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ORIGINAL RESEARCH

Immunisation coverage and its associations in rural Tanzanian infants

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ABSTRACT

Introduction: In Tanzania, vaccination rates (VRs) range from 80% to 90% for standard vaccines, but little information is available about rural populations and nomadic pastoralists. This study investigates levels and trends of the immunisation status of infants at eight mobile reproductive-and-child-health (RCH) clinics in a rural area in northern Tanzania (with a large multi-tribal population that has a significant population of nomadic pastoralists) for the years 1998, 1999, 2006 and 2007. In addition, the influence of tribal affiliation and health system-related factors on the immunisation status in this population is analysed.

Methods: Vaccination data of 3868 infants for the standard bacillus Calmette–Guérin (BCG), poliomyelitis, diphtheria, pertussis, tetanus and measles vaccines were obtained from the RCH clinic records retrospectively, and coverage for both single vaccines and full vaccination by the end of first year of life were calculated. These results were correlated with data on predominant tribal affiliation at the clinic site, skilled attendance at birth, service provision and vaccine availability as independent variables.

Results: In 1998, the full vaccination rate (FVR) across all RCH clinics was 72%, significantly higher than in the other years (1999: 58%; 2006: 58%; 2007: 57%) ($p<0.0001$). BCG and measles VRs were highest in 1998 and 1999, whereas VR was lowest for poliomyelitis in 1999, and for diphtheria–pertussis–tetanus in 2007 (all $p<0.001$). Measles VR showed a declining trend (1998: 72%; 1999: 73%; 2006: 62%; 2007: 59%) affecting the FVR, except in 1999 when poliomyelitis VR was lower (67%). FVR > 80% was only achieved at one clinic during 3 years. No clinic showed a consistent increase of VRs over time. In univariate analysis, predominant tribal affiliation (Datoga tribe) was associated with a low FVR (odds ratio (OR) 4.6 (95% confidence interval (CI) 3.8–5.5)), as were low rates of skilled attendance at birth (OR 3.6 (CI 2.9–4.4)). Other health system-related factors associated with low FVRs included interruption of scheduled monthly immunisation clinics (OR 9.8 (CI 2.1–45.5)) and lack of

vaccines (OR 1.2–2.9, depending on vaccine). In multivariate analysis, predominant Datoga tribal affiliation and lack of vaccines retained their association with the risk of low rates of vaccination.

Conclusions: Vaccination rates in this difficult-to-reach population are markedly lower than the national average for almost all years and clinics. Affiliation to the nomadic Datoga tribe and lack of vaccines determine VRs in this rural population. Improvements in immunisation service delivery, vaccine availability, stronger involvement of the nomadic communities and special outreach services for this population are required to improve VRs in these remote areas of Tanzania.

Key words: immunisation, nomadic pastoralists, rural Tanzania, service provision, vaccination coverage, vaccine availability.

Introduction

Immunisation programs are one of the success stories in international health[1,2]. While there has been significant progress in immunisation coverage in all countries through WHO's Expanded Program on Immunization (EPI), this has not been consistent, with around 19.3 million infants failing to be immunised in 2010[2,3]. Vaccination rates (VRs) have been particularly patchy and low among poor, rural and marginalised groups[1,2]. Reasons for this limited success can be attributed to features within both the vaccination programs and the target populations[1,2].

Like many other developing countries, Tanzania has witnessed some improvement of national immunisation rates over the past decade. While immunisation rates for the individual vaccines bacillus Calmette–Guérin (BCG), three doses of diphtheria–pertussis–tetanus (DPT3), three doses of poliomyelitis (Polio3), and measles have varied nationally from 72% to 90% from 1998 to 2007 and have increased in general[4,5], the three Tanzanian surveys from 1996, 1999 and 2004–2005 indicate a rather low FVR (all vaccines received by 1 year of age), with virtually no increase over the years (1996: 71%; 1999: 68%; 2004–2005: 71%)[6-8] and being well below the WHO targets of >80% coverage in an administrative district and >90% national coverage[1].

The published reports on the vaccination status of infants in Tanzania do not provide detailed data on the infants in difficult-to-reach populations in rural, remote communities. In these areas (and among poorer and less educated families, which are often in the same groups), improvement has been slower[9]. For the Arusha region in northern Tanzania, which includes some parts of the Mbulu area, the investigators' main service area, 80% FVR (based on 53 out of ~56 000 infants) was reported in 2004–2005, while for the Manyara region, which includes the Mbulu district as part of the Mbulu area, the corresponding figure was 74% (based on 57 out of ~51 000 infants)[8,10].

Nomadic pastoralists, who represent a large proportion of the population in the Mbulu area, present a special problem to immunisation services as they are mobile for almost all of the year and hard to reach[11-14]. They place a high value on the wellbeing of their livestock whose health and survival determine the wealth, health and survival of the family and the tribal members[11-14]. Thus the necessity to seek preventive and curative health care for their children and to vaccinate them is not always seen as a priority. Data from pastoralist groups in Chad showed that the vaccination coverage can be almost zero in this population[11,12].

The objectives of this retrospective study were to determine the VRs for the individual vaccines BCG, poliomyelitis, DPT and measles and for all vaccines together (full vaccination rate (FVR)) of all infants (<1 year) who were registered at eight mobile reproductive-and-child-health (RCH) clinics run by the local hospital in the remote, rural Mbulu area in northern Tanzania during the years 1998, 1999, 2006 and 2007; and to analyse differences in individual VRs and FVRs according to clinic and year. The study also examined possible underlying

factors, including predominant tribal affiliation at the clinic site, rates of skilled birth attendance, service provision and vaccine availability. The data was expected to help inform immunisation programs so that they could address any identified gaps in immunisation coverage in these vulnerable populations, and support local and district health authorities to restructure and improve immunisation services especially for disadvantaged clusters within the population.

