Gates Vaccine Beliefs and Experience Manuscript

Introduction

Caregiver perceptions and beliefs about vaccination are well documented in the literature and have been associated with immunization uptake and timeliness in Uganda.[1,2] In particular, perceptions of vaccine safety, trust in health systems, and prior experiences with immunization services can shape vaccine-seeking behavior with misinformation and fears of side-effects and pain during injection discouraging vaccination.[2–4] Caregivers in rural south-west Uganda expressed concerns about vaccine safety driven by known and anticipated adverse effects and beliefs that vaccines are profit-driven and indicated a general distrust for non-traditional healthcare.[2,4]

Nonetheless, over the past two decades, Uganda has made considerable progress in expanding immunization access and uptake.[5] National reports indicate high coverage rates between 86% and 96% for key childhood vaccines including tuberculosis (BCG), three doses of diphtheria, tetanus, and pertussis, as well as measles, hepatitis B, polio, Haemophilus influenzae type b, and rotavirus.[6] These vaccination rates exceed the 2022 regional average for sub-Saharan Africa of 72% for tetanus and 69% for measles vaccinations, reflecting significant policy and health system progress.[7]

However, subnational heterogeneity in coverage persists. Recent analyses show vaccination rates vary widely by region, household wealth, maternal education, and urban-rural location, with some areas reporting full immunization coverage as low as 17% and others above 70%.[8–10] In particular, challenges have been noted in rural areas with high dropout rates for follow-up doses of vaccines such as pneumococcal and rotavirus have been especially high, with completion rates as low as 8% in some areas in 2019.[9]

While prior studies have documented vaccine hesitancy and negative caregiver perceptions in specific contexts, including rural south-west Uganda, less is known about how these factors operate in the current landscape of higher overall national vaccine coverage. As vaccination coverage increases across the county, the distribution and characteristics of households where children remain under-vaccinated may change, including the extent caregiver beliefs and experiences with vaccination may be contributing factors.[11,12] In particular, under-vaccination may become less associated with structural barriers and more influenced by caregiver beliefs, trust in the health system, and perceptions of disease risk.[13,14]

In settings approaching high national coverage, non-vaccination may increasingly stem from demand-side factors such as distrust, misinformation, and shifting perceptions of disease risk, rather than logistical access barriers.[15] Understanding these evolving dynamics is essential to designing targeted interventions for the last mile of immunization coverage. This study aimed to explore the potential association between caregiver beliefs and experiences and the receipt of recommended childhood immunizations.

Methods

Study Area

This study was conducted in Bugoye sub-county, in Kasese District in rural western Uganda located on the border with the Democratic Republic of Congo (**Figure 1**). Bugoye sub-county is comprised of five parishes including Ibanda, Kibirizi, Bugoye, Muhambo, and Katooke. There were an estimated 6,872 households in Bugoye sub-county, of which an estimated 15–25% of had an eligible child.[16]

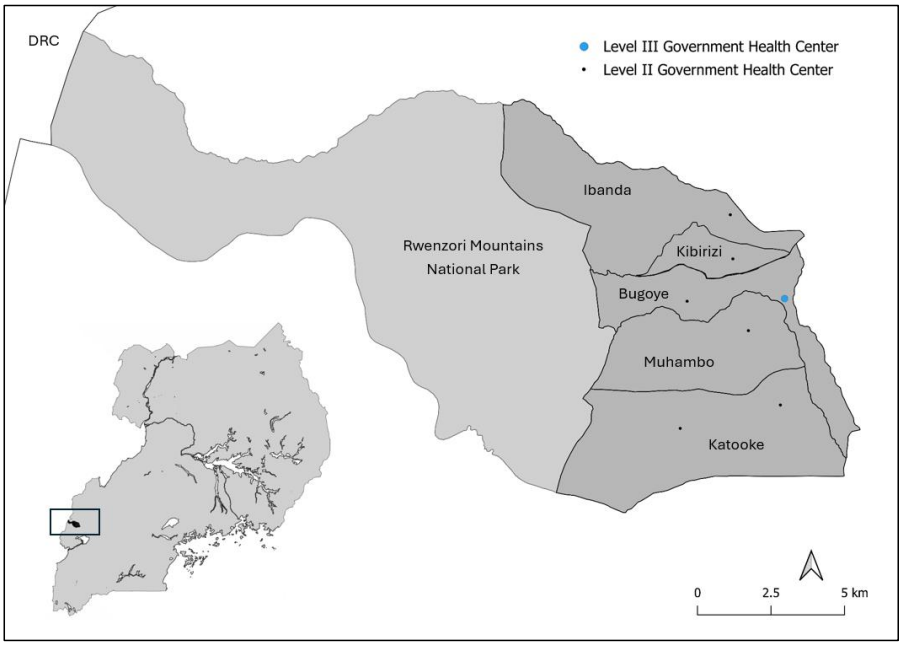

Figure 1. *Map of study area*. This map shows the location of parishes that compose Bugoye sub-county as indicated by the darker grey areas in the main map. The lighter grey area is the Rwenzori Mountains National Park. Smaller black points indicate the location of level II government health facilities, and the blue point denotes the location of the level III government health facility in Bugoye Parish. The smaller map of Uganda indicates the location of Bugoye sub-county within the black box. In the top left corner, the section labeled DRC shows the international boarder between the Democratic Republic of Congo and Uganda. The rest of the white space shows areas of Uganda outside Bugoye sub-county.
This map was created using QGIS with Ugandan administrative shapefiles from the Humanitarian Data Exchange

Each parish includes a level II government health facility while Bugoye parish additionally includes a level III government health facility. In the Ugandan health system, both level II and III government health facilities are able to administer all childhood vaccines. The area sits in the foothills of the Rwenzori Mountains and is marked by steep mountain sides and large changes in elevation ranging from 1,200 to 2,000 meters which can lead to variation in access to health care across communities.

