Title

Validation of the Shortened Vaccination Demand Questionnaire to Efficiently Identify Childhood Vaccination Acceptance and Hesitancy in DRC

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Validation of the Shortened Vaccination Demand Questionnaire to Efficiently Identify Childhood Vaccination Acceptance and Hesitancy in DRC

A thesis submitted in partial satisfaction

of the requirements for the degree Master of Science

in Epidemiology

by

Tiffani Berra

2023

ABSTRACT OF THE THESIS

Validation of the Shortened Vaccination Demand Questionnaire
to Efficiently Identify Childhood Vaccination Acceptance and Hesitancy
in DRC

by

Tiffani Berra

Master of Science in Epidemiology
University of California, Los Angeles, 2023
Professor Anne W Rimoin, Chair

Background: Given the high prevalence of vaccine preventable diseases, decline in childhood vaccination coverage, and data collection logistical challenges, we sought to validate a shortened Vaccination Demand Questionnaire (VaDQ) to estimate childhood vaccination acceptance and hesitancy in the Democratic Republic of Congo (DRC).

Methods: Using follow-up data from rVSV ZEBOV-GP vaccinated and unvaccinated populations in the DRC, we evaluated the sensitivity and specificity of two shortened VaDQs and conducted a sensitivity analysis comparing sensitivity and specificity of the shortened VaDQs at different dichotomizing cut-points.

Results: The 11-item VaDQ (VaDQ-11) was most accurate when utilizing its mean for dichotomization, resulting in the highest combination of sensitivity (94.4%) and specificity (81.1%).

Conclusion: Use of VaDQ-11 would save time and resources in data collection, allowing for its greater use. This would result in broader understanding of childhood vaccination acceptance and hesitancy in the DRC and help tailor public health interventions for optimizing childhood vaccination uptake.

The thesis of Tiffani Berra is approved.

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2023

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Background

Infectious diseases, including pneumonia, diarrheal diseases, and malaria, remain one of the leading causes of death for children under 5 years of age globally.[1] In 2020, half of all deaths for children under 5 years of age occurred in only 5 countries: Nigeria, India, Pakistan, the Democratic Republic of the Congo (DRC) and Ethiopia,[1] and these 5 countries are where 39% of unvaccinated children live.[2] Specifically, the DRC's mortality rate in children under 5 years of age is particularly high at 85 deaths per 1000 births,[3] and in 2017, acute respiratory infections, diarrheal diseases, and measles contributed the highest number of deaths among vaccine preventable diseases (VPDs) in children under 5 years of age living in the DRC.[4] From 2018 to 2019, 65% of children under 2 years of age in the DRC were considered to be undervaccinated or had not received any vaccination,[5,6] and this lack of vaccination or undervaccination contributes to VPD outbreaks and deaths due to infectious diseases in the DRC.

Vaccination is crucial to the prevention and control of infectious diseases, and is one of the most cost-effective ways to avoid disease.[7] Currently, there are vaccines to prevent more than 20 life-threatening diseases, and immunization prevents 3.5-5 million deaths each year from VPDs.[8] While vaccination coverage has improved over the last 3 decades, there are still 20 million children in the world who do not receive essential vaccines.[3] Despite the notable progress over the past few decades, vaccination coverage had plateaued in the last few years and declined since 2020.[8] The COVID-19 pandemic and related disruptions resulted in 25 million children missing out on vaccination in 2021,[8] and things like ongoing conflicts, climate crises and vaccine hesitancy also contributed to the decline in vaccination rates.[9] The pandemic resulted in essential immunization decline in over 100 countries, which led to rising outbreaks of measles, polio, diphtheria, and yellow fever.[9]

Vaccine hesitancy and the spread of misinformation continue to challenge the implementation of necessary public health interventions.[10] Reasons for which people choose not to vaccinate are multifaceted and include complacency, inconvenience in accessing vaccines, and lack of confidence as key reasons underlying hesitancy.[7] A recent survey that included the DRC, also showed a hesitancy towards the COVID-19 vaccines due to a lack of trust in public health and government agencies, and apprehensions concerning the safety and efficacy of the vaccines.[11] Earlier studies conducted in sub-Saharan Africa (Nigeria, Sudan, Kenya, Ghana, Sierra Leone, and Cameroon),[12-17] have estimated prevalence of vaccine hesitancy but little research has been conducted on childhood vaccination demand with respect to childhood vaccination acceptance and hesitancy in the DRC specifically. Given the high mortality rate of children under 5 years of age and the contribution of VPDs to this, in addition to recurrent outbreaks of Ebola virus disease (EVD) in the DRC, it is crucial to have a robust and efficient scale tool to measure and quantify childhood vaccination acceptance and hesitancy in order to direct critical public health interventions that foster optimal vaccination uptake.