Methods

Setting

The study was based at the facilities and RCH clinics of Haydom Lutheran Hospital (HLH), a rural church hospital in northern Tanzania located at the southern edge of Mbulu district in the Manyara region (Fig1)[15-19]. The 400-bed hospital serves more than half a million people in the wider catchment area, providing surgical, medical, gynaecological/ obstetric and paediatric services[15-29]. Each year, more than 12 000 inpatients and 70 000 outpatients were treated, and 2200–3500 children were born at the hospital[17,20-29], while more than 11 000 were born at home in the catchment area[10,15-17,20-29]. During the first 2 years of this study (1998–1999), 20 mobile RCH clinics were run by the hospital and located up to 100 km from HLH. In addition, other RCH clinics were operated by government and voluntary agencies in the same area (Fig1). In 2006 and 2007, the number of HLH-affiliated mobile RCH clinics had increased to 27[15-17,28,29]. These clinics, using a four-wheel-drive vehicle or a light aircraft for more remote locations and conducted by HLH staff, were held at fixed locations at regular dates once per month which were made known to the local population in advance. In addition, a permanent RCH clinic was open daily at HLH. Every year, these clinics conducted over 25 000 antenatal care examinations in pregnant women and over 65 000 examinations (including immunisations) in children younger than 5 years[15-17,20-29]. During the clinic sessions, regular educational sessions on various health topics were provided. The Tanzanian child immunisation schedule for the years 1998, 1999, 2006 and 2007 is shown in Table 1[7,30]. In the year 2002, hepatitis B vaccination was added to the national EPI program, which is organised as a governmental, centralised procurement and top-down distribution system of vaccines, and co-administered with DPT in a combination vaccine, but the overall schedule remained the same[30].

Population characteristics

The Mbulu area, located in the southern Karatu district and the Mbulu district (Fig1), is a rural, difficult-to-reach area with poor road infrastructure[8,15-17,19]. Its population is unique in that it comprises several different language groups with distinctly differing ways of life[13,15,16,31-34]. The major tribes are the Iraqw with a population of around 500 000, who are mainly subsistence farmers with some domestic cattle[15,16,31,33,35,36]; and the Datoga, who number around 100 000–150 000 people and are nomadic pastoralists, moving around with their livestock over long distances[13,14,31,33,35]. The third and smallest group, the Hadza hunter–gatherer tribe, numbers only 1000–1500 people[33,34]. The Iraqw mainly populate the highland plateau of the Mbulu and Karatu districts[15,16,31,33,36]. The Datoga and Hadzabe reside in the Yaeda Valley between Lake Eyasi and the eastern escarpment of the Rift Valley, with the Datoga additionally occupying areas south of the HLH catchment area in the Basotu division of Hanang district[13-16,32,33]. The remaining tribes belong to the Bantu who are typically subsistence farmers or small-scale traders[15,16,33]. The Datoga and the Hadzabe are difficult to reach with any kind of social services, including healthcare provision by the mobile RCH clinics[13,14,32,34]. In contrast, the Iraqw and Bantu communities are more easily accessible at these clinics[32,33,35,36].

Data collection

Eight RCH clinics (clinics 1–6 located in the Iraqw mainland; clinics 7 and 8 located in the Datoga mainland) (Table 2; Fig1) were chosen for the study to represent the characteristics of the RCH clinics (location in the Iraqw or Datoga mainland, distance to hospital, remoteness, access by car vs plane). The number of clinics increased from 20 to 27 during the study period, but none of the new clinics was added to this analysis to ensure comparability between the two periods. A retrospective, cross-sectional study design was used to compare vaccination data of the years 1998, 1999, 2006 and 2007 that had been collected by the RCH clinic staff as part of the reporting requirements for the national EPI program.

Table 1: Tanzanian child immunisation schedule for the years 1998, 1999, 2006 and 2007

Type of vaccine	Scheduled age(s) for vaccination[†]
BCG	At birth or at first clinic contact
DPT (and hepB[‡])	1, 2 and 3 months
OPV	Birth, 1, 2 and 3 months
Measles	9 months

[†] Missed vaccinations can be added later. [‡] Added in 2002. BCG, bacillus Calmette–Guérin (tuberculosis vaccine); DPT, diphtheria–pertussis–tetanus; hepB, hepatitis B; OPV, oral poliomyelitis vaccine

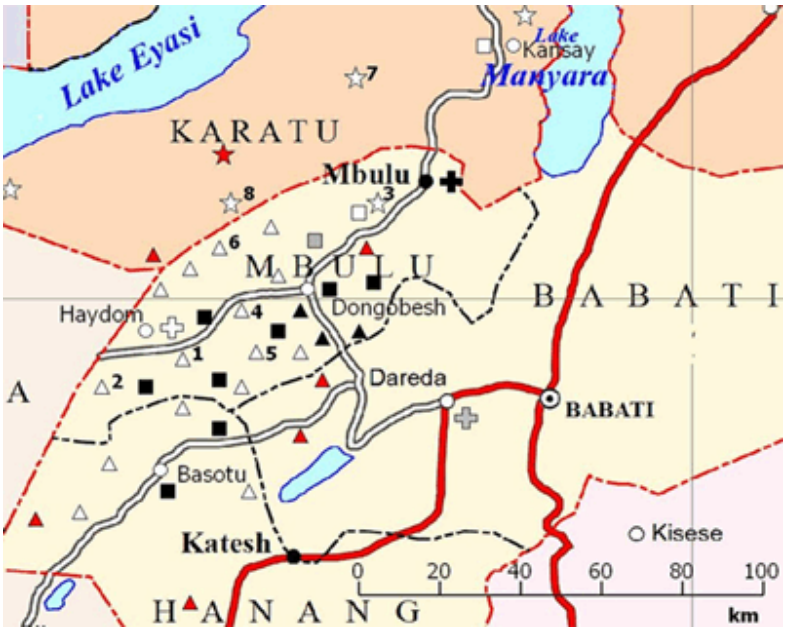

Figure 1: Map of the Mbulu area in the Mbulu district (Manyara region) and Karatu district (Arusha region) (— – — – / — – – – —, regional/district boundaries; /═, major/minor roads; ●/○, district/minor town; ✜/□, Haydom Lutheran Hospital (HLH)/health centre run by HLH; △/☆, reproductive-and-child-health (RCH) clinic run by HLH (access by car/access by plane) in 1998 and 1999; ▲/★, additional RCH clinic run by HLH (access by car/access by plane) in 2006 and 2007; ✜/■, non-government hospital/health centre; ✚/■/▲, government hospital/health centre/RCH clinic; 1–8, numbers of RCH clinics included in the study). Adapted and used with the permission of the Tanzanian Ministry of Lands, Housing & Human Settlements Development (http://xa.yimg.com/kq/groups/24162323/570285250/name/TANZANIA_0.pdf; accessed 26 September 2013)