Study Design and Data Collection

This is a cross-sectional study representing a census where all children aged 12 to 23 months living in Bugoye sub-county were eligible to participate. All households across all five parishes were visited and one-time interviewer administered surveys were conducted in household with at least one eligible child who consented to participation. If no one was home at the time of visit, three more attempts were made prior to excluding the household. Surveys included questions on caregiver and child demographics, attitudes and beliefs about vaccines, prior experiences with vaccines and vaccination, prior hospitalization of the child and related data, and vaccination status.

Vaccine status was discerned by visual inspection of vaccine cards. These cards are distributed at local health facilities when children present for their first vaccination and should be a record of all vaccines a child receives. In the event the children did not have their vaccine card, we asked the parent to self-report receipt of each vaccine. All other data was self-reported by an adult living in the house, most commonly the head of the household or main caregiver. More detailed information about data collection is described in Boyce et al. 2019 as part of phase 3.[16]

Exposure

Two main exposures of this analysis were aggregated scores for caregiver beliefs and attitudes about vaccines and previous experience or knowledge about vaccines. Belief and experience scores included components outlines in **Table 1**. All component questions were coded to have the same valence, and aggregate scores were then calculated as the sum of the component questions answered indicating presence of the belief or experience. Secondary outcomes included each component of the aggregate belief and experience scores assessed independently.

Table 1. *Vaccination Beliefs and Experience Component Questions*

Category	Component questions
Beliefs/Attitudes	Children get more vaccinations than are good for them (B1)
	Healthy children do not need immunizations (B2)
	Vaccination does more good than harm (B3)
	It is better for a child to develop immunity by getting sick than to get a vaccination (B4)
	Parents should be allowed to selectively choose the vaccines which they believe her child needs (B5)
	It is better for a child to receive two injectable vaccinations in 1 visit rather than 1 injectable vaccination in 2 visits (B6)
	Many of the illness which vaccinations prevent are severe (B7)
	When a parent refuses to vaccinate a child, it harms the entire community through risk of disease (B8)
	People in this community have expressed concerns that a child might have a serious side effect from a vaccination (B9)
	Following the nationally recommended vaccination schedule is a good idea for a child (B10)
Experiences	If the national immunization policy states that 2 injectable vaccines should be given in the same arm/leg, would you allow it? (E1)
	I believe vaccines are safe (E2)
	I believe vaccines protect my child from vaccine preventable disease (E3)
	Have you personally seen someone with either polio, pneumonia, measles or whooping cough? (E4)
	Do you know of someone in your family or community who had either polio, pneumonia, measles or whooping cough? (E5)

	Have you ever delayed having your child get a vaccination for reasons other than illness or allergy? (E6)
	Have you ever decided not to have your child get a vaccination for reasons other than illness or allergy? (E7)
	If you had another infant today, would you want your infant to get all recommended vaccinations? (E8)
	Do you know the location where you can have your child vaccinated? (E9)
	Do you know the days and times when vaccination services are offered in your community? (E10)
	Is access to immunization easy? (E11)
	If you have to spend more than one hour getting a vaccine, are you willing to take the time you think it is an important vaccine? (E12)
	Are you able to discuss any concerns you have about vaccinations with your child's healthcare provider? (E13)
	Do you trust the information that you receive from your local healthcare worker about vaccinations? (E14)

This table includes survey questions used to assess beliefs and attitudes and experiences with vaccination. These questions serve as the components for each aggregated score. Belief and attitude questions were measured using disagree/agree/not sure response options. Experience questions were measured using yes/no/not sure response options.

Outcome

The main outcome of this analysis is the vaccination status of the child. A fully vaccinated child was defined as those children who received all eight recommended childhood vaccines including the tuberculosis, polio, two doses for rotavirus, measles vaccines and 3 doses of the combination vaccine for diphtheria, tetanus, pertussis, hepatitis B, and Haemophilus influenzae type b. Children considered not fully vaccinated are those missing at least one of the included vaccinations. Vaccination status for measles alone was the secondary outcome. Both outcomes were coded as binary variables.

Analysis

This study is a secondary analysis of data collected to assess areas of low vaccination to develop methods to target underserved populations. We began with an exploratory analysis, generating summary statistics for key variables, including the primary outcome of full vaccination status, and secondary outcomes such as vaccination card availability and, if unavailable, self-reported vaccination status. Main predictors—continuous or ordinal scores for positive beliefs and vaccination experience—were summarized alongside potential confounders, including caregiver characteristics, child anthropometric measures, vaccination location, and childbirth-related variables. The confounding variables were identified using prior knowledge, and the associations between each possible confounding variable and outcome or aggregated scores were tested using Fisher's Exact tests, Chi-square tests, Wilcoxon rank-sum tests, Kendall's tau tests, and Kruskal-Wallis tests. We also used these statistical tests to examine factors associated with vaccination card availability. All statistical tests were performed at a two-sided significance level of 0.05.

