The impact of community-based outreach immunisation services on immunisation coverage with GIS network accessibility analysis in peri-urban areas, Zambia

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ABSTRACT

Background Accessibility to health services is a critical determinant for health outcome.

Objectives To examine the association between immunisation coverage and distance to an immunisation service as well as socio-demographic and economic factors before and after the introduction of outreach immunisation services, and to identify optimal locations for outreach immunisation service points in a peri-urban area in Zambia.

Methods Repeated cross-sectional surveys were conducted for two groups of children born between 1999 and 2001, and between 2003 and 2005.The association between immunisation coverage for DPT3 and measles, and access distance, child sex, female headed households, and monthly household income were assessed using logistic regression analysis. Optimal locations for outreach service points were identified using GIS network analysis and genetic algorithms.

Results Before the introduction of outreach services, longer distances to the service points were associated with lower DPT3 and measles immunisation coverage (OR=0.24, 95% CI 0.10 to 0.56, $p<0.01$ for DPT3; and OR=0.38, 95% CI 0.17 to 0.83, $p<0.05$ for measles). However, access distances were not an impediment to immunisation coverage once the outreach services were introduced. The average distance to immunisation services could be decreased from 232.3 to 168.4 metres if the current 12 outreach service points were repositioned at optimal locations.

Conclusion Access distance to immunisation services was a critical determinant of immunisation coverage in a peri-urban area. Intervention via outreach services played an important role in averting the risk of missing out on immunisation. Optimal location analysis has the potential to contribute to efficient decision making regarding the delivery of immunisation services.

INTRODUCTION

Infant immunisation substantially contributes to reducing the burden of childhood illness and improving infant and child survival.[1] Over the past decade, global immunisation programmes have considerably increased immunisation coverage worldwide. The coverage of three doses of diphtheria, pertussis and tetanus (DPT) for children younger than 1 year of age was estimated by the WHO and United Nations Children's Fund (UNICEF) to have reached 75% in 2003.[2] However, the WHO also reported that about 1.4 million children, accounting for 13% of the total number of child deaths worldwide, still died of vaccine-preventable infectious diseases, especially in developing countries.[3 4]

Access distance to immunisation services is a significant predictor of immunisation uptake in developing countries. Ensuring access to immunisation and other necessary health services is of great importance to the improvement of immunisation coverage and overall child growth and development.[5–8] The WHO and UNICEF launched the Global Immunisation Vision and Strategy with a view to reducing vaccine-preventable disease mortality and morbidity by at least two-thirds by 2015.[9] In the Global Immunisation Vision and Strategy, special attention has been paid to making efforts to extend immunisation to unreached urban populations since children in informal settlements of urban areas are at high risk of missing out on immunisation.

In Zambia, the Ministry of Health, in collaboration with the Japan International Cooperation Agency (JICA), launched a community-based outreach immunisation service integrated with other basic health services for children in underprivileged peri-urban areas in 2002. The approach, called the Growth Monitoring Program Plus (GMP+), was delivered in residential areas by trained health volunteers and health professionals in order to ensure access to child health services for potential beneficiaries. As utilisation of health services is a function of accessibility that includes distance, cost and behavioural factors,[10–12] making the provision of GMP+ services accessible contributed to the improvement of immunisation uptake rates.

However, there have been few studies done on the impact of improving accessibility to immunisation services on immunisation coverage in peri-urban areas. Moreover, the efficient allocation of health service points is an important concern for the effective utilisation of limited resources available from the government and in the community.[13 14] A geographical information system (GIS) allows access distances to health services to be measured and provides a practical way to assess the geographic accessibility of said services.[15–17] In this study, we also extended the use of genetic algorithms in optimising the location of immunisation services from within a discrete set of potential locations by minimising aggregated person-distances. This methodology enabled us to explore the threshold level of marginal utility of the number of immunisation service points to be offered.

The objective of this study was to examine the association between immunisation coverage and distance to immunisation service locations as well as socio-economic factors before and after the introduction of the GMP+, and to investigate the number of and optimal locations for outreach immunisation service points with GIS and genetic algorithms.