All registered infants from the eight sites were included in the analysis. Infants were only registered at one clinic and their mothers received vaccination cards, where all vaccinations were recorded in addition to the clinic records. The main dependent variable was the number of vaccinations per registered infant during the first year of life. Independent variables were collected additionally and included:

- major tribal affiliation at each RCH clinic. Data on tribal affiliation were not provided on an individual basis in the records according to government regulations, so each RCH clinic was assigned a major tribal affiliation based on the predominant tribe (>80%) that used the clinic services (Table 2; Fig1)
- distance from RCH clinic to main healthcare provider (HLH or other hospital) (Table 2). This parameter was not used for statistical analysis, but should demonstrate the remoteness of some of the clinics (Fig1)
- skilled attendance status at birth of each registered infant (at a hospital, health centre, dispensary or at home). All births in health institutions (dispensary, health centre, hospital) were deliveries with skilled attendance (Table 2). At home, births were attended by traditional birth attendants, relatives or no attendants at all
- service provision at the RCH clinics (Table 2), defined as the provision of immunisation services regularly once a month. Reasons for not providing the service were inaccessibility of the clinic sites by car or plane due to bad road or airstrip conditions
- vaccine availability at the RCH clinics, which would affect all sites on schedule during the time of vaccine shortage (see later for further explanation in relation to Table 6).

Data analysis

All data were entered manually in data collection sheets, checked for inconsistencies and then entered into the Stastical Package for the Social Sciences v15.0 (SPSS, Inc.; http://www.ibm.com/software/analytics/spss‎) for analysis. The VR at the different RCH clinics was calculated for each single vaccine type and for full vaccination before the first birthday as follows: (number of vaccinated registered infants at RCH clinics ÷ number of all registered infants at RCH clinic) × 100. Differences in VRs (for the single vaccines and for full vaccination) between the different RCH clinics and between the 4 years of study were analysed with the χ^2 test and univariate logistic regression for calculation of odds ratios and confidence intervals. To correlate the outcome variable VR at the different clinics and over the time periods with possible underlying factors, both univariate and multivariate forward logistic regression analyses were performed, adjusting for predominant tribal affiliation at the clinic site and skilled attendance at birth. The independent variables – predominant tribal affiliation, deliveries with skilled attendance (both related to the target group) and service provision (provider-related) – were tested with the FVR as the outcome variable. For the variable vaccine availability (provider-related), the respective single VR was used as the outcome variable. Odds ratios (OR) with 95% confidence intervals (CI) were calculated by these analyses. The level of significance (two-sided) was defined as $p<0.05$.

Ethics approval

Ethics approval for the study was granted by the National Institute of Medical Research (approval number NIMR/HQ/R.8a/Vol. IX/824) and the Commission for Science and Technology (approval number 2010-60-NA-2009-02) in Tanzania and the Human Research Ethics Committee at Curtin University (approval number CIH 8-2008) in Australia. Permission to use the RCH records was obtained from the HLH management.

Results

In all, 3868 infants (1941 male, 1927 female; $p=0.822$) were included in the analysis (Table 3). The annual FVRs varied between 57% and 72% and showed a significant difference

between the highest rate in 1998 and the remaining 3 years (OR = 1.83 (95% CI 1.55–2.16)) (Tables 3,4). Looking at the combined VR for BCG, DPT3 and Polio3 (65–84%), but excluding measles vaccination, there was a significant difference between the rates in 1998, 2006 and 2007 and the lowest rate in 1999 (OR = 2.10 (95% CI 1.79–2.47)) (Tables 3,4). These patterns persisted when clinics 7 and 8, with the lowest FVRs, were excluded from the analysis (Tables 3,4).

For all years, VR for BCG was 93%, for DPT3 82%, for Polio3 80%, and for measles 66% (Table 3). For most of the single vaccines, there appears to have been a reduction in the VR over the years (Tables 3,4). The Polio3 VR increased over the period, with it being lowest in 1999, and achieving better results in 1998, 2006 and 2007 (OR = 2.62 (95% CI 2.21–3.09)). Measles VR was consistently the lowest among all the vaccine types, except for 1999 when Polio3 VR was even lower. FVR was determined by measles VR, except in 1999 when the Polio3 VR affected the FVR even more (Table 3).

Full vaccination coverage as defined by WHO (at least 80% in each administrative unit) was only achieved at clinic 6 during three of the 4 years (Table 3). At no clinic was a consistent increase observed in individual VR or FVR over the study period. The RCH clinics 7 and 8 showed the lowest results for FVRs and individual VRs of the single vaccines (OR = 4.55 (95% CI 3.76–5.48)) (Tables 3,4).

The FVR was lower at the clinics predominantly consulted by the Datoga tribe compared to the Iraqw tribe (OR between 3.33 and 4.97) (Table 5). Combining all years, RCH clinics with low rates of deliveries with skilled attendance (Table 5) tended to have lower FVRs compared to those with intermediate and high rates of skilled deliveries (OR= 3.56 (95% CI 2.91-4.36)). RCH clinics with intermediate rates of skilled deliveries had higher FVR results than RCH clinics with the highest rates (OR = 0.83 (95% CI 0.72-0.96)) (Table 5). The results for single years were more variable (Table 5).

On the provider side, interruption of monthly service provision at the respective RCH clinics (Tables 2,5) was a significant risk factor for low FVRs (Table 5). Even an interruption of up to three service dates per 1 year (<25%) affected the FVR adversely. Interruption of monthly service provision occurred mainly at the RCH clinics that had a predominant Datoga tribal affiliation (except for clinic 3 in 1998, 1999 and 2007, and for clinic 4 in 2006) (Tables 2,5).

Interruptions in the regular supply of vaccines had a detrimental effect on VRs (Table 6). For each single vaccine the degree of lack of vaccine supply corresponded closely with the VRs throughout the years. Bacillus Calmette–Guérin coverage dropped in 2006 and 2007 when the supply of BCG vaccines was interrupted for around 30 days in 2006 and for around 15 days in 2007. The oral polio vaccine was not available for more than half a year during the period 1999–2000 with a resultant marked drop in the VR, particularly for 1999.