Validated scales that measure vaccine hesitancy in low- and middle-income countries (LMIC) are limited, and few have been validated and used in Africa.[17,18] Therefore, for this study we used the Vaccination Demand Questionnaire (VaDQ), which was previously validated in Sierra Leone,[18] to estimate childhood vaccination demand among those with children in the household in the DRC. Using follow-up data collected from rVSV ZEBOV-GP vaccine recipients and unvaccinated populations in the DRC, from December 2020 through May 2021, we evaluated the sensitivity and specificity of the shortened versions of the Vaccination Demand Questionnaire (VaDQ-15 and VaDQ-11) compared to the full questionnaire (VaDQ-22) to determine the usefulness of the shortened questionnaires in assessing childhood vaccination demand in the DRC. Classification as childhood vaccination accepting or hesitant could inform us of areas and populations within the DRC that could be successfully targeted with tailored

public health interventions that include vaccination programs/vaccine campaigns based on the childhood vaccination demand outcome. This would help guide efforts to optimize childhood vaccination uptake and in turn decrease childhood morbidity and mortality in the DRC due to infectious diseases.

Methods

This data was collected as a part of a larger study to explore the humoral immune responses, and durability of these responses, in participants post Merck & Co. rVSV ZEBOV-GP vaccination.[19,20] In the study by Hoff et el., cohorts of vaccine recipients along with unvaccinated individuals were enrolled in three Mbandaka city health zones (Wangata, Mbandaka, and Bolenge) between June and July 2018,[19] and Beni between August and September 2018,[20] and followed prospectively. Participants in Mbandaka were recruited after the final case of the 2018 EVD Mbandaka was confirmed, but before the official declaration of the end of the Mbandaka outbreak on July 24th, 2018, and participants in Beni were recruited after the start of the Beni outbreak in 2018, but almost 2 years prior to the end of that outbreak on June 25th, 2020. While participants were recruited in Mbandaka and Beni, some participants moved over the course of the follow-up and thus our province data also includes Kinshasa and other provinces. Recruitment criteria and selection procedures have been described in detail by Hoff et al.[19,20]

Questionnaires were collected from consenting participants at a vaccination visit (or a baseline visit for unvaccinated participants) and at multiple follow-up visits. Informed consent procedures were provided to participants, and they had the right to refuse participation at any time. This analysis uses questionnaire data from the 2.5-year post-outbreaks follow-up. Electronic questionnaires were administered by trained study staff in the local language (French, Lingala, or Swahili), and collected data on demographics, Ebola knowledge, general adult vaccination demand, childhood vaccination demand via the validated VaDQ, potential

exposures to Ebola virus, transmission behaviors for Ebola virus, occupational exposures, animal exposures, and health history.

The 22-item Vaccination Demand Questionnaire (VaDQ), which was previously validated in Sierra Leone,[17] was included in the follow-up questionnaire to assess the level of childhood vaccination demand among participants. The questionnaire consisted of items with either a 4-point or a 3-point Likert scale and questions covered general attitude towards childhood vaccination, spousal and community vaccine acceptance, religious beliefs towards immunization, and knowledge of VPDs and experience with vaccination. The initial 22-item VaDQ (VaDQ-22) was previously narrowed down into a shorter validated 15-item scale (VaDQ-15) using exploratory factor analysis as a part of a larger analysis in Sierra Leone.[17] The VaDQ-15 was then further narrowed down to an 11-item scale (VaDQ-11) in Ethiopia (paper forthcoming). All participants answered all 22 scale items, and for this analysis, participants who did not have children under 5 years old living in the household (children/child in the household) were excluded. We did so because the VaDQ-22 questions are focused specifically on the participant's child. As a result, out of 1782 survey respondents, 1165 were included in our final analysis. Details of all questions and response values of the VaDQ are provided in the Supplemental Table 1.

Frequencies and percentages of sociodemographic and participant vaccination behavior variables among the total sample, by whether participants had children in the household, and by childhood vaccination demand categorization were tabulated. Childhood vaccination demand was calculated by summing all 22 question responses of the validated VaDQ-22 and dividing by the total points possible (79) to get a total score, and then calculating the mean of the VaDQ-22 total score among those who have children in the household and dichotomizing participants into childhood vaccination accepting (score greater than the mean) or childhood vaccination hesitant (score less than or equal to the mean). Frequencies and percentages of responses to all 22

childhood vaccination questions (VaDQ-22) were also tabulated, and the distribution of each of the 22 items was examined. Proportions by vaccination demand status were assessed via chi square tests, and a p-value of less than 0.05 was considered statistically significant.