METHOD

Study area

The study area called George Proper is located on the north-western outskirts of Lusaka city in Zambia and is categorised as one of the low-income peri-urban areas. The population of the study area was 40 352 in 8256 households and 48 798 in 9943 households according to the household surveys conducted by the JICA Primary Health Care Project in 2003 and 2006, respectively. Within the population, 2693 households in the 2003 survey and 3065 in 2006 had at least one or more children under 2 years old. In the study area there is a public health facility called George Health Centre which provides health services for outpatients, mother and child health, maternity, and laboratory services. Public transportation was not available in the study area. Residents went to George Health Centre usually on foot. Roads and paths in the area were not paved.

Intervention

Outreach immunisation services started to be provided monthly at 12 GMP+ service points that were identified in each of 12 administrative zones of the study area in 2002. The GMP+ services were delivered at vacant spaces, gardens or community places where sufficient spaces for service delivery were available. The GMP+ was managed by trained community volunteers who delivered basic child health services including growth monitoring, nutrition counselling, health education, vitamin A supplementation and other necessary services.[18] Immunisation services that offered one dose of BCG, three doses of oral polio (OPV), three doses of DPT and one dose of measles were provided free of charge by medical outreach personnel from the George Health Centre. Before initiation of the GMP+, immunisation services in the study areas were provided only at the George Health Centre and outside the study area in private clinics.

Data collection

Two repeated surveys were conducted. A sample survey in February 2003 was repeated in September 2006. The surveys collected immunisation uptake and socio-demographic information from 280 household samples. For the analysis, children born between 1 September 1999 and 31 August 2001, before the GMP+ intervention, were selected as baseline data from the 2003 survey, and children born between 1 September 2003 and 31 August 2005, after the intervention, were selected as 4-year follow-up data from the 2006 survey (figure 1). Immunisation records for DPT3 and measles, and the dates of birth of sampled children, together with socio-demographic information including the age of caretakers, sex of the children and geographic location were obtained from the Child Health Cards of children under 5 years old and via interviews of caretakers. The sample surveys were conducted by trained surveyors with a systematic random sampling method. The study area was divided into 12 administrative zones, and the number of samples per zone was calculated by a zone to study area population ratio. Ten surveyors were trained in survey methods and two surveyors made up a pair of a survey team. The trained survey team started visiting houses at the south end and moved west along the border of the zone after bypassing a specific number of households which was calculated by dividing the total population of the zones by the number of samples to be collected.

The second survey was a household survey taken in January 2003 and July 2006 which collected information regarding the socio-economic status of all the households in the study area, including monthly income, head of household and employment. Thirty trained surveyors participated in the surveys. Each surveyor was assigned a demarcated survey area and interviewed a head of household or adult family member. From the household survey data gathered in 2003 and 2006, matched data by caretaker, child and house address from the baseline and follow-up data, respectively were used for the analysis (figure 1).

For the analysis of optimal locations for GMP+ sites, all the children in the study area born between 1 September 2004 and 31 August 2005 were selected; information on the address and location of their household was obtained from the 2006 household survey.

Geographic information

A digital base map of Lusaka city was developed by the JICA Primary Health Care Project with satellite imagery (SPOT 5). The map included streets, major official buildings and public health facilities. Based on the Lusaka base map, we digitised households with addresses, small roads and footpaths along which residents moved in the area, with aerial photographs (Ministry of Land, Zambia) and satellite images (QuickBird with 60 cm resolution). The locations of the selected households with targeted children were mapped by means of an address matching method. Address matching is the process of relating an address to a geographic location. The household geographic locations with addresses in the study area were predetermined by the

