage factors to be independent, contact coverage can then be specified as a multiplicative term:

$$\text{Contact coverage} = \prod_{i=1}^{n} \beta_{(i)}.$$

Values for the coverage factors $\beta_{(i)}$ were primarily derived from the household survey. Survey participants who did not attend ANC were asked the reason. Questions were administered as open questions, and the interviewer assigned respondent answers to a pre-defined category (see Table 1). The process of correctly assigning open responses to answer categories was practiced during training of data collectors. The answer categories, in turn, were matched to the five coverage factors to derive proportions of respondents pertaining to a specific category. Suitability of the answer categories and assignment to the coverage factors were reviewed by local health experts and validated through repeated pre-tests in the study region. The answer categories and assignment to the coverage factors are presented in Table 1. The availability parameter was approximated, based on the health facility survey, through the average availability of folic acid (FeFo) for anaemia prophylaxis, as it is typically provided to women attending ANC.

For the multiplicative model to be accurate, individual factors are assumed to be mutually exclusive and

Table 1 Assessment of coverage factors

Coverage factor	Measure	Answer category in the household questionnaire
Availability coverage	Health facility survey: Availability of folic acid (FeFo) for anaemia prophylaxis, provided to women attending antenatal care (ANC)	NA
Accessibility coverage	Household survey: proportion of interviewees who consider the location of the service point as reason for not attending ANC	Hospital or health centre is distant
Affordability coverage	Household survey: proportion of interviewees who consider direct and indirect costs of the service as reason for not attending ANC	I do not have enough money to pay for health care I didn't have time to reach the facility
Adequacy coverage	Household survey: proportion of interviewees who consider the long waiting time and reception at the service point as reason for not attending ANC	Bad reception (health staff is unpleasant) Waiting time is too long
Acceptability coverage	Household survey: proportion of interviewees who report that visiting ANC is not their habit, that they are not sufficiently informed and that they don't have the husbands permission	It is not our custom It was advised to me Lack of information

uncorrelated. As factors, $\beta_{(i)}$, were principally calculated based on proportions of reported reasons for not attending ANC, the denominator for calculating these proportions was adjusted using the term $(N_{\text{tot}} - \sum_{j=1}^{i-1} N_j)$ for $i = 2, \ldots, n$. N_{tot} denotes the total number of participants (mothers with child) and N_j the number of responses with reason related to an antecedent coverage factors. Each reason was converted into coverage factors by calculating 1 minus the proportion. Robustness of the assumption related to the independence of the factor was evaluated by examining the distribution of multiple answers given by participants. Probabilistic sensitivity analysis was applied to address parameter uncertainty around the five coverage factors and to assess how the final model outcome and the according difference between population subgroups is affected. More specifically, normal distributions were constructed for the number of participant responses with the estimates of the survey being the most likely value (mean), and the standard deviation being 5% of the actual responses. Latin hypercube sampling was applied to allow for uncertainty around the estimated coverage factors. Contributions of variations in each single factor to the final model outcome were investigated by examining partial correlations between these factors and the contact coverage.

Ethical approval

Ethical approval was given by the Ministry of Health, Chad. Participation was voluntary. All data were treated confidentially. Informed consent by all study participants was obtained and signed (or a fingerprint in the case of illiterate individuals). All interviews, discussions and questionnaires were conducted in participants' local languages (specifically Chadian Arabic in Yao health district and Sara in addition to Chadian Arabic in the Danamadji district).

Results

Socio-demographic characteristics of study participants

In total, 1144 interviews with mothers were conducted. The survey covered 786 mothers from rural settled and 358 mothers from mobile pastoralist communities. Socio-demographic characteristics of study participants are presented in Table 2. Mothers of both settled and mobile pastoralist communities were mainly in the age class of 21 and 30 years. The proportion of mothers below 21 years was higher in mobile pastoralist communities (30%) than in settled communities (19%). The mean educational level was considerably higher among rural settled mothers, with 41% of settled mothers having completed at least primary school as compared to 9% of mothers from mobile pastoralist communities.