In our aggregated score, the more vaccine-positive response was assigned a score of 1, the less vaccine-positive response was assigned a score of 0, and responses which expressed uncertainty were assigned a score of 0.5. A weighted logistic regression was fitted for a primary outcome, fully vaccinated status, to obtain adjusted odds ratios and 95% confidence intervals. A weighted random forest was then implemented to compare performance against the weighted logistic regression after splitting the dataset into a train set (80%) and test set (20%). The evaluation metrics included receiver operating characteristic (ROC) curve, area under the curve (AUC), and Kappa. Although the weighted random forest outperformed the weighted logistic regression, the performance improvement over weighted logistic regression was modest (**Figure S1**). Given our focus on interpretability, we chose to use weighted logistic regression. After adjusting confounding variables identified from the exploratory analysis, our final model is given below.

$$logit(\Pr(Vaccination\ Status_i = 1)) = \beta_0 + \beta_1 Belief\ Score_i + \beta_2 Experience\ Score_i + \sum_{j=0}^{4} \beta_{3j} 1(Main\ Vaccination\ Location_i = j) + \sum_{j=0}^{3} \beta_{4j} 1(Education_i = j) + \sum_{j=0}^{3} \beta_{5j} 1(Marital\ Status_i = j) + \sum_{j=0}^{1} \beta_{6j} 1(Bed\ Net_i = j) + \sum_{j=0}^{1} \beta_{7j} 1(Inpatient_i = j)$$

Among individuals without vaccine cards, 309 individuals reported fully vaccinated, whereas 230 individuals reported not fully vaccinated. Thus, a sensitivity analysis was conducted to assess the impact of potential recall bias. The model was re-run 100 times at each of five fully vaccinated status that represented 10%, 20%, 30%, 40% and 50% recall bias. This procedure was conducted separately for both underreporting and overreporting scenarios. For instance, 10% of individuals who were not fully vaccinated and did not have vaccine cards were randomly recoded as fully vaccinated under the underreporting scenarios. On the other hand, 10% of individuals who were fully vaccinated and did not have vaccine cards were randomly recoded as not fully vaccinated under the overreporting scenarios. The adjusted odds ratios and 95% confidence intervals were presented in a forest plot.

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Results

Study Population

Between January 20th, 2021 and April 30th, 2021, 1689 children were enrolled from --- households. Of those children, 78 were missing data on at least one vaccine and were excluded from analyses using full vaccination as the outcome of which --- children were missing data on the measles vaccine and were excluded from all analyses. The majority of children, 67.8% of children, had their vaccination card compared to 32.2% that did not.

Commented [AG2]: Is this true? If not, feel free to edit.

Commented [YY3R2]: There are 78 children missing information on if they are fully vaccinated.

Most children, 81.8% (1381 children) were fully vaccinated, accounting for 94.7% (1078 children) among those with their vaccination card compared to 56.0% (303 children) among those without their vaccination card (**Table 2**). Measles was the vaccine with the greatest variability with 97.5% of children having been vaccinated specifically for measles, though 32.6% of data for this vaccine were missing. Vaccines were received at a level III government health center and level II health

facility for 39.0% and 61.0% of children, respectively with no children having been vaccinated a a private health facility. Among caregivers, most survey respondents were female (86.3%) and most commonly the mother (80.5%) of the eligible child followed by the father (11.5%). Primary and secondary education were most common accounting for 60.7% and 27.4% of caregivers, respectively.

Table 2 - include parish of residence.

Table 2. *Characteristics of Study Population*

	Fully Vaccinated (n, %)	Not Fully Vaccinated (n, %)	Total population (n, %)
Number of Children	**1381**	**230**	
Caregiver Sex			
Male	173 (12.6)	48 (20.9)	221 (13.8)
Female	1204 (87.4)	182 (79.1)	1386 (86.2)
Missing	4	0	4
Caregiver Relationship			
Mother	1136 (82.7)	151 (66.2)	1287 (80.3)
Father	147 (10.7)	37 (16.2)	184 (11.5)
Grandparent	53 (3.9)	22 (9.6)	75 (4.7)
Aunt or Uncle	27 (2.0)	12 (5.3)	39 (2.4)
Other*	11 (0.8)	6 (2.6)	17 (1.1)
Missing	7	2	9
Caregiver Education			
No School	115 (8.3)	36 (15.7)	151 (9.4)
Primary School	839 (60.8)	137 (59.6)	976 (60.7)
Secondary School	389 (28.2)	55 (23.9)	444 (27.6)
University	36 (2.6)	2 (0.9)	38 (2.4)
Missing	2	0	2
Caregiver Marital Status			
Unmarried	65 (4.7)	16 (7.0)	81 (5)
Married	1273 (92.2)	196 (85.6)	1469 (91.2)
Divorced	36 (2.6)	15 (6.6)	51 (3.2)
Widowed	7 (0.5)	2 (0.9)	9 (0.6)
Missing	0	1	2
Number of Children in the home			
No children	15 (1.1)	2 (0.9)	17 (1.1)
1 to 2 children	484 (35.4)	77 (34.1)	561 (35.3)
3 to 5 children	571 (41.8)	79 (34.9)	650 (40.8)
6 to 10 children	275 (20.1)	66 (29.3)	341 (21.3)
More than 10 children	22 (1.6)	2 (0.9)	24 (1.5)

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Commented [YY5R4]: We don't have available data for parish of residence

Commented [AG6]: This column doesn't appear to match the component columns

Commented [YY7R6]: In total 1689 population, there are 78 participants which are coded as vacc_full = "NA"(neither fully vaccinated nor fully vaccinated) because their Child's Immunization Cards are not available and their Self-reported vaccination status are missing at the same time

Commented [AG8]: Are these households or children?