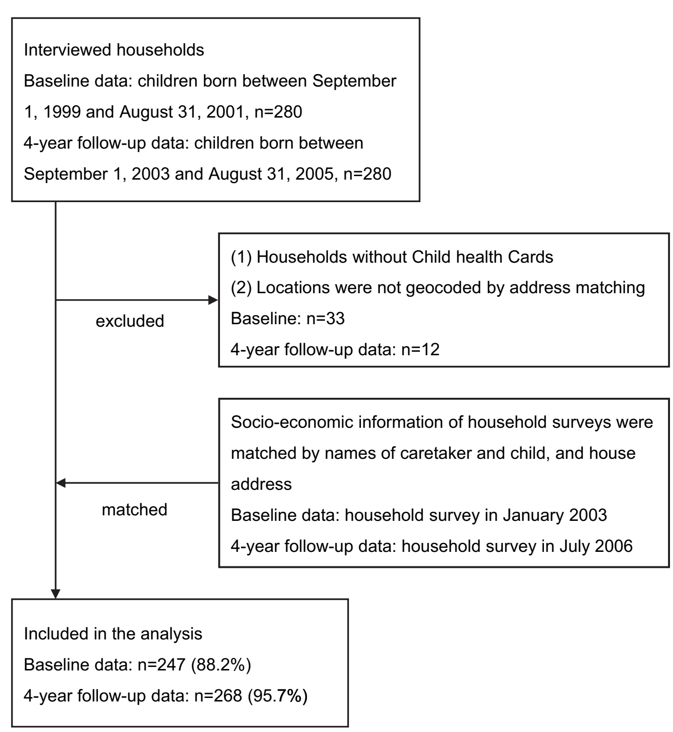

Figure 1 Flow chart of study subjects.

project. Distances from the households to the George Health Centre and the nearest GMP+ sites were measured by network analysis (Arc GIS Network Analyst, ESRI).

For the identification of the optimal location of GMP+ service points, we applied a methodology using a genetic algorithm developed by AJC. The genetic algorithm is a search and optimisation algorithm that simulates the process of genetic mutation and selection in biological evolution.[19] Grid points (20 m) as potential locations were digitised in the study area. The network analysis generated a matrix of distances between grid points and the locations of all the eligible households. The distance matrix was input to a modified grouping genetic algorithm that identified sets of 1 to 20 potential optimal locations. The genetic algorithm ran for 1500 iterations, selecting a set of locations that minimised household to potential location distances. R statistics software was used for the analysis.

Data analysis

A logistic regression analysis was applied to analyse the association between immunisation coverage of DPT3 and measles, and distances to the health facility and other socio-demographic and economic factors. Explanatory variables including child sex, caretaker's age, female headed households, monthly income, distances to George Health Centre from the baseline data, and distances to the nearest GMP+ sites from the 4-year follow-up data, were used to analyse their association with immunisation coverage. Monthly income was divided into two groups: <250 000 and ≥250 000 Kwacha. Survey data were divided into quartiles by distances. Baseline data were divided by distances from households to the George Health Centre; the 4-year follow-up data were divided by distance from households to the George Health Centre and to the nearest GMP+ sites. Groups of the nearest 25% to the health centre and to the GMP+ sites were used as references to compare immunisation coverage of farther distance groups. The OR, 95% CI, and p value of DPT3 and measles for crude and adjusted models were calculated with SPSS V.17.0.

FINDINGS

Of the 280 sampled households in both the baseline and 4-year follow-up data, 247 (88.2%) and 268 (95.7%), respectively, were eligible for the analysis after excluding households which either did not have Child Health Cards for children under the age of 5 years old, or were not geocoded by address matching (figure 1). The mean ages of caretakers in the households in the baseline and follow-up data were 28.07 and 28.23 years, respectively (table 1). The percentage of female headed households was almost the same in the baseline and the 4-year follow-up data (11.3% for the baseline, 13.4% for the 4-year follow-up, p=0.47). Monthly household income increased from the baseline to the 4-year follow-up data (mean: 221 053 Kwacha for the baseline, 293 138 Kwacha for the 4-year follow-up, p<0.01). The mean distance from the households to the George Health Centre in the baseline and the 4-year follow-up data was 810.89 and 860.49 m, respectively.

Immunisation coverage percentages for DPT3 and measles were 75.7% (187/247) and 66.8% (165/247) in the baseline data, respectively. Immunisation coverage increased to 87.3% (234/268) for DPT3 and 76.1% (204/268) for measles in the follow-up data after the GMP+ intervention. Figure 2 shows the locations of the households with immunised and non-immunised children.