We evaluated the sensitivity and specificity of the shortened versions of the Vaccination Demand Questionnaire (VaDQ-15 and VaDQ-11) by first summing all 15 or 11 question responses of each version and dividing by the total points possible, 57 and 41 respectively. We then utilized different cut-points to dichotomize participants into childhood vaccination accepting (score greater than the determined cut-point) or childhood vaccination hesitant (score less than or equal to the cut-point). These cut-points included the VaDQ-22 mean, each VaDQ version's own mean, the VaDQ-22 median, each VaDQ version's own median, the VaDQ-22 mode, and each VaDQ version's own mode. For the purposes of this analysis, the validated VaDQ-22 is considered gold standard in evaluating childhood vaccination demand and was therefore used as such in calculating the sensitivity and specificity of the VaDQ-15 and VaDQ-11. We conducted a sensitivity analysis comparing the sensitivity and specificity of the VaDQ-15 and VaDQ-11 at the different dichotomizing cut-points, described above, to examine how the sensitivity and specificity of the shortened VaDQ versions varied with use of different cut-points. All statistical analyses were carried out using SAS software, version 9.4 (SAS Institute, Cary, NC).

Results

Of the 1,782 participants, 1,165 (65%) had at least 1 child in the household. The majority of participants with at least 1 child in the household were male (61%), living in Equateur (79%) or North Kivu (20%) province, and were the head of the household (44%), the wife or husband of the head of the household (27%), or the son or daughter of the head of the household (16%). Most had 4 or fewer (52%) or 5 to 9 (38%) adults living in the household, 2 or more (58%) children in the household, and were healthcare workers (34%), farmers (10%), merchants (9%),

or students (8%). The majority had received an Ebola vaccine (60%), more than half reported receiving the BCG tuberculosis vaccine (55%), and about 1/5 had been involved in an Ebola outbreak in the past 6 months (21%) (Table 1). All 1,165 participants who had at least 1 child in the household completed all 22 questions of the validated VaDQ-22.

Table 1: Sociodemographic characteristics and vaccination behaviors of total sample, DRC, 2021			
		Children in Household	
Characteristics	**Total**	**Yes**	**No**
	N = 1782, n (%)	**N = 1165, n (%)**	**N = 617, n (%)**
Sex			
Male	1048 (58.81)	710 (60.94)	338 (54.78)
Female	734 (41.19)	455 (39.06)	279 (45.22)
Province			
Equateur	1396 (78.34)	917 (78.71)	479 (77.63)
North Kivu	364 (20.43)	235 (20.17)	129 (20.91)
Other	22 (1.23)	13 (1.12)	9 (1.46)
Relationship with Head of Household			
I am the head of the household	771 (43.27)	507 (43.52)	264 (42.79)
Wife or husband	473 (26.54)	311 (26.70)	162 (26.26)
Son or daughter	303 (17.00)	185 (15.88)	118 (19.12)
Father or mother	146 (8.19)	106 (9.10)	40 (6.48)
Brother or sister	24 (1.35)	16 (1.37)	8 (1.30)
Other relationship	23 (1.29)	12 (1.03)	11 (1.78)
No relationship	42 (2.36)	28 (2.40)	14 (2.27)
Number of Adults in Household			
4 or fewer	951 (53.37)	606 (52.02)	345 (55.92)
5 - 9	674 (37.82)	439 (37.68)	235 (38.09)
10 - 14	135 (7.58)	103 (8.84)	32 (5.19)
15 or more	22 (1.23)	17 (1.46)	5 (0.81)
Number of Children (under 5 years old) in Household			
0	617 (34.62)	-	617 (100.00)
1	487 (27.33)	487 (41.80)	-
2 or more	678 (38.05)	678 (58.20)	-
Healthcare Worker			
Yes	657 (36.87)	395 (33.91)	262 (42.46)
No	1125 (63.13)	770 (66.09)	355 (57.54)
Primary Occupation			
Farmer	159 (8.92)	119 (10.21)	40 (6.48)
Health care worker (i.e., doctor, nurse, hygiene)	657 (36.87)	395 (33.91)	262 (42.46)
Merchant	138 (7.74)	104 (8.93)	34 (5.51)
Student	159 (8.92)	92 (7.90)	67 (10.86)
Other	669 (37.54)	455 (39.06)	214 (34.68)
Ever received Ebola Vaccine			
Yes	1087 (61.00)	694 (59.57)	393 (63.70)
No	695 (39.00)	471 (40.40)	224 (36.30)
Ever Received BCG TB Vaccine[1]			
Yes	782 (57.50)	482 (54.52)	300 (63.03)
No	578 (42.50)	402 (45.48)	176 (36.97)
Involved in Ebola outbreak past 6 months			
Yes	358 (20.09)	243 (20.86)	115 (18.64)
No	1424 (79.91)	922 (79.14)	502 (81.63)

[1]Totals vary due to missing data.