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Missing	14	4	18
If the child was born at home			
No	738 (54.9)	129 (58.1)	867 (55.3)
Yes	607 (45.1)	93 (41.9)	700 (44.7)
Missing	36	8	44
Age of oldest child, Mean (SD)	9.94 (7.76)	10.76 (8.60)	10.06 (7.88)
Missing (count)	34	8	42
Location where the child was vaccinated			
Government Health Centre 3	340 (24.7)	75 (32.8)	415 (25.8)
Government Health Centre 2	545 (39.5)	95 (41.5)	640 (39.8)
Private Health Centre or Hospital	377 (27.3)	48 (21)	425 (26.4)
Visit by Immunization Program (example EPI)	68 (4.9)	9 (3.9)	77 (4.8)
Other**	49 (3.6)	2 (0.9)	51 (3.2)
Missing	2	1	3
Child's Immunization Card Availability			
Yes	1072 (77.6)	0 (0)	1072 (66.5)
No	309 (22.4)	230 (100)	539 (33.5)
Missing	0	0	0
BCG			
Yes	1087 (100)	5 (100)	1092 (100)
No	0 (0)	0 (0)	0 (0)
Missing	294	225	519
OPV			
Yes	1085 (100)	2 (100)	1187 (100)
No	0 (0)	0 (0)	0 (0)
Missing	296	228	524
Penta (DPT-Hep-Hib) #1			
Yes	1083 (100)	2 (100)	1085 (100)
No	0 (0)	0 (0)	0 (0)
Missing	298	228	526
Penta (DPT-Hep-Hib) #2			
Yes	1081 (100)	2 (100)	1083 (100)
No	0 (0)	0 (0)	0 (0)
Missing	300	228	528
Penta (DPT-Hep-Hib) #3			
Yes	1079 (100)	2 (100)	1081 (100)
No	0 (0)	0 (0)	0 (0)
Missing	302	228	530
Measles			
Yes	1078 (100)	1 (100)	1079 (100)
No	0 (0)	0 (0)	0 (0)

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Commented [AG11]: I thought this vaccine was the most commonly missing?

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Missing	303	229	532
Rotavirus #1			
Yes	1078 (100)	1 (100)	1079 (100)
No	0 (0)	0 (0)	0 (0)
Missing	303	229	532
Rotavirus #2			
Yes	1077 (100)	1 (100)	1078 (100)
No	0 (0)	0 (0)	0 (0)
Missing	304	229	533

Caption here ----------

Supplementary table – Please create a second similar table but that includes the percentage of people with each response for each belief and experience item with separate columns for children that have their full vaccination and those that did not and a total column

Table S1. Vaccination Attitudes, Beliefs, and Experiences by Vaccination Status in the Study Population

	Fully Vaccinated (n, %)	**Not Fully Vaccinated (n, %)**	**Total population (n, %)**
Number of Children	**1381**	**230**	**1611**
Vaccination Attitudes & Beliefs			
Children receive more vaccines than are good.			
Agree	536 (38.8)	104 (45.2)	640 (39.9)
Disagree	665 (48.2)	81 (35.2)	746 (46.5)
Not sure	175 (12.7)	45 (19.6)	220 (13.7)
Missing	5	0	5
Healthy children do not need immunizations.			
Agree	168 (12.2)	15 (6.5)	183 (11.4)
Disagree	1093 (79.1)	183 (79.6)	1276 (79.4)
Not sure	117 (8.5)	32 (13.9)	149 (9.3)
Missing	3	0	3
Vaccination does more good than harm.			
Agree	1333 (96.5)	223 (97.0)	1556 (96.8)
Disagree	30 (2.2)	6 (2.6)	36 (2.2)
Not sure	14 (1.0)	1 (0.4)	15 (0.9)
Missing	4	0	4
Gaining immunity through illness is preferable to vaccination for children.			
Agree	180 (13.0)	27 (11.7)	207 (12.9)
Disagree	1117 (80.9)	188 (81.7)	1305 (81.4)
Not sure	77 (5.6)	14 (6.1)	91 (5.7)
Missing	7	1	8
Parents should be allowed to choose which vaccines their child receives.			
Agree	206 (14.9)	24 (10.4)	230 (14.4)

Disagree	1096 (79.4)	191 (83.0)	1287 (80.4)
Not sure	69 (5.0)	15 (6.5)	84 (5.2)
Missing	10	0	10
Receiving two shots in one visit is better than one shot across two visits.			
Agree	718 (52.0)	113 (49.1)	831 (52)
Disagree	578 (41.9)	93 (40.4)	671 (42)
Not sure	73 (5.3)	22 (9.6)	95 (5.9)
Missing	12	2	14
Many of the illness which vaccinations prevent are severe.			
Agree	1231 (89.1)	193 (83.9)	1424 (88.9)
Disagree	96 (7.0)	29 (12.6)	125 (7.8)
Not sure	44 (3.2)	8 (3.5)	52 (3.2)
Missing	10	0	10
Refusing to vaccinate a child puts the community at risk.			
Agree	1170 (84.7)	172 (74.8)	1342 (83.9)
Disagree	134 (9.7)	41 (17.8)	175 (10.9)
Not sure	67 (4.9)	16 (7.0)	83 (5.2)
Missing	10	1	11
There are community concerns about serious vaccine side effects in children.			
Agree	243 (17.6)	29 (12.6)	272 (17)
Disagree	928 (67.2)	168 (73.0)	1096 (68.5)
Not sure	200 (14.5)	33 (14.3)	233 (14.6)
Missing	10	0	10
Following the nationally recommended vaccination schedule is a good idea for a child.			
Agree	1361 (98.6)	225 (97.8)	1586 (99)
Disagree	6 (0.4)	3 (1.3)	9(0.6)
Not sure	5 (0.4)	2 (0.9)	7 (0.4)
Missing	9	0	9
Vaccine Experience			
If advised by national policy, would you accept two injections in the same limb?			
Yes	1032 (74.7)	165 (71.7)	1197 (74.6)
No	251 (18.2)	42 (18.3)	293 (18.3)
Not sure	92 (6.7)	23 (10.0)	115 (7.2)
Missing	6	0	6
I believe vaccines are safe.			
Yes	1361 (98.6)	226 (98.3)	1587 (98.8)
No	7 (0.5)	1 (0.4)	8 (0.5)
Not sure	8 (0.6)	3 (1.3)	11 (0.7)
Missing	5	0	5
I believe vaccines protect my child from vaccine preventable disease.			
Yes	1336 (96.7)	223 (97.0)	1559 (97.3)