The logistic regression analysis of the factors contributing to immunisation coverage in the baseline data indicated that caretakers located at more than 1108 m from the immunisation service points were less likely to have their children immunised against DPT3 (OR=0.25, 95% CI 0.11 to 0.58, p<0.01) and measles (OR=0.25, 95% CI 0.19 to 0.86, p<0.05) when compared to the nearest distance group (0–593 m) (table 2). Likewise, after adjusting potential confounding factors, multivariable models indicated that longer distances to a service point were associated with lower immunisation coverage of DPT3 (OR=0.24, 95% CI 0.10 to 0.56, p<0.01) and measles (OR=0.38, 95% CI 0.17 to 0.82, p<0.05). Children in female-headed households were less likely to be immunised against measles in both crude (OR=0.38, 95% CI 0.18 to 0.83, p<0.05) and adjusted models (OR=0.42, 95% CI 0.19 to 0.95, p<0.05). Other socio-demographic and socio-economic factors were not associated with immunisation coverage for DPT3 and measles in both crude and multivariable models. Logistic regression analysis for both crude and multivariable models of the follow-up data after the GMP+ intervention showed that distance to health centres and GMP+ service sites, and any other explanatory factors were not significantly associated with immunisation coverage for DPT3 and measles.

In order to assess optimal outreach service points, the locations of 1110 households with children born between 1 September 2004 and 31 August 2005 were analysed. The optimal outreach service points for 1 to 20 GMP+ sites were identified and the mean distance to the nearest service points was estimated with network analysis and genetic algorithms. The decline in the mean distance from households to the nearest optimal locations gradually levelled out (figure 3), showing that

Table 1 Socio-demographic and socio-economic characteristics of households and distances to the health centre and the nearest GMP+ service points in the baseline and 4-year follow-up data

Characteristics of variables	Baseline (n=247) n (%)	4-year follow-up (n=268) n (%)	p Value
Child sex			
Male	120 (48.6)	139 (51.9)	0.46
Female	127 (51.4)	129 (48.1)	
Age of caretaker			
Mean±SD	28.07±7.27	28.23±7.49	0.08
<20	18 (7.3)	25 (9.3)	
20–29	136 (55.1)	121 (45.1)	
30–39	77 (31.2)	102 (38.1)	
≥40	16 (6.5)	20 (7.5)	
Head of household			
Female	30 (12.1)	36 (13.4)	0.47
Male	217 (87.9)	232 (86.6)	
Monthly income (Kwacha)			
Mean±SD	221053 ± 105277	293138±150327	<0.01
<250000	103 (41.7)	80 (29.9)	
≥250000	144 (58.3)	188 (70.1)	
Distance to the health facility (metres)			
Mean±SD	810.89±119.66	860.49±343.62	0.11
0–593	70 (28.3)	59 (22.0)	
594–842	55 (22.3)	74 (27.6)	
843–1107	68 (27.5)	61 (22.8)	
≥1108	54 (21.9)	74 (27.6)	
Distance to the nearest GMP+ (metres)			
Mean±SD		183.52±85.68	NA
0–119		67 (25.0)	
120–173		67 (25.0)	
174–247		67 (25.0)	
≥248		67 (25.0)	

GMP+, Growth Monitoring Program Plus.