Our sample significantly differed in distributions of primary occupation, whether they were a healthcare worker, whether they had received an Ebola vaccine, whether they had received the BCG tuberculosis vaccine, and whether they had been involved in an Ebola outbreak in the last 6 months across childhood vaccination demand status (Table 2). Those who were childhood vaccination accepting more commonly resided in Equateur (81% vs. 74%) and were healthcare workers (36% vs. 28%) or merchants (11% vs. 4%), while those who were childhood vaccination hesitant more commonly resided in North Kivu (25% vs. 18%) and were more commonly farmers (16% vs. 8%) or fishermen (6% vs. 2%). Additionally, childhood vaccination accepting individuals more commonly had received an Ebola vaccine (63% vs. 52%), had received the BCG tuberculosis vaccine (62% vs. 36%), and had been involved in an Ebola outbreak in the last 6 months (23% vs. 15%).

Table 2: Distribution of 22-item Vaccination Demand Questionnaire (VaDQ-22) among those with at least 1 child in the household across demographics and vaccination behaviors, Kinshasa, DRC

	Parental Vaccination Demand[1]		P
Characteristics	**Accepting**	**Hesitant**	
	N = 826, n (%)	**N = 339, n (%)**	
Sex			0.634
Male	507 (61.38)	203 (59.88)	
Female	319 (38.62)	136 (40.12)	
Province			0.0412
Equateur	667 (80.75)	250 (73.75)	
North Kivu	150 (18.16)	85 (25.07)	
Other	9 (1.09)	4 (1.18)	
Relationship with Head of Household			0.0937
I am the head of the household	351 (42.49)	156 (46.02)	
Wife or husband	238 (28.81)	73 (21.53)	
Son or daughter	127 (15.38)	58 (17.11)	
Father or mother	72 (8.72)	34 (10.03)	
Brother or sister	10 (1.21)	6 (1.77)	
Other relationship	11 (1.33)	1 (0.29)	
No relationship	17 (2.06)	11 (3.24)	
Number of Adults in Household			0.067
4 or fewer	410 (49.64)	196 (57.82)	
5 - 9	323 (39.10)	116 (34.22)	
10 - 14	80 (9.69)	23 (6.78)	
15 or more	13 (1.57)	4 (1.18)	

Number of Children (under 5 years old) in Household			0.2932
1	358 (43.34)	129 (38.05)	
2 or more	468 (56.66)	210 (61.95)	
Healthcare Worker			0.0099
Yes	299 (36.20)	96 (28.32)	
No	527 (63.80)	243 (71.68)	
Primary Occupation			<.0001
Farmer	65 (7.87)	54 (15.93)	
Fisherman	15 (1.82)	19 (5.60)	
Health care worker (i.e., doctor, nurse, hygiene)	299 (36.20)	96 (28.32)	
Merchant	89 (10.77)	15 (4.42)	
Student	68 (8.23)	24 (7.08)	
Other	290 (35.11)	131 (38.64)	
Ever received Ebola Vaccine			0.0022
Yes	518 (62.71)	176 (51.92)	
No	308 (37.29)	163 (48.08)	
Ever Received BCG TB Vaccine[2]			<.0001
Yes	389 (62.14)	93 (36.05)	
No	237 (37.86)	165 (63.95)	
Involved in Ebola outbreak past 6 months			0.0005
Yes	193 (23.37)	50 (14.75)	
No	633 (76.63)	289 (85.25)	

[1]Based on VaDQ-22 score mean as cut-point: Accepting defined as a score greater than the mean (coded 1) and Hesitant defined as a score less than or equal to the mean (coded 0).
[2]Totals vary due to missing data.

According to the VaDQ-22 vaccination demand questionnaire, out of the 1,165 participants with at least 1 child in the household who were included in the final analysis, almost 88% considered vaccines very good, safe, and protective, felt confident in their ability to take their child for scheduled vaccinations, and would encourage others to get their children vaccinated. About 82% of respondents' spouse/partner and trusted community leaders approved of childhood vaccinations, and around 3/4 perceived that other parents approved of and community members valued childhood vaccinations. Around 80% considered measles a health threat for unvaccinated children and felt that illnesses vaccination prevents are severe. Religion influenced childhood vaccination decisions for 69%, and 61% said childhood vaccination goes together with their religious beliefs. Approximately 85% don't know of any child in their family/community that has experienced vaccine side effects, have never refused getting a recommended vaccine for their child, and have never delayed getting a recommended

vaccine for their child. Regarding their last childhood vaccination visit, 56% were treated with respect by vaccination staff, 64% were satisfied with how their child was handled by vaccination staff, and 52% said people in their community usually speak about childhood vaccination services in a mixed (positively and negatively) manner. In the event of a future child, 72% plan to accept all recommended childhood vaccinations and feel that their child receiving just 1 vaccine in a single visit is acceptable (Table 3).