ANC contact coverage

Table 3 shows the direct estimates for ANC contact coverage as well as the rate of home delivery stratified for rural settled and mobile populations. ANC was differentiated according to the number of visits: at least one visit (ANC), at least three visits (ANC3) and at least four visits (ANC4). Contact coverage was systematically higher for rural settled populations. The proportions for ANC decreased with the number of required visits, ranging

Table 2 Socio-demographic characteristics of study participants

Rural settled populations		Mobile pastoralists	
Sample size	Frequency (% of full sample)	Sample size	Frequency (% of full sample)
	786 (69)		358 (31)
Age groups in years	Frequency (% of subsample)	Age groups in years	Frequency (% of subsample)
16–20	147 (19)	16–20	105 (30)
21–30	375 (48)	21–30	161 (45)
31–40	219 (28)	31–40	84 (23)
40+	45 (6)	40+	8 (2)
Education level	Frequency (% of subsample)	Education level	Frequency (% of subsample)
Primary school	324 (41)	Primary school	34 (9)
Secondary school	129 (16)	Secondary school	4 (1)
Higher education	9 (1)	Higher education	0 (0)
Main ethnic groups	Frequency (% of subsample in one study district)	Main ethnic groups	Frequency (% of subsample in one study district)
Main group Yao: *Boulala*	378 (85)	Main group Yao: *Arab*	137 (68)
Main group Danamadji: *Sara*	385 (86)	Main group Danamadji: *Arab*	167 (87)

from 79% to 29%. For mobile pastoralists, only 46% of pregnant women attended ANC at least one time, 20% at least three times and 9% at least four times. 87% of the rural settled and 92% of the pastoralist mothers delivered their last child at home.

Antenatal care visits and homebirths were significantly associated with a higher socio-economic status of the household and with being in the district of Danamadji (Table 4). Although utilisation rates of health services were systematically lower for mobile pastoralists, shown in Table 3, associations in the regression model are not significant.

Assessment of bottlenecks

Coverage factors were principally derived from the study participant reported reasons for non-participation allowing for multiple answers. Thus, individual factors are not *a priori* mutually exclusive and can therefore not be assumed to be uncorrelated. The distribution of the reported answers reveals, however, that the majority of participant answers could be matched to a single factor, which generally supports the independence assumption and, thus, the application of the multiplicative model. In particular, 59% of answers from an individual participant were assigned to a single factor for rural settled populations and 72% for mobile pastoralists.

Figures 2 and 3 depict the multiplicative relation as specified by the coverage model differentiating between the single factors ($\beta_{(i)}$) and its cumulative effect.

In both population groups, the availability factor had the same effect as it was calculated based on the availability of folic acid in the health facilities (contributing up to 82% to contact coverage). A substantial number of respondents from both communities considered long distances as a reason for not attending ANC. Translated into a coverage factor, accessibility contributed almost equally to the ANC contact coverage in both populations (82% for rural settled populations and 80% for mobile pastoralists).

As shown in the regression analysis results (Table 4), health service utilisation was closely associated with the socio-economic status of the population. In the coverage model, willingness and ability to pay for health service together with time spent as an indirect cost were expressed as an affordability factor that reduces the service's coverage. The result indicates that affordability contributed equally to reduction in coverage, 86% for both populations.

The way that health services are organised in terms of reception, hospitalisation and care provision (adequacy) is

Table 3 Utilisation of maternal health services

	Any visit to antenatal care (ANC) (95% CI)	At least three ANC visits (95% CI)	At least four ANC visits (95% CI)	Homebirth (95% CI)
Rural settled population (n = 786)	79% (71–85)	63% (55–71)	29% (23–36)	87% (77–93)
Mobile pastoralists (n = 358)	46% (40–53)	20% (12–32)	9% (3–23)	92% (81–97)

Table 4 Association between the utilisation of maternal health services, and socio-demographic and geographical variables