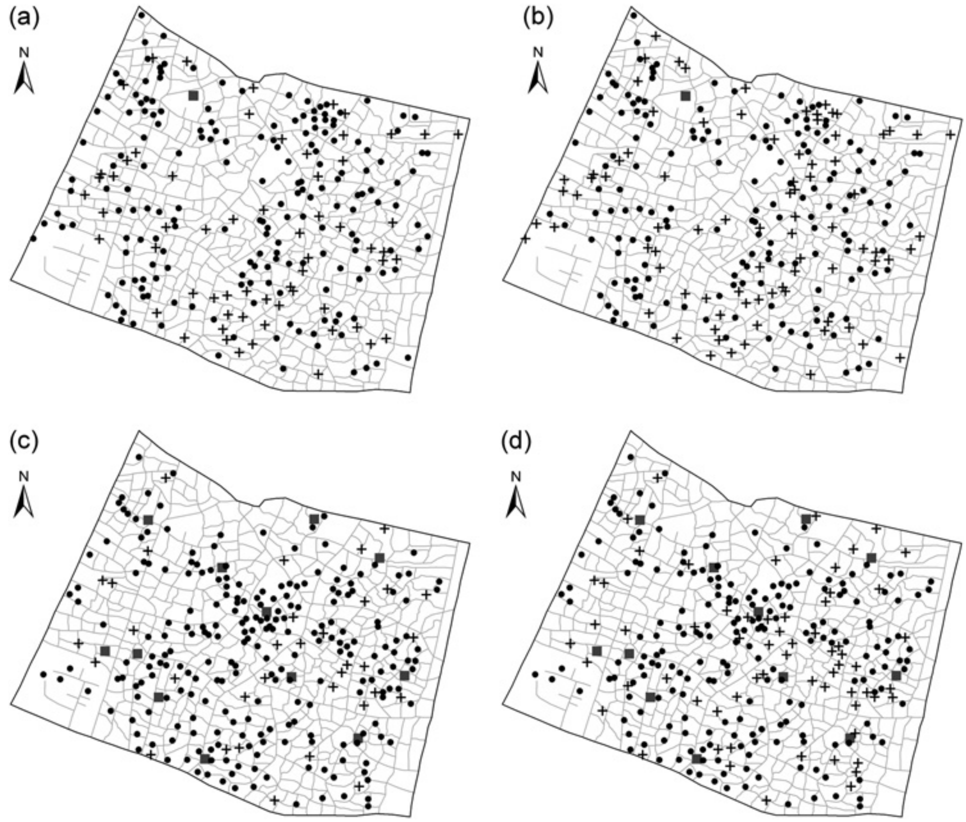

Figure 2 Spatial distribution of households with immunisation uptake of DPT3 and measles in the study area of the baseline and 4-year follow-up data: (A) immunisation of DPT3 in the baseline data; (B) immunisation of measles in the baseline data; (C) immunisation of DPT3 in the 4-year follow-up data; (D) immunisation of measles in the 4-year follow-up data. The circles (●) indicate household locations of immunised children and the crosses (+) indicate household locations of non-immunised children. The squares (■) mark locations of the George Health Centre in the baseline data and GMP+ sites in the 4-year follow-up data.

the average distance could be decreased from 232.3 to 168.4 m if the 12 current service points were placed at optimal locations (figure 4).

DISCUSSION

Access distances to immunisation service points are important determinants of immunisation coverage. In urban areas, children who lived close to the health facilities were more likely to have completed all their immunisations.[8] Utilisation of health facilities proportionally decreased as access distance to the facilities increased.[10] This study also showed that caretakers living at further distances from the health centre were less likely to have their children vaccinated before the GMP+ was initiated. Compared to the nearest distance group by way of reference, certain levels of distance to the health centre were identified as thresholds of negative impact on immunisation coverage. However, after outreach immunisation services were launched at GMP+ points, the access distance factor was no longer found to be an impediment to the improvement of immunisation coverage. Several studies also indicated that proximity to outreach services was significantly associated with full immunisation of children.[5 8] Since the utilisation and uptake of health services are influenced by accessibility variables, the provision of accessible immunisation services can contribute to improving immunisation coverage.

Socio-economic situation is considered to be a significant variable of accessibility. The accessibility of health services, defined as geographical distance to the health services as well as transportation costs and opportunity costs such as absence from one's workplace and waiting time at a health facility, was found to be associated with caretakers' health-related behaviour.[11] Our previous research in the same study area on the association of health service accessibility with caretakers' response to children's danger signs found that longer distances to the health facility and lower monthly income had a negative impact on immediate care-seeking practices for their severely sick children.[17] In this study we have shown that children in female-headed households were less likely to be immunised against measles in the baseline data. However, after the GMP+ was introduced, female-headed households were not a significant determinant of immunisation coverage. Outreach immunisation services have a major potential to benefit the socially vulnerable by minimising the distances and opportunity costs of accessing immunisation services.