Table 3: Distribution of responses to 22-Item Vaccination Demand Questionnaire (VaDQ-22) among total and those with at least 1 child in the household, DRC, 2021

Questions		Total	Children in Household
		(N = 1782), n (%)	(N = 1165), n (%)
1	**How much do you think that vaccines are good for your child?**		
	Not at all	101 (5.67)	79 (6.78)
	Very little	56 (3.14)	39 (3.35)
	Somewhat	58 (3.25)	31 (2.66)
	Very much	1567(87.93)	1016 (87.21)
2	**How much do you think that vaccines are safe for your child?**		
	Not at all	80 (4.49)	63 (5.41)
	Very little	52 (2.92)	38 (3.26)
	Somewhat	74 (4.15)	43 (3.69)
	Very much	1576 (88.44)	1021 (87.64)
3	**How much do you think that vaccines protect your child against diseases?**		
	Not at all	81 (4.55)	63 (5.41)
	Very little	51 (2.86)	36 (3.09)
	Somewhat	80 (4.49)	47 (4.03)
	Very much	1570 (88.10)	1019 (87.47)
4	**How much do you feel confident in your ability to take your child for scheduled vaccination visits?**		
	Not at all	80 (4.49)	57 (4.89)
	Very little	54 (3.03)	39 (3.35)
	Somewhat	75 (4.21)	42 (3.61)
	Very much	1573 (88.27)	1027 (88.15)
5	**How much would you encourage others to get their children vaccinated?**		
	Not at all	87 (4.88)	67 (5.75)
	Very little	62 (3.48)	37 (3.18)
	Somewhat	91 (5.11)	53 (4.55)
	Very much	1542 (86.53)	1008 (86.52)
6	**How much do people in your community value childhood vaccination services?**		
	Not at all	94 (5.27)	64 (5.49)
	Very little	85 (4.77)	53 (4.55)
	Somewhat	284 (15.94)	184 (15.79)
	Very much	1319 (74.02)	864 (74.16)

7	**How much does your spouse or partner approve of childhood vaccination?**		
	Not at all	143 (8.02)	100 (8.58)
	Very little	76 (4.26)	53 (4.55)
	Somewhat	96 (5.39)	54 (4.64)
	Very much	1467 (82.32)	958 (82.23)
8	**How much do other parents in your community approve of childhood vaccination?**		
	Not at all	94 (5.27)	61 (5.24)
	Very little	74 (4.15)	44 (3.78)
	Somewhat	281 (15.77)	179 (15.36)
	Very much	1333 (74.80)	881 (75.62)
9	**How much do trusted leaders in your community approve of childhood vaccination?**		
	Not at all	90 (5.05)	59 (5.06)
	Very little	75 (4.21)	44 (3.78)
	Somewhat	163 (9.15)	105 (9.01)
	Very much	1454 (81.59)	957 (82.15)
10	**How much does your religion influence vaccination decision for your child?**		
	Not at all	354 (19.87)	228 (19.57)
	Very little	97 (5.44)	68 (5.84)
	Somewhat	108 (6.06)	64 (5.49)
	Very much	1223 (68.63)	805 (69.10)
11	**How much would you say childhood vaccination goes together with your religious beliefs?**		
	Not at all	450 (25.25)	287 (24.64)
	Very little	108 (6.06)	72 (6.18)
	Somewhat	162 (9.09)	97 (8.33)
	Very much	1062 (59.60)	709 (60.86)
12	**How much of a health threat do you think measles is for children who are unvaccinated?**		
	Not at all	223 (12.51)	144 (12.36)
	Very little	77 (4.32)	53 (4.55)
	Somewhat	61 (3.42)	33 (2.83)
	Very much	1421 (79.74)	935 (80.26)
13	**How much do you think the illnesses which vaccination prevent are severe?**		
	Not at all	190 (10.66)	139 (11.93)
	Very little	78 (4.38)	51 (4.38)
	Somewhat	60 (3.37)	29 (2.49)
	Very much	1454 (81.59)	946 (81.20)
14	**Do you know of any child in your family or community that was infected with measles in the last year?**		
	No	1521 (85.35)	988 (84.81)
	Unsure	10 (0.56)	7 (0.60)
	Yes	251 (14.09)	170 (14.59)
15	**During your last vaccination visit for this child, were you treated with respect by the vaccination staff?**		
	No	653 (36.64)	438 (37.60)
	Unsure	133 (7.46)	70 (6.01)
	Yes	996 (55.89)	657 (56.39)
16	**During your last vaccination visit for this child, were you satisfied with how the child was handled by vaccination staff?**		
	No	535 (30.02)	347 (29.79)
	Unsure	133 (7.46)	72 (6.18)
	Yes	1114 (62.51)	746 (64.03)