	ANC1		Homebirth	
	OR (95% CI)	P value	OR (95% CI)	P value
Belonging to the intermediate socio-economic category	1.48 (0.66–3.34)	0.34	0.66 (0.30–1.47)	0.31
Belonging to the rich socio-economic category	2.86 (1.01–8.05)	0.04	0.29 (0.10–0.86)	0.02
Living in the Danamadji district	7.01 (3.34–14.70)	<0.01	0.11 (0.03–0.49)	<0.01
Belonging to the sedentary population	1.03 (0.28–3.82)	0.97	0.93 (0.14–6.18)	0.94
Secondary school completed	1.54 (0.59–4.02)	0.38	0.28 (0.11–0.76)	0.01

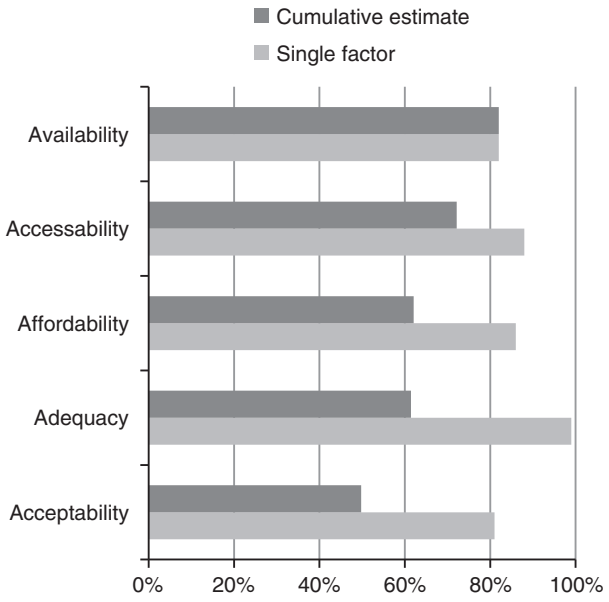


Figure 2 Contribution of parameters determining the contact coverage of antenatal care services among rural settled populations.

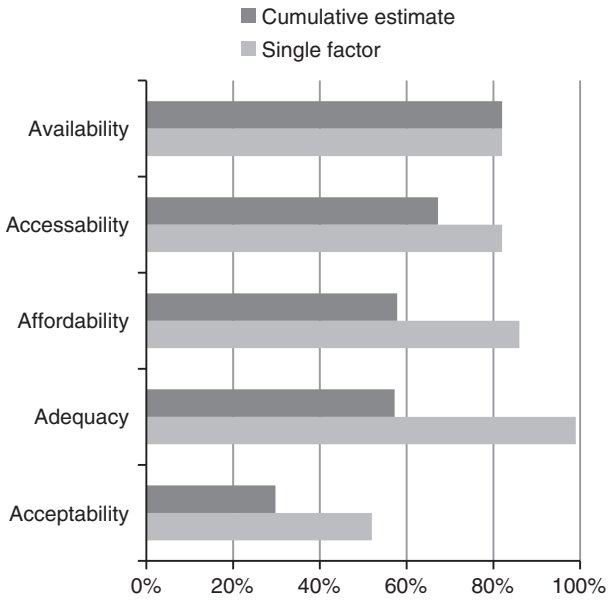


Figure 3 Contribution of parameters determining the contact coverage of antenatal care services among mobile pastoralists.

expected to contribute to the coverage of a given health service. When these elements meet client expectations, then the service's coverage is not expected to be considerably reduced. In fact, adequacy represents the parameter with the highest value among all factors for both populations (it contributed up to 99% to contact coverage).

The acceptability parameter revealed the lowest value compared to the remaining factors and was particularly low for mobile pastoralists (81% among rural settled and only 52% among mobile pastoralists) contributing considerably to the reduction of contact coverage. Acceptability implies that participants have enough and appropriate

information about ANC services and that the service corresponds with their socio-cultural values. In fact, 'not in our habits', 'not having husband's permission' or 'lack of information' were often reported by participants as reasons for not attending ANC. For mobile pastoralists, acceptability clearly stood out as a major reported reason among participants who did not attend ANC.

According to the multiplicative model, ANC 1 contact coverage is 50% for rural settled populations and 30% for mobile populations and is lower than the direct estimates presented above.