Establishing routine outreach services is a critical concern for providing accessible and sustainable immunisation services. The immunisations at GMP+ sites were regularly provided by outreach health centre staff from the nearest health centre. The overall management of the GMP+ and provision of other basic health services including growth monitoring, health education, nutrition counselling and other services were carried out by trained health volunteers. The Reaching Every District strategy initiated in the African region in 2002 emphasises the full involvement of target communities and the utilisation of available local resources for well-planned outreach services.[20 21] Our results suggest that, as a model of routine outreach services, the GMP+ has a potential for improving immunisation coverage.

Integration of outreach immunisation services with other health services is an effective strategy to improve immunisation coverage in urban areas. The population groups most often under-immunised are those in slum areas, illegal squatter settlements and newly expanding peri-urban areas, where vaccine-preventable diseases have high potential transmission rates.[22 23] The WHO and UNICEF have emphasised that the provision of access to immunisation for such unreached urban populations is of great importance in averting the risk of missing out on immunisation.[5] Our observations suggest that regular outreach immunisation services integrated with essential health

Table 2 Logistic regression analysis of immunisation coverage for DPT3 and measles, socio-demographic and socio-economic variables, and distances to immunisation services

	Baseline (n=247)							
			Crude			**Adjusted**		
Variables	**Immunised**	**(%)**	**OR**	**95% CI**	**p Value**	**OR**	**95% CI**	**p Value**
DPT3								
Child sex								
Male	97/120	(80.8)	1.00			1.00		
Female	90/127	(70.9)	0.58	0.32 to 1.05	0.07	0.61	0.33 to 1.14	0.14
Age of caretaker								
<20	13/18	(72.2)	1.00			1.00		
20–29	107/136	(78.7)	1.41	0.47 to 4.31	0.54	1.81	0.55 to 5.82	0.33
30–39	55/77	(71.4)	0.96	0.31 to 3.02	0.95	1.33	0.38 to 4.15	0.64
≥40	12/16	(75.0)	1.15	0.25 to 5.34	0.86	0.97	0.26 to 6.38	0.97
Head of household								
Female	20/30	(66.7)	0.60	0.26 to 1.36	0.22	0.71	0.29 to 1.72	0.45
Male	167/217	(77.0)	1.00			1.00		
Monthly income (Kwacha)								
<250000	77/103	(74.8)	1.00			1.00		
≥250000	110/144	(76.4)	1.09	0.61 to 1.97	0.77	0.99	0.54 to 1.88	0.99
Distance to health facility (metres)								
<593	59/70	(84.3)	1.00			1.00		
593–842	43/55	(78.2)	0.67	0.27 to 1.66	0.38	0.62	0.25 to 1.57	0.31
843–1107	54/68	(79.4)	0.72	0.30 to 1.72	0.46	0.75	0.31 to 1.86	0.54
≥1108	31/54	(57.4)	0.25	0.11 to 0.58	<0.01	0.24	0.10 to 0.56	<0.01
Measles								
Child sex								
Male	87/120	(72.5)	1.00			1.00		
Female	78/127	(61.4)	0.58	0.32 to 1.05	0.07	0.68	0.39 to 1.18	0.17
Age of caretaker								
<20	10/18	(55.6)	1.00			1.00		
20–29	95/136	(69.9)	1.85	0.68 to 5.03	0.23	2.00	0.69 to 5.80	0.20
30–39	49/77	(63.6)	1.25	0.45 to 3.53	0.67	1.54	0.52 to 4.59	0.44
≥40	11/16	(68.8)	3.47	0.73 to 16.53	0.12	1.98	0.45 to 8.56	0.37
Head of household								
Female	14/30	(46.7)	0.38	0.18 to 0.83	<0.05	0.42	0.19 to 0.95	<0.05
Male	151/217	(69.6)	1.00			1.00		
Monthly income (Kwacha)								
<250000	67/103	(65.0)	1.00			1.00		
≥250000	98/144	(68.1)	1.15	0.67 to 1.96	0.62	1.03	0.59 to 1.82	0.91
Distance to health facility (metres)								
<593	52/70	(74.3)	1.00			1.00		
593–842	36/55	(65.5)	0.67	0.30 to 1.42	0.28	0.61	0.28 to 1.35	0.22
843–1107	48/68	(70.6)	0.72	0.39 to 1.76	0.63	0.84	0.39 to 1.84	0.42
≥1108	29/54	(53.7)	0.25	0.19 to 0.86	<0.05	0.38	0.17 to 0.83	<0.05
	4-year follow-up (n=268)							
			Crude			**Adjusted**		
Variables	**Immunised**	**(%)**	**OR**	**95% CI**	**p Value**	**OR**	**95% CI**	**p Value**
DPT3								
Child sex								
Male	122/139	(87.8)	1.00			1.00		
Female	112/129	(86.8)	0.92	0.45 to 1.89	0.82	0.89	0.42 to 1.88	0.75
Age of caretaker (years)								
<20	23/25	(92.0)	1.00			1.00		
20–29	105/121	(86.8)	0.57	0.12 to 2.66	0.48	0.44	0.09 to 2.14	0.31
30–39	88/102	(86.3)	0.55	0.12 to 2.58	0.45	0.41	0.08 to 2.00	0.27
≥40	18/20	(90.0)	0.78	0.10 to 6.11	0.82	0.60	0.08 to 4.90	0.64
Head of household								
Female	30/36	(83.3)	0.70	0.26 to 1.80	0.44	0.75	0.27 to 2.03	0.57
Male	204/232	(87.9)	1.00			1.00		
Monthly income (Kwacha)								
<250000	67/80	(83.8)	1.00			1.00		
≥250000	167/188	(88.8)	1.54	0.73 to 3.26	0.26	1.61	0.74 to 3.50	0.23