For the DPT vaccine, the picture was more variable, but overall periods of interrupted vaccine supply closely corresponded to changes in DPT3 VRs, being the lowest in 2007. For measles vaccination, there was a correlation between diminished vaccine availability (lack of supply less than 15 days) and low VRs in 2006 and 2007. FVR also reflected the measles VR (overall measles VR being the lowest of all four vaccine types). This is unlike the other three vaccines, where a temporary drop in the VR due to interrupted vaccine supply did not affect the overall FVR (except for Polio3 in 1999).

The adjusted OR (AOR) for predominant tribal affiliation at the clinic sites remained significant, demonstrating its strong effect on FVR, while the AOR for skilled attendance at delivery became insignificant in 2007 and for all years together (Table 5).

When looking at the influence of predominant tribal affiliation and delivery with skilled attendance on interruption of service provision, a consistent finding was that adjusting for tribal affiliation lowered the AOR in general, sometimes leading to an insignificant ratio (1998 and 2007). The influence of delivery with skilled attendance and of both parameters together on the AOR was not consistent (Table 5).

Table 2: Predominant tribal affiliation, distance to hospital, skilled attendance at delivery and degree of service interruption at reproductive-and-child-health clinics

			1998	1999	2006	2007
Clinic number	Predominant tribal affiliation	Distance to hospital (km)	Skilled attendance, service interruption	Skilled attendance, service interruption	Skilled attendance, service interruption	Skilled attendance, service interruption
1	Iraqw	8	>30%, 0%	>30%, 0%	>30%, 0%	>30%, 0%
2	Iraqw	10	>30%, 0%	>30%, 0%	>30%, 0%	>30%, 0%
3	Iraqw	20[†]	0–15%, 1–25%	0–15%, 1–25%	16–30%, 0%	16–30%, 0%
4	Iraqw	22	16–30%, 0%	16–30%, 0%	>30%, 1–25%	>30%, 0%
5	Iraqw	25	>30%, 0%	16–30%, 0%	>30%, 0%	>30%, 0%
6	Iraqw	30	16–30%, 0%	16–30%, 0%	16–30%, 0%	16–30%, 0%
7	Datoga	50[‡]	16–30%, >50%	0–15%, 1–25%	0–15%, 1–25%	0–15%, 1–25%
8	Datoga	70	16–30%, 26–50%	0–15%, 1–25%	0–15%, 1–25%	16–30%, 1–25%

[†] Distance to Mbulu Hospital shown; distance to Haydom Lutheran Hospital would be 60 km. [‡] Distance to Mbulu Hospital shown; distance to Haydom Lutheran Hospital would be >100 km

When analysing the AOR for the single vaccines BCG, DPT3, Polio3 and measles, some small changes could be observed for adjusting with predominant tribal affiliation and delivery with skilled attendance, but the main effect of lack of vaccine supply on the single VRs was not altered throughout the analyses (Table 6). This demonstrated a strong effect of interrupted vaccine supply on achievable VRs.

Table 7 summarises the risk factors identified as predictors for poor vaccination coverage rates at the different RCH clinics. Clinics 7 and 8 were particularly vulnerable to risk factors, followed by clinic 3. These were the clinics with the lowest VRs and FVRs. Strong predictors for lower VR and FVR were predominant affiliation with the Datoga tribe, low rate of deliveries with skilled attendance and frequent service interruptions. Lack of individual vaccines determined differences in the vaccination rates of these vaccines between the years, and was a potent factor for the respective VRs.

Discussion

This study provides a detailed analysis of vaccination coverage rates and their associations during the first year of life among a difficult-to-reach population in a remote area in rural Tanzania. While some of the sites in the study had similar annual FVRs to the rural and national FVRs, at other sites they were much lower than national figures[6-8] and rarely reached or exceeded the 80% WHO district target[1]. Although the rates for single vaccines were considerably better than the FVRs, they were still too low, particularly for measles and for Polio3 in 1999. In a study from rural southern Tanzania during 2004, VRs for BCG were 89% (our pooled data: 93%), for DPT3 81% (82%), for Polio3 91% (80%), and for measles 69% (66%)[37]. Similar studies have been published from South Africa[38,39], Uganda[40] and Bangladesh[41], which found that late vaccinations such as the third dose of DPT or measles were consistently affected and that timely administration of the vaccines was frequently delayed[39,40].

Another area of concern was the finding that VRs would not increase over the study period, but in fact decreased at several sites. This parallels to some extent the results of the Tanzanian surveys between 1996 and 2005 with stagnating FVR between 68% and 71%[6-8]. These data indicate first that there is considerable room for improvement of immunisation coverage in difficult-to-reach populations, and second that national immunisation figures can give a misleading impression of the vaccination status of sub-groups like nomadic or remote rural populations.

Table 3: Vaccination rates at reproductive-and-child-health clinics 1998, 1999, 2006 and 2007