17	**If you have another child in the future, do you plan to accept all recommended vaccinations for him/her?**		
	No	431 (24.19)	280 (24.03)
	Unsure	78 (4.38)	49 (4.21)
	Yes	1273 (71.44)	836 (71.76)
18	**Do you know of any child in your family or community that has experienced vaccine side effects in the last year?**		
	Yes	220 (12.35)	146 (12.53)
	Unsure	3 (0.17)	2 (0.17)
	No	1559 (87.49)	1017 (87.30)
19	**Have you ever refused getting a recommended vaccine for your child?**		
	Yes	190 (10.66)	118 (10.13)
	Unsure	64 (3.59)	44 (3.78)
	No	1528 (85.75)	1003 (86.09)
20	**Have you ever delayed getting a recommended vaccine for your child?**		
	Yes	207 (11.62)	129 (11.07)
	Unsure	73 (4.10)	49 (4.21)
	No	1502 (84.29)	987 (84.72)
21	**How many vaccines do you find acceptable for your child to receive at a single visit?**		
	One	1268 (71.16)	836 (71.76)
	Two	225 (12.63)	139 (11.93)
	Three or more	289 (16.22)	190 (16.31)
22	**How do people in your community usually speak about childhood vaccination services?**		
	Negatively	109 (6.12)	76 (6.52)
	Mixed	980 (54.99)	609 (52.27)
	Positively	693 (38.89)	480 (41.20)

The VaDQ-22 score mean was 84.6, and after dichotomizing the scores utilizing the mean as our cut-point, 71% were childhood vaccination accepting while 29% were childhood vaccination hesitant. The VaDQ-15 mean score was 88.8; after dichotomizing the scores, 68% were childhood vaccination accepting and 32% were childhood vaccination hesitant, and the VaDQ-11 mean score was 90.1; after dichotomizing the scores, 72% were childhood vaccination accepting and 28% were childhood vaccination hesitant. When utilizing each VaDQ version's own mean score as the cut-point for dichotomization, and the VaDQ-22 as the gold standard, VaDQ-15 had a sensitivity of 89.3% (95% CI: 87.2%, 91.4%) and specificity of 83.2% (95% CI: 79.2%, 87.2%), and VaDQ-11 had a sensitivity of 94.4% (95% CI: 92.9%, 96.0%) and specificity of 81.1% (95% CI: 77.0%, 85.3%). Regarding our sensitivity analysis, we found that alternatively using the VaDQ-22 mean score (84.6) as the dichotomization cut-point across the

board resulted in a VaDQ-15 sensitivity of 99.5% (95% CI: 99.0%, 100.0%) and specificity of 74.6% (95% CI: 70.0%, 79.3%), and a VaDQ-11 sensitivity of 99.4% (95% CI: 98.9%, 99.9%) and specificity of 52.2% (95% CI: 46.9%, 57.5%). Using each VaDQ version's own median score (VaDQ-22 median of 88.6, VaDQ-15 median of 93.0, and VaDQ-11 median of 95.1) as an alternate cut-point for dichotomization resulted in a VaDQ-15 sensitivity of 77.7% (95% CI: 74.0%, 81.4%) and specificity of 75.7% (95% CI: 72.5%, 79.0%), and VaDQ-11 sensitivity of 65.3% (95% CI: 61.1%, 69.5%) and specificity of 66.7% (95% CI: 63.1%, 70.2%). Finally, using the VaDQ-22 mode score (86.1) as the dichotomization cut-point across the board resulted in a VaDQ-15 sensitivity of 99.5% (95% CI: 99.0%, 100.0%) and specificity of 73.5% (95% CI: 69.1%, 77.9%), and a VaDQ-11 sensitivity of 99.1% (95% CI: 98.4%, 99.8%) and specificity of 66.7% (95% CI: 61.9%, 71.4%). We were unable to calculate sensitivity and specificity when using each VaDQ version's own mode as both the VaDQ-15 and VaDQ-11 modes were 1.00 resulting in all participants being dichotomized to childhood vaccination hesitant (Table 4).