No	10 (0.7)	3 (1.3)	13 (0.8)
Not sure	27 (2.0)	4 (1.7)	31 (1.9)
Missing	8	0	8
Have you personally seen someone with either polio, pneumonia, measles or whooping cough?			
Yes	902 (65.3)	137 (59.6)	1039 (64.7)
No	459 (33.2)	89 (38.7)	548 (34.1)
Not sure	15 (1.1)	4 (1.7)	19 (1.2)
Missing	5	0	5
Do you know of someone in your family or community who had either polio, pneumonia, measles or whooping cough?			
Yes	708 (51.3)	83 (36.1)	791(49.3)
No	645 (46.7)	142 (61.7)	787 (49.0)
Not sure	22 (1.6)	5 (2.2)	27 (1.7)
Missing	6	0	6
Have you ever delayed having your child get a vaccination for reasons other than illness or allergy?			
Yes	368 (26.6)	109 (47.4)	477 (29.7)
No	978 (70.8)	112 (48.7)	1090 (67.8)
Not sure	31 (2.2)	9 (3.9)	40 (2.5)
Missing	4	0	4
Have you ever decided not to have your child get a vaccination for reasons other than illness or allergy?			
Yes	383 (27.7)	81 (35.2)	464 (29)
No	960 (69.5)	140 (60.9)	1100 (68.7)
Not sure	29 (2.1)	9 (3.9)	38 (2.4)
Missing	9	0	9
If you had another infant today, would you want your infant to get all recommended vaccinations?			
Yes	1328 (96.2)	219 (95.2)	1547 (96.9)
No	38 (2.8)	10 (4.3)	48 (3)
Not sure	1 (0.1)	1 (0.4)	2 (0.1)
Missing	14	0	14
Do you know the location where you can have your child vaccinated?			
Yes	1352 (97.9)	224 (97.4)	1576 (98.7)
No	10 (0.7)	3 (1.3)	13 (0.8)
Not sure	5 (0.4)	2 (0.9)	7 (0.4)
Missing	14	1	15
Do you know the days and times when vaccination services are offered in your community?			
Yes	1323 (95.8)	215 (93.5)	1538 (96.2)
No	29 (2.1)	8 (3.5)	37 (2.3)
Not sure	18 (1.3)	5 (2.2)	23 (1.4)
Missing	11	2	13
Is access to immunization easy?			
Yes	1282 (92.8)	203 (88.3)	1485 (93.1)

No	85 (6.2)	25 (10.9)	110 (6.9)
Not sure	0 (0.0)	0 (0.0)	0 (0.0)
Missing	14	2	16
Are you willing to spend more than an hour for an important vaccine?			
Yes	1344 (97.3)	223 (97.0)	1567 (97.9)
No	17 (1.2)	4 (1.7)	21 (1.3)
Not sure	10 (0.7)	3 (1.3)	13 (0.8)
Missing	10	0	10
Are you able to discuss any concerns you have about vaccinations with your child's healthcare provider?			
Yes	1314 (95.1)	207 (90.0)	1521 (95.1)
No	39 (2.8)	17 (7.4)	56 (3.5)
Not sure	16 (1.2)	6 (2.6)	22 (1.4)
Missing	12	0	12
Do you trust the information that you receive from your local healthcare worker about vaccinations?			
Yes	1363 (98.7)	227 (98.7)	1590 (99.7)
No	2 (0.1)	0 (0.0)	2 (0.1)
Not sure	2 (0.1)	1 (0.9)	3 (0.2)
Missing	14	2	16

Aggregate Belief and Experience Scores

The odds of a child being fully vaccinated were 1.05 (95% CI: (0.97, 1.15)) times higher for each additional positive belief help by the caregiver and 1.03 (95% CI: (0.95, 1.12)) times higher for each additional positive experience compared to children who were not fully vaccinated when adjusting for vaccination location, caregiver education, caregiver marital status, LLIN use, and history of hospitalization for malaria.

When considering the measles vaccine alone, positive beliefs about vaccines indicated as a higher beliefs score were associated with lower odds of vaccination (OR: 0.54, (95% CI: (0.39, 0.73))). Positive experiences with vaccines were also found to have a positive associated with vaccination (OR: 1.10 (95% CI: (0.82, 1.48))).