Continued

Table 2 Continued

	4-year follow-up (n=268)							
			Crude			Adjusted		
Variables	Immunised	(%)	OR	95% CI	p Value	OR	95% CI	p Value
Distance to health facility (metres)								
0–593	53/59	(89.8)	1.00			1.00		
593–842	65/74	(87.8)	0.82	0.27 to 2.44	0.72	0.78	0.26 to 2.38	0.66
843–1107	52/61	(85.2)	0.65	0.22 to 1.97	0.45	0.66	0.21 to 2.05	0.47
≥ 1108	64/74	(86.5)	0.73	0.25 to 2.12	0.56	0.69	0.23 to 2.06	0.50
Distance to GMP+ (metres)								
0–119	62/67	(92.5)	1.00			1.00		
120–173	56/67	(83.6)	0.41	0.13 to 1.26	0.12	0.37	0.12 to 1.14	0.08
174–247	57/67	(85.1)	0.46	0.15 to 1.43	0.18	0.46	0.14 to 1.45	0.18
≥ 248	59/74	(88.1)	0.60	0.18 to 1.92	0.39	0.58	0.18 to 1.90	0.37
Measles								
Child sex								
Male	106/139	(76.3)	1.00			1.00		
Female	98/129	(76.0)	0.92	0.45 to 1.89	0.82	0.91	0.50 to 1.64	0.75
Age of caretaker								
<20	18/25	(72.0)	1.00			1.00		
20–29	89/121	(73.6)	1.08	0.41 to 2.83	0.87	0.98	0.36 to 2.68	0.98
30–39	81/102	(79.4)	1.50	0.55 to 4.06	0.43	1.28	0.46 to 3.62	0.64
≥40	16/20	(80.0)	1.56	0.38 to 6.31	0.54	1.44	0.34 to 6.08	0.62
Head of household								
Female	25/36	(69.4)	0.67	0.31 to 1.46	0.32	0.75	0.34 to 1.66	0.47
Male	179/232	(77.2)	1.00			1.00		
Monthly income (Kwacha)								
<250000	62/80	(77.5)	1.00			1.00		
≥250000	142/188	(75.5)	0.90	0.48 to 1.67	0.73	0.88	0.46 to 1.68	0.70
Distance to health facility (metres)								
0–593	48/59	(81.4)	1.00			1.00		
593–842	56/74	(75.7)	0.71	0.31 to 1.66	0.72	0.68	0.29 to 1.60	0.37
843–1107	44/61	(72.1)	0.59	0.25 to 1.40	0.45	0.54	0.22 to 1.30	0.17
≥1108	56/74	(75.7)	0.71	0.31 to 1.66	0.56	0.68	0.29 to 1.62	0.38
Distance to the nearest GMP+ (metres)								
0–119	53/67	(79.1)	1.00			1.00		
120–173	44/67	(65.7)	0.51	0.23 to 1.10	0.08	0.51	0.23 to 1.13	0.10
174–247	53/67	(79.1)	1.00	0.44 to 2.30	1.00	1.05	0.45 to 2.47	0.91
≥248	54/67	(80.6)	1.10	0.47 to 2.55	0.83	1.15	0.49 to 2.71	0.75