Year and clinic		Vaccination (*n*(%))						
		Total	BCG	Polio3	DPT3	Measles	All except measles vacc.	All
1998	1	128	127 (99.2)	109 (85.2)	109 (85.2)	91 (71.1)	108 (84.4)	90 (70.3)
	2	43	42 (97.7)	36 (83.7)	36 (83.7)	25 (58.1)	36 (83.7)	25 (58.1)
	3	64	64 (100)	53 (82.8)	53 (82.8)	46 (71.9)	53 (82.8)	46 (71.9)
	4	248	248 (100)	226 (91.1)	226 (91.1)	198 (79.8)	226 (91.1)	196 (79.0)
	5	159	159 (100)	134 (84.3)	130 (81.8)	106 (66.7)	130 (81.8)	105 (66.0)
	6	139	137 (98.6)	131 (94.2)	128 (92.1)	121 (87.1)	126 (90.6)	118 (84.9)
	7	11	11 (100)	2 (18.2)	2 (18.2)	2 (18.2)	2 (18.2)	2 (18.2)
	8	73	66 (90.4)	45 (61.6)	44 (60.3)	37 (50.7)	42 (57.5)	37 (50.7)
	Subtotal	865	854 (98.7)	736 (85.1)	728 (84.2)	626 (72.4)	723 (83.6)	619 (71.6)
1999	1	127	127 (100)	106 (83.5)	120 (94.5)	107 (84.3)	105 (82.7)	99 (78.0)
	2	29	29 (100)	23 (79.3)	25 (86.2)	22 (75.9)	22 (75.9)	17 (58.6)
	3	108	105 (97.2)	59 (54.6)	74 (68.5)	62 (57.4)	58 (53.7)	41 (38.0)
	4	216	216 (100)	164 (75.9)	191 (88.4)	172 (79.6)	159 (73.6)	145 (67.1)
	5	179	178 (99.4)	132 (73.7)	147 (82.1)	130 (72.6)	125 (69.8)	115 (64.2)
	6	151	151 (100)	103 (68.2)	143 (94.7)	136 (90.1)	102 (67.5)	98 (64.9)
	7	64	62 (96.9)	21 (32.8)	30 (46.9)	25 (39.1)	20 (31.3)	12 (18.8)
	8	79	76 (96.2)	32 (40.5)	42 (53.2)	39 (49.4)	30 (38.0)	26 (32.9)
	Subtotal	953	944 (99.1)	640 (67.2)	772 (81.0)	693 (72.7)	621 (65.2)	553 (58.0)
2006	1	108	102 (94.4)	99 (91.7)	99 (91.7)	84 (77.8)	96 (88.9)	84 (77.8)
	2	73	57 (78.1)	64 (87.7)	62 (84.9)	58 (79.5)	52 (71.2)	42 (57.5)
	3	86	76 (88.4)	74 (86.0)	77 (89.5)	52 (60.5)	72 (83.7)	50 (58.1)
	4	216	190 (88.0)	177 (81.9)	179 (82.9)	120 (55.6)	163 (75.5)	114 (52.8)
	5	145	139 (95.9)	134 (92.4)	136 (93.8)	100 (69.0)	132 (91.0)	99 (68.3)
	6	167	166 (99.4)	162 (97.0)	161 (96.4)	137 (82.0)	159 (95.2)	136 (81.4)
	7	73	39 (53.4)	32 (43.8)	34 (46.6)	3 (4.1)	24 (32.9)	2 (2.7)
	8	126	90 (71.4)	90 (71.4)	90 (71.4)	58 (46.0)	86 (68.3)	54 (42.9)
	Subtotal	994	859 (86.4)	832 (83.7)	838 (84.3)	612 (61.6)	784 (78.9)	581 (58.5)
2007	1	107	103 (96.3)	97 (90.7)	89 (83.2)	81 (75.7)	88 (82.2)	79 (73.8)
	2	61	54 (88.5)	54 (88.5)	49 (80.3)	40 (65.6)	48 (78.7)	38 (62.3)
	3	87	79 (90.8)	72 (82.8)	66 (75.9)	40 (46.0)	66 (75.9)	39 (44.8)
	4	263	247 (93.9)	237 (90.1)	216 (82.1)	159 (60.5)	216 (82.1)	156 (59.3)
	5	179	170 (95.0)	157 (87.7)	145 (81.0)	97 (54.2)	145 (81.0)	95 (53.1)
	6	181	170 (93.9)	169 (93.4)	161 (89.0)	148 (81.8)	157 (86.7)	146 (80.7)
	7	59	36 (61.0)	25 (42.4)	23 (39.0)	9 (15.3)	22 (37.3)	8 (13.6)
	8	119	93 (78.2)	77 (64.7)	78 (65.5)	44 (37.0)	75 (63.0)	43 (36.1)
	Subtotal	1056	952 (90.2)	888 (84.1)	827 (78.3)	618 (58.5)	817 (77.4)	604 (57.2)
All years	Total	3868	3609 (93.3)	3096 (80.0)	3165 (81.8)	2549 (65.9)	2945 (76.1)	2357 (60.9)

BCG, bacillus Calmette–Guérin; DPT3, three doses of diphtheria–pertussis–tetanus vaccine; Polio3, three doses of poliomyelitis vaccine; vacc., vaccine

Table 4: Analysis of vaccination rates over the years and across the different study sites

Variable	*p*-value	Odds ratio (95% CI)
Years, all clinics[†], full vaccination		
All years combined	<0.0001[‡]	
1998 vs remaining years	<0.0001[§]	1.83 (1.55–2.16)[§]
Years, clinics 1–6, full vaccination		
All years combined	<0.0001	
1998 vs remaining years	<0.0001	1.61 (1.35–1.93)
Years, all clinics, combined vaccination without measles vacc.		
All years combined	<0.0001	
1998 + 2006 + 2007 vs 1999	<0.0001	2.10 (1.79–2.47)
Years, clinics 1–6, combined vaccination without measles vacc.		
All years combined	<0.0001	
1998 + 2006 + 2007 vs 1999	<0.0001	2.28 (1.89–2.75)
Years, all clinics, BCG vacc.		
All years combined	<0.0001	
1998 + 1999 vs 2006 + 2007	<0.0001	11.86 (7.48–18.81)
Years, all clinics, DPT3 vacc.		
All years combined	0.0009	
1998 + 1999 + 2006 vs 2007	0.0006	1.37 (1.14–1.63)
Years, all clinics, Polio3 vacc.		
All years combined	<0.0001	
1998 + 2006 + 2007 vs 1999	<0.0001	2.62 (2.21–3.09)
Years, all clinics, measles vacc.		
All years combined	<0.0001	
1998 + 1999 vs 2006 + 2007	<0.0001	1.76 (1.54–2.02)
Clinics, full vaccination		
1998, all clinics	<0.0001	
1998, clinics 1–6 vs clinics 7 and 8	<0.0001	3.33 (2.11–5.26)
1999, all clinics	<0.0001	
1999, clinics 1–6 vs clinics 7 and 8	<0.0001	4.82 (3.24–7.18)
2006, all clinics	<0.0001	
2006, clinics 1–6 vs clinics 7 and 8	<0.0001	4.97 (3.53–6.99)
2007, all clinics	<0.0001	
2007, clinics 1–6 vs clinics 7 and 8	<0.0001	4.24 (2.98–6.03)
All years combined, all clinics	<0.0001	
All years combined, clinics 1–6 vs clinics 7 and 8	<0.0001	4.55 (3.76–5.48)