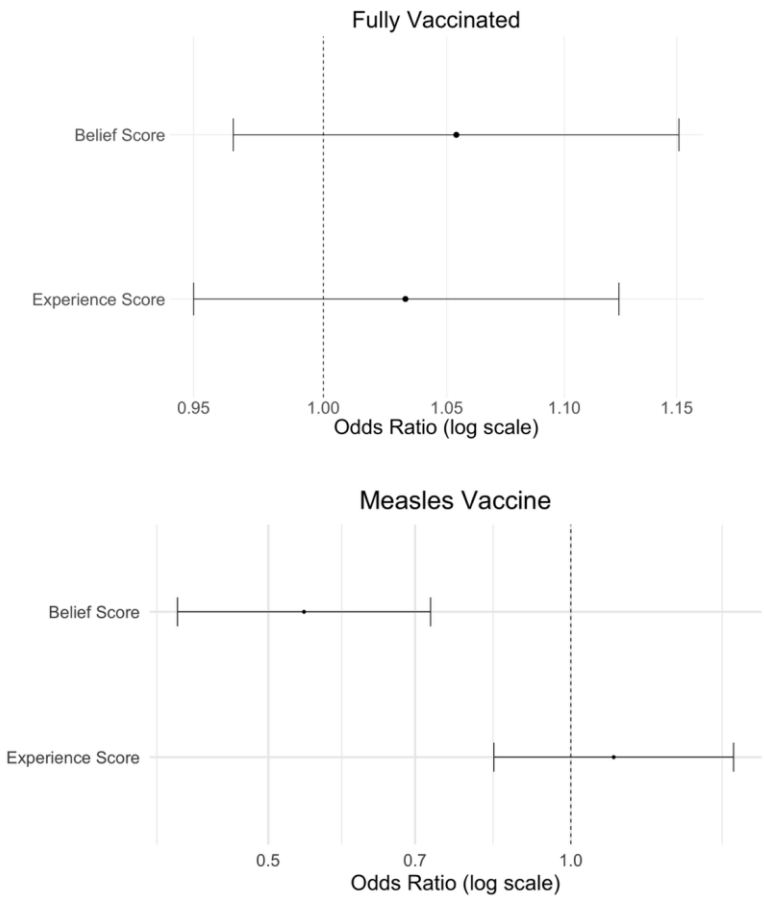

Figure 2 – Forest plot that includes two panels, one for full vaccination as the outcome and the other with just measles including just the beliefs and experience scores.

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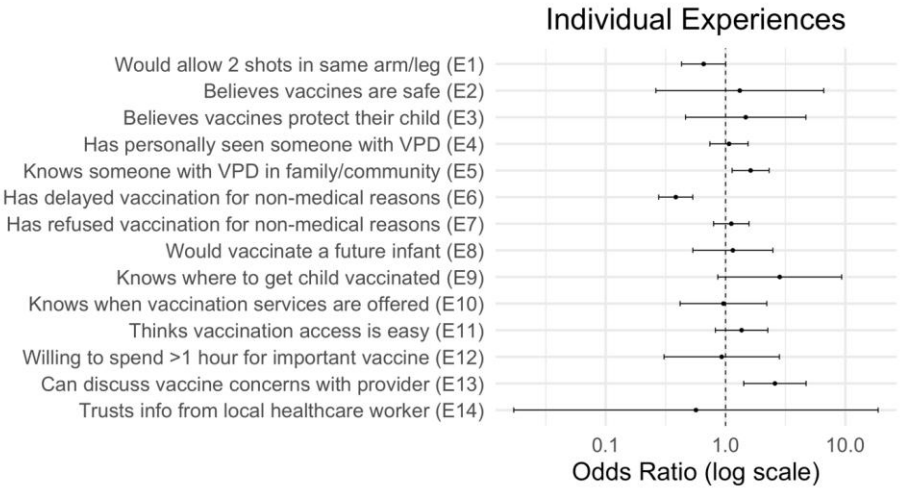
Individual Belief Components

Of individual belief components, agreeing with the statement "Children get more vaccinations than are good for them" was associated with a lower odd of a caregiver's child being fully vaccinated with an adjusted OR of 0.59 (95% CI: (0.42, 0.81)). In contrast, agreement with the statements "Many of the illness which vaccinations prevent are severe" or "When a parent refuses to vaccinate a child, it harms the entire community through risk of disease" was associated with a higher odds of a caregiver's child being fully vaccinated with adjusted ORs of 2.05 (95% CI: (1.23, 3.40)) and 1.80

(95% CI: (1.21, 2.70)), respectively. All other individual beliefs and attitudes were not statistically associated with receipt of all vaccinations.

Individual Experience Components

Regarding individual experiences, delaying a child's vaccination for reasons other than allergy or illness was associated with a 0.38 (95% CI: 0.28, 0.53) times lower odds of a caregiver's child being fully vaccinated. Being able to discuss any concerns with a child's healthcare provider or knowing a person who had either polio, pneumonia, measles, or whooping cough was associated with a 2.58 (95% CI: 1.42, 4.71) and 1.68 (95% CI: (1.134, 2.315)) times higher odds of a caregiver's child being fully vaccinated respectively. All other individual experiences were not statistically associated with receipt of all vaccinations.



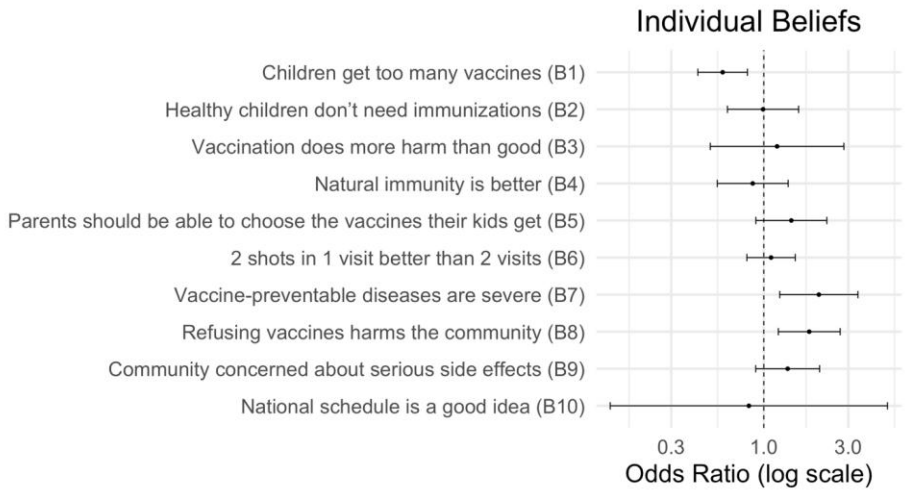


Figure 3 – Forest plot that includes two panels, one for all belief questions and the other for all experience questions

Commented [AG14]: Need bigger font and have y-axis be the component names and not the variable names

Factors Associated with Belief and Experience Scores

Commented [JC15]: Choe, Joyce added.