Sensitivity analysis

Probabilistic sensitivity analysis showed that results are robust to inclusion of uncertainty. Looking at the empirical density functions in Figure 4, it can be noted that the contact coverage was with high probability between 0.47 and 0.51 for rural settled and between 0.25 and 0.33 for mobile populations. The according functions did not overlap, suggesting that the difference in contact coverage of ANC services between rural settled and mobile populations persisted also when accounting for parameters uncertainty.

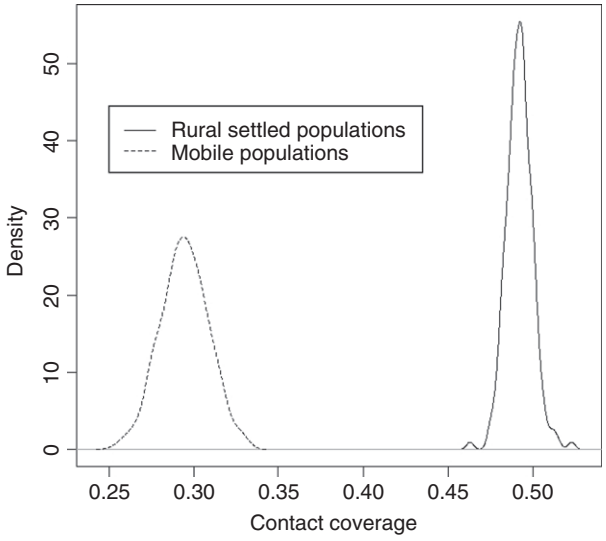


Figure 4 Empirical density function of the model result (contact coverage).

The partial correlations presented in Figure 5 measured how strong the linear associations were between the contact coverage and each coverage factor, after removing the effect of the other factors. For both populations, adequacy was weakly related to the final outcome. On the other hand, contact coverage was considerably sensitive to availability, affordability and acceptability. For nomadic populations, acceptability was the most sensitive factor, whereas availability, affordability and acceptability appeared to be equally important for rural settled populations.

Discussion

Our study found that the coverage of ANC services in rural Chad is low. The rate of respondents who attended at least one ANC visit among settled populations was 79%, while that among mobile pastoralists was only 46%. According to the national DHS survey conducted in 2014, 59% of rural mothers between 15 and 49 years in Chad attended at least one ANC during pregnancy, which lies between the utilisation rate estimated for rural settled and mobile populations in the present study. Consistent with our findings, the national estimates for rural areas decreased with the number of required visits: 54% attended ANC at least three times and 26% at least four times (the national health system policy in Chad requires a minimum of four antenatal visits). These figures are well above the estimated utilisation rate of mobile

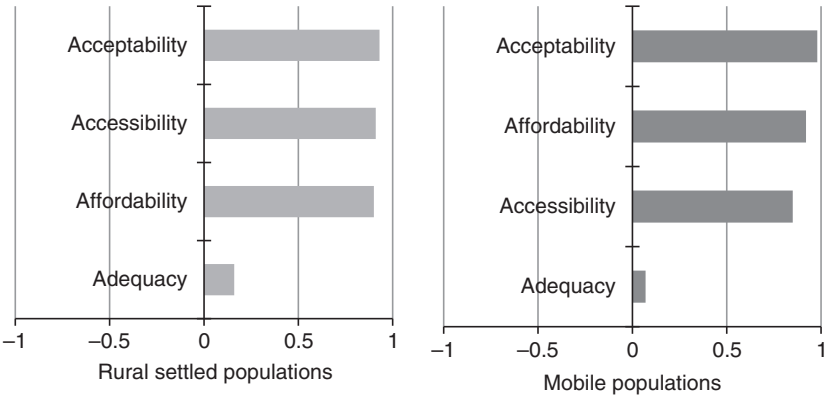


Figure 5 Partial correlation coefficients between the model outcome (antenatal care contact coverage) and each coverage factor.