[†] Clinics 1–6, predominantly Iraqw affiliation; clinics 7 and 8, predominantly Datoga affiliation. [‡] $\square^2$ test. [§] Univariate logistic regression. BCG, bacillus Calmette-Guérin; CI, confidence interval; DPT3, three doses of diphtheria–pertussis–tetanus vaccine; Polio3, three doses of poliomyelitis vaccine; vacc., vaccine

Whether the national Tanzanian vaccination data represent over-estimates of vaccine coverage as suggested recently by Lim and colleagues cannot be confirmed by this study, but their results might indicate that the findings of this study are closer to real vaccination coverage than official data[42]. However, national immunisation days can considerably help in improving vaccination coverage. In 1999 and 2000, the Tanzanian government conducted national immunisation days for improving poliomyelitis vaccine uptake[43]. Thus it may be possible that the actual figures for Polio3 VRs in 1999 were considerably better than documented in the RCH records as these national vaccination days were not recorded in the same system.

Table 5: Univariate and multivariate logistic regression analyses for the dependent variable 'full vaccination status'

Variable		Vaccinated?		OR (95% CI)	AOR (95% CI)† (tribe)	AOR (95% CI)† (delivery)
		Yes	No			
Predominant tribal affiliation						
Iraqw	1998	580	201	Reference	–	Reference
(clinics 1–6)	1999	515	295	Reference	–	Reference
	2006	525	270	Reference	–	Reference
	2007	553	325	Reference	–	Reference
	All years	2173	1091	Reference	–	Reference
Datoga	1998	39	45	3.33 (2.11–5.26)	–	3.91 (2.44–6.26)
(clinics 7, 8)	1999	38	105	4.82 (3.24–7.18)	–	2.19 (1.35–3.54)
	2006	56	143	4.97 (3.53–6.99)	–	11.78 (6.08–22.84)
	2007	51	127	4.24 (2.98–6.03)	–	4.91 (3.12–7.74)
	All years	184	420	4.55 (3.76–5.48)	–	4.54 (3.62–5.71)
Deliveries with skilled attendance						
1998	>30%	220	110	Reference	Reference	–
	16–30%	353	118	0.67 (0.49–0.91)	0.47 (0.33–0.65)	–
	0–15%	46	18	0.78 (0.43–1.41)	n.c.	–
	Overall	619	264	0.77 (0.60–0.99)	0.66 (0.50–0.86)	–
1999	>30%	116	40	Reference	Reference	–
	16–30%	358	188	1.52 (1.02–2.27)	n.c.	–
	0–15%	79	172	6.31 (4.04–9.88)	2.18 (1.67–2.84)	–
	Overall	553	400	2.82 (2.25–3.53)	2.16 (1.66–2.83)	–
2006	>30%	339	203	Reference	Reference	–
	16–30%	186	67	0.60 (0.43–0.84)	n.c.	–
	0–15%	56	143	4.26 (2.99–6.08)	n.c.	–
	Overall	581	413	1.73 (1.47–2.04)	1.66 (1.19–2.31)	–
2007	>30%	368	242	Reference	Reference	–
	16–30%	228	159	1.06 (0.82–1.38)	0.68 (0.50–0.93)	–
	0–15%	8	51	9.69 (4.52–20.79)	n.c.	–
	Overall	603	453	1.63 (1.32–1.99)	1.15 (0.88–1.52)	–
All	>30%	1043	595	Reference	Reference	–
	16–30%	1125	532	0.83 (0.72–0.96)	n.c.	–
	0–15%	189	384	3.56 (2.91–4.36)	1.31 (1.12–1.53)	–
	Overall	2357	1511	1.56 (1.43–1.72)	1.00 (0.89–1.12)	–
Interruption of service provision						
1998	0%	534	183	Reference	Reference	Reference
	1–25%	46	18	1.14 (0.65–2.02)	n.c.	3.62 (1.66–7.89)
	26–50%	37	36	2.84 (1.74–4.63)	n.c.	2.05 (1.57–2.66)
	>50%	2	9	13.13 (2.81–61.33)	n.c.	2.69 (1.59–4.51)
	Overall	619	246	1.73 (1.40–2.12)	1.38 (0.83–2.29)	2.16 (1.71–2.73)
1999	0%	474	228	Reference	Reference	Reference
	1–25%	79	172	4.53 (3.32–6.17)	3.39 (2.23–5.17)	3.43 (2.26–5.20)
	Overall	553	400	4.53 (3.32–6.17)	3.39 (2.23–5.17)	3.43 (2.26–5.20)
2006	0%	411	168	Reference	Reference	Reference
	1–25%	170	245	3.53 (2.70–4.59)	2.19 (1.59–3.02)	2.99 (2.27–3.95)
	Overall	581	413	3.53 (2.70–4.59)	2.19 (1.59–3.02)	2.99 (2.27–3.95)
2007	0%	553	325	Reference	Reference	Reference
	1–25%	51	127	4.24 (2.98–6.03)	n.c.	4.91 (3.12–7.74)
	Overall	604	452	4.24 (2.98–6.03)	n.c.	4.91 (3.12–7.74)

Table 5 cont'd.

Variable		Vaccinated?		OR (95% CI)	AOR (95% CI)† (tribe)	AOR (95% CI)† (delivery)
		Yes	No			
Interruption of service provision						
All	0%	1972	904	Reference	Reference	Reference
	1–25%	346	562	3.54 (3.03–4.14)	2.03 (1.64–2.51)	3.39 (2.83–4.08)
	26–50%	37	36	2.12 (1.33–3.38)	n.c.	1.57 (1.24–1.99)
	>50%	2	9	9.82 (2.12–45.52)	n.c.	2.25 (1.35–3.76)
	Overall	2357	1511	2.77 (2.42–3.17)	1.58 (1.29–1.92)	2.52 (2.16–2.94)

† Combined adjustment for predominant tribal affiliation and delivery with skilled attendance yielded similar results as for the separate adjustments; data not shown. AOR, adjusted odds ratio (adjusted for predominant tribal affiliation and deliveries with skilled attendance); CI, confidence interval; n.c., not computable (due to 'perfect predictor' problem in logistic regression); OR, crude odds ratio