Children who slept under a bed net in the previous night were associated with a higher aggregate belief score (Cohen's d = 0.089, p <0.001, **Table 3**). Caregivers who brought their child to Government Health Centres 2, 3, or Immunization Program Visits to receive vaccinations over private healthcare were associated with a higher aggregate belief score (mean rank difference (m) = 130, 158, 224, respectively; p <0.001). Caregivers who did not complete school compared to those who completed primary or secondary school were associated with a lower aggregate belief score (m = -138, -132; p <0.001, 0.01, respectively). Children born at home or government health facilities over private clinics or hospitals were associated with a higher aggregate belief score (m = 102, 114; p=0.003, <0.001, respectively).

Caregivers taking care of more children than less children in the home were associated with a higher aggregate experience score (Kendall's tau = 0.070, p < 0.001, **Table 3**). Children who stayed overnight in a hospital or clinic at least once were associated with a higher aggregate experience score (Cohen's d = 0.131, p <0.001). Caregivers who brought their child to Government Health Centre 2 over Centre 3 to receive vaccinations were associated with a higher aggregate experience score (m = 109, p <0.001). In contrast to belief score, caregivers who did not complete school compared to those who completed primary and secondary school were associated with a higher

aggregate experience score (m = 103, 129; p = 0.04, 0.01, respectively). Married caregivers over those unmarried were associated with a higher aggregate experience score (m = 182.4; p=0.003).

Table 3. *Caregiver and Child Factors Associated with Aggregate Belief and Experience Scores*

	Belief Score		Experience Score	
	Effect size	p-value	Effect size	p-value
Number of children living in the home	-0.001	0.946	0.070	<0.001 ***
If the child slept under an LLIN the previous night	0.089	<0.001 ***	0.006	0.808
If the child has ever been hospitalized	0.003	0.623	0.131	<0.001 ***
Primary vaccination location		<0.001 ***		0.002 **
Govt. Health Centre 2 vs. Private Health Centre or Hospital	130	<0.001 ***	68.8	0.137
Govt. Health Centre 3 vs. Private Health Centre or Hospital	158	<0.001 ***	-40.2	1.00
Visit by Immunization Program vs. Private Health Centre or Hospital	224	<0.001 ***	-46.5	1.00
Visit by Immunization Program vs. Other	242	0.02 *	-38.2	1.00
Govt. Health Centre 2 vs. Govt. Health Centre 3	27.3	0.696	109	<0.001 ***
Education level of the caregiver		0.006 **		0.019 *
No school vs. Primary school	-138	<0.001 ***	103	0.04 *
No school vs. Secondary school	-132	0.01 *	129	0.01 *
Marital status of the caregiver		0.396		0.002 **
Married vs. Unmarried	82.8	0.714	182.4	0.003 **
Where the child born		<0.001 ***		0.833
Home vs. Private clinic or Hospital	102	0.003 **	-15.2	1.00

Government Health Facility vs. Private Clinic or Hospital	114	<0.001 ***	-2.32	0.927

The Kendall's Tau rank correlation test was used to assess an association between the number of children living in the home and aggregate score. The Wilcoxon Rank Sum test and Cohen's d statistic were used to assess whether a child who slept under an LLIN the previous night or had ever been hospitalized was associated with aggregate score. The Kruskal-Wallis test was used to assess whether primary vaccination location, caregiver education level, caregiver marital status, or child birthplace was associated with aggregate score. Dunn's test was used to perform multiple comparisons and calculate mean rank differences. The significance level (α) was adjusted to 0.05 using Holm's method.

Note: (*) is used to indicate $p < 0.05$, ** for $p < 0.01$, and *** for $p < 0.001$

Factors Associated with Vaccination Card Availability

Caregiver sex, relationship to child, marital status, education level, and bed net use were significantly associated with vaccination card reports (**Table 4**). Among households with child vaccination cards, caregivers were 1.30 times as likely to be female than male. Additionally, mothers were more likely to show vaccination cards than fathers, grandparents, aunts, uncles, and other caregivers (RR = 1.28, 1.77, 1.70, 2.17). Caregivers who did not complete school were less likely to provide vaccination cards than those who completed primary school, secondary school, or university (RR = 0.81, 0.80, 0.70). Married caregivers were more likely to show vaccination cards than unmarried and divorced caregivers, but vaccination card reports were not significantly different between married and widowed caregivers (RR = 1.26, 1.36, 0.99). Households with bed nets were 1.43 times as likely to show vaccination cards than those without bed nets.

Table 4. *Caregiver Characteristics Associated with Vaccination Card Reports*

	Vaccination Card		
Characteristics	Yes N = 1138 (68%)	No N = 541 (32%)	p-value[1]
Caregiver sex, n (%)			< 0.001 ***
Female	1,010 (89%)	435 (80%)	
Male	124 (11%)	106 (20%)	
Missing	4 (0.4%)	0 (0%)	
Relationship to Child, n (%)			< 0.001 ***
Mother	970 (86%)	374 (70%)	
Father	108 (9.5%)	84 (16%)	
Grandparent	31 (2.7%)	45 (8.4%)	
Aunt or Uncle	17 (1.5%)	23 (4.3%)	
Other	6 (0.5%)	12 (2.2%)	
Missing	6 (0.5%)	3 (0.6%)	
Caregiver Education, n (%)			0.003 **
No school	87 (7.7%)	70 (13%)	
Primary school	699 (62%)	323 (60%)	
Secondary school	319 (28%)	140 (26%)	
University	31 (2.7%)	8 (1.5%)	
Missing	2 (0.2%)	0 (0%)	
Marital Status, n (%)			0.002 **
Unmarried	46 (4.0%)	38 (7.0%)	
Married	1,057 (93%)	473 (88%)	

Divorced	27 (2.4%)	26 (4.8%)	
Widowed	7 (0.6%)	3 (0.6%)	
Missing	1 (<0.1%)	1 (0.2%)	
Bed net, n (%)			< 0.001 ***
Yes	1,068 (94%)	469 (87%)	
No	68 (6.0%)	72 (13%)	
Missing	2 (0.2%)	0 (0%)	

[1]Pearson's Chi-squared test; Fisher's exact test.