Table 4: Sensitivity analysis: sensitivity and specificity VaDQ-15 and VaDQ-11 among those with at least 1 child in the household, DRC, 2021 (N = 1165)

Cut-Point Description	VaDQ-22 Vs. VaDQ-15		VaDQ-22 Vs. VaDQ-11	
	Sensitivity (95% CI)	Specificity (95% CI)	Sensitivity (95% CI)	Specificity (95% CI)
Each VaDQ Version's Mean	VaDQ-15 Cut-point Score: 88.8		VaDQ-11 Cut-point Score: 90.1	
	89.3% (87.2%, 91.4%)	83.2% (79.2%, 87.2%)	94.4% (92.9%, 96.0%)	81.1% (77.0%, 85.3%)
VaDQ-22 Mean	VaDQ-22 Cut-point Score: 84.6		VaDQ-22 Cut-point Score: 84.6	
	99.5% (99.0%, 100.0%)	74.6% (70.0%, 79.3%)	99.4% (98.9%, 99.9%)	52.2% (46.9%, 57.5%)
Each VaDQ Version's Median	VaDQ-15 Cut-point Score: 93.0		VaDQ-11 Cut-point Score: 95.1	
	77.7% (74.0%, 81.4%)	75.7% (72.5%, 79.0%)	65.3% (61.1%, 69.5%)	66.7% (63.1%, 70.2%)
VaDQ-22 Median	VaDQ-22 Cut-point Score: 88.6		VaDQ-22 Cut-point Score: 88.6	
	100.0% (100.0%, 100.0%)	55.1% (51.3%, 58.8%)	98.0% (96.7%, 99.2%)	46.3% (42.5%, 50.0%)
Each VaDQ Version's Mode	VaDQ-15 Cut-point Score: NA		VaDQ-11 Cut-point Score: NA	
	-	-	-	-
VaDQ-22 Mode	VaDQ-22 Cut-point Score: 86.1		VaDQ-22 Cut-point Score: 86.1	
	99.5% (99.0%, 100.0%)	73.5% (69.1%, 77.9%)	99.1% (98.4%, 99.8%)	66.7% (61.9%, 71.4%)

Discussion:

Just above two-thirds of those with at least 1 child in the household in this cohort were childhood vaccination accepting based on the VaDQ-22 and utilization of the mean for dichotomization as described above. This lines up with previous studies in other LMICs in South and Southeast Asia (Indonesia[21] Malaysia[22,23] South India[24]) and other African countries including Cameroon,[14] Nigeria[15] and Sierra Leone[17] which also reported fairly high levels of childhood vaccination acceptance among parents/caretakers. This also further supports the use of the validated VaDQ-22 as our gold standard for assessing accuracy of the shortened versions of the VaDQ via sensitivity and specificity.

In establishing the sensitivity and specificity of both the VaDQ-15 and VaDQ-11 using various dichotomization cut-points, we determined that the VaDQ-11 had the most accurate result when utilizing the VaDQ-11 mean for dichotomization, resulting in the highest combination of sensitivity and specificity. Based on these results, there is evidence to support the use of the VaDQ-11 as a robust but efficient tool to accurately identify caretakers who are childhood vaccination accepting (94.4% sensitivity) while maintaining good accuracy to also identify caretakers who are truly childhood vaccination hesitant (81.1% specificity). This would allow for the saving of time and resources in the field, which is extremely valuable when working in LMICs, like the DRC, where resources are scarce and data collection can often be very time consuming and logistically challenging. Additionally, our use of the VaDQ-11 mean as the dichotomization cut-point aligns well with the methods used for dichotomization in the VaDQ validation study done in Sierra Leone.[17] While slight, we found it interesting that the VaDQ-15 was a little less accurate than the VaDQ-11 as it is more similar to the gold standard VaDQ-22. However, looking at the distribution of the question items that remained in the VaDQ-15 and were removed from the VaDQ-11, it's likely the two items that asked about religion impacted this outcome the most as the distribution of those two items was notably different from all other

VaDQ items, but they were given more weight when other items were removed from the VaDQ-22 to get to the VaDQ-15.

While we had considerable childhood vaccination acceptance among our study participants, just under one-third were childhood vaccination hesitant. Given the ongoing rates of unvaccinated and undervaccinated children in the DRC, combined with recent events related to the Covid-19 pandemic that affected vaccine coverage in the DRC, including healthcare infrastructure and lacking vaccine supply,[25] and the continuing challenges of the spread of misinformation and vaccine hesitancy, it is important to address childhood vaccination hesitancy among caretakers in the DRC as even fewer childhood vaccination hesitant caretakers than resulted from this study can contribute to an increase in VPD outbreaks and VPD-related morbidity and mortality.[26] This highlights the need to ensure high levels of childhood vaccination acceptance among parents/caretakers, and use of a robust and efficient tool like the VaDQ-11 to get an accurate quantification of the levels of childhood vaccination acceptance and hesitancy would help support public health initiatives by providing data to support targeting populations in the DRC with tailored vaccination programs, campaigns and interventions based on the resulting childhood vaccination demand (accepting or hesitant).