Table 6: Univariate and multivariate logistic regression analyses for the dependent variable 'single vaccination status'

Vaccine and supply interruption	Vaccinated?		OR (95% CI)	AOR (95% CI)† (tribe + delivery)
	Yes	No		
BCG vacc.				
None	854	11	1.35 (0.56–3.28)	n.c.
None	944	9	Reference	Reference
16–31 days	859	135	16.48 (8.34–32.57)	3.78 (2.66–5.38)
≤15 days	952	104	11.46 (5.77–22.78)	17.26 (8.19–36.39)
All years	3609	259	2.87 (2.42–3.39)	2.79 (2.34–3.35)
DPT3 vacc.				
≤15 days	728	137	1.01 (0.79–1.29)	1.29 (0.99–1.68)
16–31 days	772	181	1.26 (0.99–1.59)	1.13 (0.98–1.29)
None	838	156	Reference	Reference
>31 days	827	229	1.49 (1.19–1.86)	1.17 (1.08–1.27)
All years	3165	703	1.15 (1.07–1.24)	1.18 (1.09–1.27)
Polio3 vacc.				
None	736	129	Reference	Reference
>31 days	640	313	2.79 (2.22–3.52)	1.34 (1.24–1.46)
≤15 days	832	162	1.11 (0.86–1.43)	0.88 (0.67–1.15)
≤15 days	888	168	1.08 (0.84–1.39)	0.89 (0.68–1.17)
All years	3096	772	1.48 (1.38–1.59)	1.46 (1.34–1.58)
Measles vacc.				
1998 None	626	239	1.02 (0.83–1.25)	n.c.
1999 None	693	260	Reference	Reference
2006 ≤15 days	612	382	1.66 (1.37–2.02)	1.76 (1.41–2.21)
2007 ≤15 days	618	438	1.89 (1.57–2.28)	2.24 (1.77–2.84)
All years	2549	1319	1.76 (1.54–2.02)	1.62 (1.39–1.88)

† Separate adjustments for predominant tribal affiliation and delivery with skilled attendance yielded similar results as for the combined adjustment; data not shown. AOR, adjusted odds ratio (adjusted for predominant tribal affiliation and delivery with skilled attendance); CI, confidence interval; BCG, bacillus Calmette–Guérin; DPT3, three doses of diphtheria–pertussis–tetanus vaccine; OR, crude odds ratio; Polio3, three doses of poliomyelitis vaccine; n.c., not computable (due to 'perfect predictor' problem in logistic regression); vacc., vaccine

Table 7: Distribution of identified risk factors at the eight reproductive-and-child-health clinics

RCH clinic	Vaccination rank†	Risk factor						
		Predom. tribal affil. Datoga	Lack of skilled attendance	Interruption of service provision	Lack of vaccine supply			
					BCG	Polio	DPT	Measles
1	2	–	–	–	+	++	++	(+)
2	5	–	–	–	+	++	++	(+)
3	6	–	+	+	+	++	++	(+)
4	3	–	–	(+)	+	++	++	(+)
5	3	–	–	–	+	++	++	(+)
6	1	–	(+)	–	+	++	++	(+)
7	8	+++	++	+++	+	++	++	(+)
8	7	+++	++	++	+	++	++	(+)

† 1, best; 8, worst. +++, risk factor strongly present; ++, risk factor moderately present; +, risk factor mildly present; (+), risk factor hardly present; –, risk factor absent. BCG, bacillus Calmette–Guérin; DPT, diphtheria–pertussis–tetanus; RCH, reproductive and child health

The retrospective approach of this study using secondary data meant that the possibility of some infants receiving missing vaccinations at other RCH clinics while the families were moving from one place to another cannot be excluded. But if these infants attended at a later date the original RCH clinic where they had been initially registered, then vaccinations received at the other clinic and recorded on their vaccination card would have been transferred into the records of the original RCH clinic. As the vast majority of mothers and infants have to walk to the mobile clinics meaning 1–2 hours travelling time for one direction on that day, it is not very likely that they would have changed the clinic site frequently.

A potential unexpected explanation for the low documented measles VR was revealed by informal inquiry. Health staff observed several times that mothers would not return to the registration desk after having their infants vaccinated with the measles vaccine, the last one in the schedule, but would leave the RCH clinic immediately. These vaccinations were not documented in the infants' RCH records and were neither available nor quantifiable in this retrospective analysis. Thus, the registration system at the RCH clinics needed to be modified so that vaccines that were administered would reliably be recorded for each infant. This change has consequently been implemented.

Measles VRs could be 10–20% higher then, giving a potential for considerably higher FVRs. This would explain why so few cases of infants and children with vaccine-preventable diseases were seen at HLH, the main health institution in the area, despite quite a low documented coverage, although up to 50 measles cases were diagnosed in some of the years[20-29]. However, this observation does not explain the differing VRs of the other vaccines as they were given on previous RCH clinic visits, were at least documented on the child's own vaccination card carried by the mother, and could be recorded in the RCH records on the following visits to the clinic.

Due to its retrospective nature, this study could not document infants registered in the RCH files at their first contact who were lost due to late neonatal mortality or death during infancy. When considering data from UNICEF[4,5] and the Tanzanian surveys[6-8], infant mortality in Tanzania was 70–90 deaths per 1000 live births, and 10–15 more deaths per 1000 live births in rural areas. Thus the number of surviving infants at the RCH clinics could well have been smaller by 8–10%. This could increase VRs and FVRs considerably for the surviving infant cohort.

Reproductive-and-child-health clinics in the nomadic Datoga mainland had the lowest VRs throughout the years. Therefore

the effect of underlying factors like tribal affiliation and utilisation of health services (measured as levels of skilled birth attendance as a proxy) on VRs and FVRs was analysed. Univariate analysis showed that differences between the RCH clinics were well explained by predominant tribal affiliation at the sites. Infants from predominant Datoga-affiliated sites had markedly lower immunisation coverage, both for single vaccines and FVRs. Incidentally, these were the sites located farthest from the hospitals in the area (Table 2; Fig1). Whether geographical distance really explains these differences is questionable, as mobile clinics were held close to the population. A better explanation would be the nomadic lifestyle of the Datoga, rendering them less accessible. The wellbeing of their livestock is of major importance for the tribe's survival and wealth, thus they may forego immunisation visits to an RCH clinic in favour of livestock survival[11,12].