pastoralists in the study districts (20% attended ANC at least three times and 9% at least four times) and are roughly covered by the 95% confidence interval of the according utilisation rates for rural settled populations (63% attended ANC at least three times and 29% at least four times). Both communities in the two study districts had high rates of home birth attendance (87% of rural settled and 92% of mobile populations), meaning only very few mothers benefitted from skilled assisted delivery at a health facility. This corresponds with the latest DHS estimates that indicate that in rural Chad, 85.3% of the mothers gave birth at home. In general, compared to rural settled populations, mobile pastoralists in the study districts revealed larger deviations from national (rural) averages of ANC utilisation and facility-based delivery which were systematically below these estimates. This confirms the inherent inequality of maternal health service contact.

Antenatal care contact coverage was significantly associated with high socio-economic status of respondents and geographical factors. This was expected as maternal health service utilisation is known to be associated with the socio-economic situation of women. For example, analysis of data issued from health and demographic surveys conducted in 31 countries revealed that for the poorest women (those in the poorest wealth quintile) the odds of having a skilled attendant at delivery are 94% lower than those in the highest wealth quintile [24]. Similar patterns linking maternal health utilisation and more generally health service utilisation with high socio-economic status were documented in low-income countries aiming at addressing the inequity in health service delivery between and within countries [25–27]. With regard to the geographical factor, in line with our findings, the latest DHS survey confirms a large difference in ANC attendance between the two regions where the study districts are situated: only 26% of the mothers have attended at least one ANC in Batha region (Yao district) as compared to 81% of the mothers in Moyen Chari region (Danamadji district). The latter district is generally known to be better equipped in terms of infrastructure including health services, which might be an explanation of the low utilisation rate in Yao. A recent study indicates that the quality of services is found to be higher in the Danamadji health district than in Yao in terms of structural attributes [28].

To explore bottlenecks in provision of ANC services and enable the population-specific design and optimisation of interventions, a multiplicative model of ANC contact coverage was calibrated to household and health facility data. The model gave an ANC contact coverage of 50% for rural settled population and 30% for mobile pastoralists, which mirrors the differences in the directly estimated contact coverage (utilisation rates) between the two populations groups. The model outcome corresponds roughly with the percentage of mothers attending ANC at least three times.

Five coverage factors were used to quantify the bottlenecks in ANC service provision: availability, affordability, accessibility, adequacy and acceptability. Although availability was calculated primarily based on folic acid availability at health facilities, other factors should be considered such as the availability of qualified health personnel for ANC. Results from a qualitative study on access to maternal health services conducted in the same study region showed that mothers mentioned concerns with the availability of qualified personnel in health centres mirroring the fact that maternal health services are usually provided by matrons. Furthermore, quality of care as well as the availability of medications and prescriptions were considered as barriers to access maternal health services [29].

Accessibility contributed equally to contact coverage among both study populations, by up to 82%, which is relatively high. Consideration should be given regarding travel distances to health centres, which are often mentioned as reasons for not attending ANC at health facilities especially in rural areas of developing countries. Poor road conditions, especially during the wet season, and long distances between health facilities and households (both in villages and camps), pose transportation challenges for pregnant women [30–33]. This corresponds to the results of the qualitative study, where rural settled and nomadic mothers raised concerns about the distance to health facilities [29].

Affordability contributed to contact coverage with 86% for both rural settled and nomadic populations which is comparable to the accessibility dimensions. Issues with ability to pay for ANC services are typically related to transport, waiting time and sometimes bribes in exchange for better services. Mothers from settled populations generally showed more concern about the costs related to ANC attendance and assisted delivery at a health facility [29]. This could be partially explained by the fact that mobile pastoralists have more possibilities to cover costs related to health services through relying on sale of livestock while the majority of rural settled populations depend only on agricultural activities.

Although adequacy clearly represented the least important coverage factor, findings from the qualitative study revealed that poor reception, such as health personnel being unpleasant, and long waiting time were considered as reasons for not attending ANC for both settled and mobile populations [29]. Nonetheless, only very few respondents in both communities did not attend ANC due to a lack of adequacy.