A key strength of our study was that we did not have any missing data for all 22 items of the validated VaDQ-22, and therefore also had complete data for all items of both the VaDQ-15 and VaDQ-11, allowing all analyses to be run with a large sample size. Additionally, this study provides evidence that the more efficient VaDQ-11 would be quite accurate in determining childhood vaccination acceptance and hesitancy in the DRC, and utilization of this tool would allow for the saving of time and resources in the field.

However, we also had a few limitations in our study. We included participants in our analysis based on whether they had at least 1 child in the household. However, this did not specify whether the participant was responsible for vaccination decisions for the child, which

may have led to bias and may have therefore over- or underestimated the childhood vaccination demand reported here. We also did not have a confirmatory variable in our dataset, such as whether the child in the household was fully vaccinated, partially vaccinated/delayed, or unvaccinated which would have allowed us to verify our results. Finally, there are other studies forthcoming in which the authors were able to optimize the VaDQ using a different number of items (e.g., VaDQ-14) which suggests more research utilizing the VaDQ would help confirm which combination of VaDQ items results in optimal efficiency while maintaining robustness in different populations.

Conclusion:

Our study identified the VaDQ-11 as an efficient and effective alternative to the longer, validated VaDQ-22 for use among those with at least 1 child in the household in the DRC. We found that the VaDQ-11 is quite accurate for quantifying childhood vaccination demand, with an excellent sensitivity and good specificity when utilizing the mean as the dichotomization cut-point. Use of the VaDQ-11 would afford for the saving of time and resources when used in LMICs, particularly in the DRC, where resources can be scarce, and efficiency is a necessity. The improved efficiency of the VaDQ-11 would allow for greater use of this quantifying questionnaire, resulting in a broader understanding of childhood vaccination acceptance and hesitancy in the DRC. This would help guide efforts to tailor public health interventions focused on optimizing childhood vaccination uptake, such as implementing a program focused on vaccination accessibility in communities in which it is determined that the population has high levels of childhood vaccination acceptance, or a program focused on addressing the factors contributing to childhood vaccination hesitancy, such as vaccine misinformation, in a population that is determined to have higher levels of hesitancy, resulting in an overall increase in childhood vaccination rates.

Supplemental Table 1. Questions on Vaccination Demand Questionnaire (VaDQ)				
Item		**Questionnaire Version**		
	Responses	VaDQ-22	VaDQ-15	VaDQ-11
1. How much do you think that vaccines are good for your child?	(1) not at all (2) very little (3) somewhat (4) very much	X	X	X
2. How much do you think that vaccines are safe for your child?		X	X	X
3. How much do you think that vaccines protect your child against diseases?		X	X	X
4. How much do you feel confident in your ability to take your child for scheduled vaccination visits?		X	X	Dropped
5. How much would you encourage others to get their children vaccinated?		X	Dropped	
6. How much do people in your community value childhood vaccination services?		X	X	X
7. How much does your spouse or partner approve of childhood vaccination?		X	X	Dropped
8. How much do other parents in your community approve of childhood vaccination?		X	X	X
9. How much do trusted leaders in your community approve of childhood vaccination?		X	X	X
10. How much does your religion influence vaccination decision for your child?		X	X	Dropped
11. How much would you say childhood vaccination goes together with your religious beliefs?		X	X	Dropped
12. How much of a health threat do you think measles is for children who are unvaccinated?		X	X	X
13. How much do you think the illnesses which vaccination prevent are severe?		X	X	X
14. Do you know of any child in your family or community that was infected with measles in the last year?	(1) No (2) Unsure (3) Yes	X	Dropped	
15. During your last vaccination visit for this child, were you treated with respect by the vaccination staff?		X	Dropped	
16. During you last vaccination visit for this child, were you satisfied with how the child was handled by vaccination staff?		X	Dropped	
17. If you have another child in the future, do you plan to accept all recommended vaccinations for him/her?		X	Dropped	
18. Do you know of any child in your family or community that has experienced vaccine side effects in the last year?	(1) Yes (2) Unsure (3) No	X	Dropped	
19. Have you ever refused getting a recommended vaccine for your child?		X	X	X
20. Have you ever delayed getting a recommended vaccine for your child?		X	X	X
21. How many vaccines do you find acceptable for your child to receive at a single visit?	(1) One (2) Two (3) Three or more	X	Dropped	
22. How do people in your community usually speak about childhood vaccination services?	(1) Negatively (2) Mixed (3) Positively	X	X	X

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