Anthropological research suggests that the Datoga are not well reached by the official health system, which they do not perceive with confidence[13-16]. This view is supported by the finding that the rate of deliveries with skilled attendance, which was used as a proxy for contact with the formal health system, was quite low among the Datoga sites compared to the other sites. Preliminary results from another anthropological study indicate that the Datoga do not place a high health priority on vaccination, and perceive interaction with health staff as difficult[44]. Similar findings were reported from nomadic populations in Chad[11].

As the Tanzanian EPI program is a national public health priority with a centralised procurement and distribution system of vaccines, lower-level health facilities like the RCH clinics run by HLH depend on good management and uninterrupted supply to administer this program continuously. Great effort was taken by the RCH staff to calculate correctly the amount of vaccines and other supplies needed and to order these well in advance from the central district office. In addition, it was deemed crucial to adhere strictly to the monthly RCH schedule, which people relied on. Nevertheless, due to difficulties in the timely and adequate supply of vaccines and due to unforeseeable problems to reach the RCH clinic sites on the given day (like impassable roads in the rainy season or no plane available), at times vaccines could not be administered or clinics were not held at all.

The negative effect of interrupted service provision and vaccine availability on VRs and FVRs was evident in the analysis. The predominantly Datoga-affiliated sites, having the lowest VRs and FVRs, were affected by higher levels of interruption of service provision. Poor or absent service provision has been shown to be detrimental to the success of health services such as vaccinations[11,45], antenatal and obstetric care[46] or hospital services[47], as people lose trust in the quality of the services[44,46-49]. There are also the opportunity costs of lost income or time away from caring for other family members which may be a disincentive for health service utilisation[50-52].

The study also highlighted the negative impact of even short periods of disruption to the vaccine supply on vaccination rates[45]. Disruptions to vaccine supply did not affect single vaccine types equally, with some vaccines, such as oral polio vaccine, being more prone to disruptions in supply.

It is debatable whether lack of vaccines is the only explanation for the statistical difference found for BCG and measles VRs. For measles, the problems with correct registration of the vaccination in the RCH records was another likely explanation. The BCG vaccine can be given later during the first year of life, so short periods of interruption in the supply of vaccines, as documented in this study, do not explain the differences fully. The same argument applies to measles vaccination. Less than 15 days of lack of vaccine is too short an interruption to service to explain the drop in VR in 2006 and 2007. Measles vaccine could have been administered at the next clinic date. But given that interruptions in vaccine supply or scheduled clinic dates can lead to a significant loss of trust in the health system, mothers would be less likely to bring their children back for the final vaccine at another date[11,44,47-49]. As noted before, other studies reported that the final vaccines of an immunisation program were especially prone to high attrition rates[39,40].

In multivariate analysis predominant tribal affiliation was a strong underlying effect modifier of VR and FVR. The effect of deliveries with skilled attendance was more variable. The effect of interruption of service provision persisted throughout most of the years. The effect of lack of vaccine supply on vaccination rates for the single vaccines remained almost unchanged in multivariate analysis, demonstrating its importance for vaccination coverage. Other reasons for the low VR and FVR such as educational level[45,53,54], socioeconomic status[39,45,54] and acceptance of vaccination services[44,45,54], could not be analysed as there was no information available due to the retrospective nature of the study and the data sources.

Possible solutions to improve immunisation rates of nomadic and other difficult-to-reach populations can be found from the experience of countries such as Ethiopia, Bangladesh and Chad. In Ethiopia, local community health workers followed the pastoralist Afar tribe to locate their children in the respective locations and vaccinate them. This proactive approach made it possible to increase VRs for DPT3 from almost zero to 42% within a short period of time[55], though sustaining such services over long distances and time periods is a continuing challenge. In Bangladesh, a multifaceted approach including changes to the vaccination sessions and the introduction of community support groups led to significantly higher VRs[56]. In Chad, an innovative approach has been developed to increase immunisation rates[11,12,57,58] . In a region where almost no children had been vaccinated among nomadic pastoralists, the EPI services were combined with veterinary immunisation sessions. The importance which the pastoralist tribes placed on survival of their livestock was used to approach their infants at the same time. This enabled the health system to increase VRs for the first time above 15% in this population[11,12,57,58]. Cost-effectiveness studies have also demonstrated additional benefits[11].

Another area needing attention relates to the service provider. Interruption of monthly service provision is detrimental to the overall success of vaccination programs, even though the actual interruption may be quite short. Similarly, interruptions to the vaccine supply will have equally detrimental effects[45]. Beyond these, differences in access due to mobility of populations, quality of care, and trust and confidence in providers may have accounted for the differences in coverage across the clinics.

Based on recent systematic analyses of failures within immunisation programs[45,54], several areas were identified for action: immunisation services should be brought closer to the communities, involving community-based health workers and community volunteers; the program itself needs better management; actual immunisation sessions need to be aligned closer to the needs of the communities; and information for and communication with the communities (including usage of new media) must be improved[59,60]. Such changes can be expected to lead to significant additional improvements in immunisation coverage[59,60].

The financial and structural support of immunisation programs, as provided by the Global Alliance for Vaccines and Immunization (GAVI), has improved service provision and vaccine supply to a great extent and has boosted vaccination rates considerably[61]. But with 19.3 million children worldwide who had not been vaccinated in 2010[3], the international health community should not underestimate the effort still needed to sustain and improve immunisation coverage even further[59-62].

Conclusion

This study documented VRs and FVRs lower than the national average in a rural and partially nomadic population at different RCH clinics over several years with no consistent increase of coverage rates over time. The nomadic Datoga people seemed to have low acceptance of the RCH clinics and were less able or willing to access the immunisation clinics. These results should help inform public health care providers in restructuring these important preventive services in order to increase vaccination coverage. Equally, improved monitoring systems, improvements in vaccine supply, service delivery, and re-organisation of outreach services for nomadic

communities are urgently required to increase VRs in these remote rural areas of Tanzania.

Dedication

This work is dedicated to the children and their families in the Haydom area; and to all staff at the hospital and at the RCH clinics.

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