Acceptability was the key factor providing the main contribution to the model outcome, reducing ANC contact coverage by 81% for rural settled populations and 52% for mobile pastoralists. It was also the coverage factor revealing the largest difference between the two population groups, which suggests a large potential to improve equality of maternal health outcomes. The specific reasons of low acceptability of ANC services are likely to be inadequate information and cultural issues. The cultural distance between the provision of maternal health services and the target communities seemed particularly large for mobile populations. For example, it was found that rural women rely on the husband's approval for visiting a health facility which was particularly challenging in nomadic communities where men are frequently absent due to mobile pastoralism [29]. Furthermore, appropriate information on ANC services and the importance for pregnant women and child health was lacking. Confusion about ANC services and not being aware of the importance of delivery in a health facility was among the reasons preventing child and maternal health service utilisation for mothers from rural settled and mobile populations. Women from mobile pastoralist communities appeared to be particularly ill-informed which led to a biased perception on ANC, where they considered the services only necessary in case of severe illness [29]. In line with these findings, results from a recent study on vaccine hesitancy among mobile pastoralist communities conducted in one of the two concerned health districts (Danamadji) revealed that the lack of appropriate information and cultural issues were respectively cited as the main factors preventing mobile pastoralists from accessing vaccination services [34]. These reasons were all captured under the acceptability factor in the present study. Furthermore, rural populations typically prefer to utilise alternative health services such as traditional birth attendants, traditional healers and 'marabout' services, only travelling to health facilities for complicated cases [35, 36], which is also confirmed by the results of the qualitative study [29].

To foster more equal coverage between rural settled and mobile populations in Chad, these results suggest that particular attention must be paid to acceptability of ANC and general maternal health services among mobile pastoralist communities. Adapted information campaigns for illiterate men and women which target specific cultural barriers of mobile pastoralist as well as rural settled populations are required to increase acceptability in these communities. Furthermore, next to improving the quality of care, appropriate health financing schemes for poor households need to be considered. A participatory process bringing together all relevant stakeholders and community representatives would contribute to increase acceptability and also help prioritise actions towards greater ANC service contact. Encouraging and accompanying the current community health worker strategy of the Chadian Ministry of Health would be an appropriate option to increase coverage and reduce inequalities.

This study was limited by challenges in observing health outcomes of ANC services, so the actual ANC coverage was measured through contact coverage which only covers the proportion of persons in need of a service who receive an appropriate intervention. This measure did not capture the probability that this population receives the health gain. As a consequence, the analysis focused more on the demand-side limitations of the service provision excluding potential bottlenecks arising from insufficient quality of the service that prevent it from having an impact on the target population. Furthermore, the different coverage factors were derived based on participant reported reasons for not attending ANC. This process was based on a deductive approach: participant open answers were mapped to pre-defined answer categories which were then assigned to the five coverage factors. As this process allowed for possible misclassifications, sensitivity analysis was applied to address uncertainty around these answers and to validate and quantify the impact on the model outcome. In addition, the multiplicative model assumed independence between the single factors. As coverage factors were derived based on potential multiple answers from study participants, potential correlations between the single factors could not be excluded, which might explain that ANC 1 coverage from the multiplicative model is lower than the direct estimate. To address this concern, the distribution of multiple answers was carefully examined, revealing that most answers from individual participants could be matched to a single coverage factor. Differences in coverage factors between the two populations may also be driven by socio-demographic differences between the two groups. In fact, mobile pastoralist mothers appeared to be younger and less educated on average. Sensitivity analysis showed, however, that the difference in contact coverage between the two population groups was robust to the inclusion of uncertainty in participant responses. Last, the choice of different data sources for calibrating the coverage factors (household and health facility survey) was subject to different sources of bias and level of quality which might have affected the final results.

Conclusions

Contact coverage of ANC services was low in rural Chad, particularly for mobile pastoralists. Acceptability of ANC services was the most sensitive factor for

increasing coverage, especially among mobile pastoralists. Interventions focused on overcoming bottlenecks by targeting the factors with the highest population-specific leverage will foster effective and equitable health services and increase coverage.

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