Note: (*) is used to indicate p < 0.05, ** for p < 0.01, and *** for p < 0.001

Sensitivity Analysis

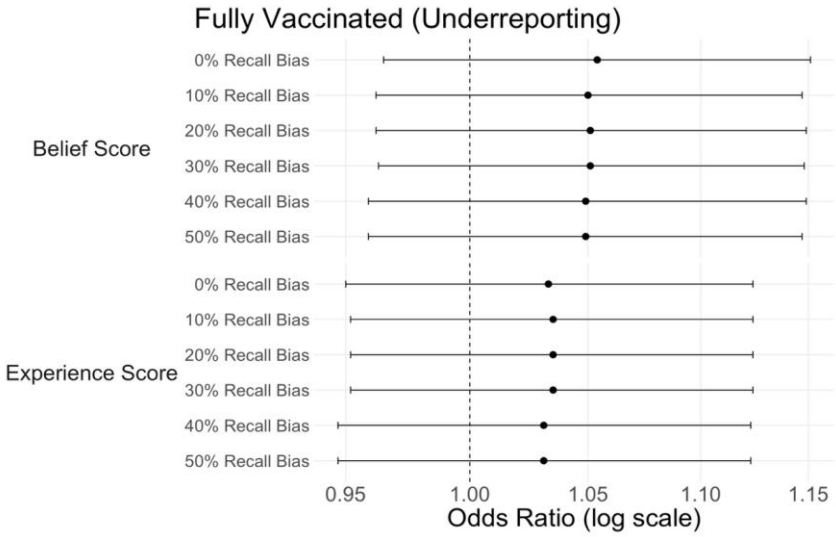
The sensitivity analysis assessing the impact of having a vaccine card versus relying on caregiver recall produced similar results to the main analysis, though differences exist. In the model for vaccine card availability, caregivers with a secondary level education, being married, and use of an LLIN for the child associated with vaccine card presence. Importantly, vaccine card presence was significantly associated with positive caregiver experiences as an aggregated score, after adjusting for vaccination location, caregiver education level, caregiver marital status, child LLIN use, history of inpatient care, and caregiver beliefs.

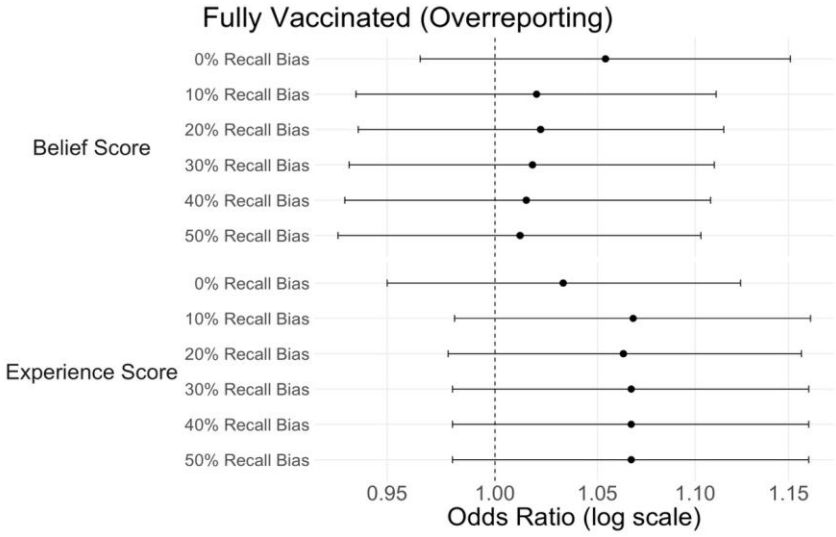
Models fit to assess the association between beliefs and experiences score and measles vaccination status, show more positive beliefs about vaccines were associated with a lower odds of vaccination (OR: 0.54 (95% CI: (0.39, 0.73))). In contrast, more positive experiences with vaccines were associated with a higher odds of measles vaccination (OR: 1.10 (95% CI: (0.82, 1.48))).

The belief item “Many of the illness which vaccinations prevent are severe” was more associated with a higher odds of a caregiver’s child being fully vaccinated among those with a vaccine card (OR: 3.85 (95% CI: (1.41, 10.49))) compared to the full analysis (OR: 2.05 (95% CI: (1.23, 3.40))). The experience item “Delaying a child’s vaccination for reasons other than allergy or illness” had a very similar adjusted OR for caregiver’s child being fully vaccinated in the vaccine card group (OR: 0.35 (95% CI: (0.17, 0.72))) compared to the main analysis group (OR: 0.38 (95% CI: 0.28, 0.53))). The other belief and experience scores identified in the main analysis were not seen in the sensitivity analysis. Though an additional association between vaccination status and agreement with the belief statement “Healthy children do not need immunizations” was identified (OR = 0.33 (95% CI: (0.13, 0.831))).

Next, the results of the sensitivity analysis for recall bias were presented in the forest plot. The adjusted odds ratios and 95% confidence intervals for both belief score and experience score under the underreporting scenarios were close to those without recall bias. However, under the

overreporting scenarios, the adjusted odds ratios and 95% confidence intervals for both belief score and experience score were notably different from those without recall bias. This suggests that the results are sensitive to overreporting, although the associations still remained the same.





Discussion

Limitations

While this study was benefited by a large sample size and a census of children from the target population, a relatively large subset of children did not have vaccination card. Sensitivity analyses did indicate difference in people with vaccine cards and those who did not which appears to have included recall bias.

Additionally, due to the higher-than-expected vaccination coverage for a rural area, there was little variation in outcome measures. This homogeneity limited the study's statistical power and increased the risk of model instability. Given the imbalance in the outcome data, caution should be taken when interpreting the results

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