GMP+, Growth Monitoring Program Plus.

services motivate caretakers through the provision of a wide variety of accessible health services. Routine screening for immunisation status of all the children who visit outreach health services contributes to fewer missed opportunities for immunisation.[24]

Analysis of the optimal number and location of outreach service points contributes to the efficient planning and delivery of services. The current GMP+ points were identified by health volunteers without any access distance analysis. Our study demonstrated that the reallocation of GMP+ points would minimise distances to the service points and that the decline of the mean distance to the health services levelled out as the number of the service points increased. This analysis provides scientific justification for the number and location of GMP+ points. Since most developing countries including Zambia have scarce resources, an analysis of cost efficiency and effectiveness is recognised as being critical in decision making.[25] Optimisation of numbers and location of GMP+ service points enables health administrators to plan the appropriate number of volunteers, materials and recurrent cost. Hence, initial cost for the service may be reduced and its cost benefit be improved.

Geographic information systems provide a set of effective tools for assessing the accessibility of health services in terms of physical distances and for identifying appropriate locations that would minimise distance burdens.[13] Since distances to health services were associated with health-seeking behaviours, the evaluation of the impact of distance on health outcome is of great importance. Geographical accessibility has been measured mainly by Euclidian distance, defined as the straight line distance between two points, or network distance which is measured by connecting points along roads, footpaths or other polylines.[16] Since Euclidian distance simply measures the length of a straight line, it may underestimate travel distances as well as time consumption,[26] whereas network distance overcomes the shortcomings of Euclidian distance and provides more accurate measurements of people's movements.

The adoption of the methodology for quantifying access distances and optimising of health service locations still has a number of challenges. To calculate access distances requires spatial data on health resources, road networks and population. Human resources are also key as the method requires geographic information skills. However, the last decade has seen the radical development of basic GIS infrastructures, such as digital base maps, user-friendly interfaces and a talented pool of human resources. In this study, we utilised satellite imagery to digitise location of facilities, roads and footpaths—a solution which was

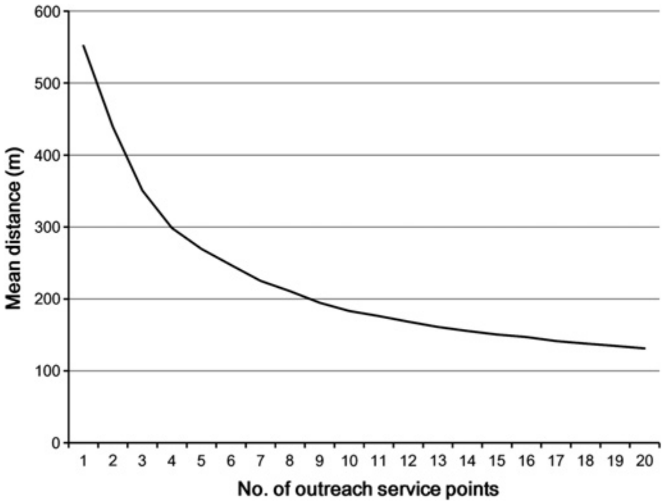

Figure 3 Change in mean distance from the eligible households to the nearest optimal outreach service points as the number of outreach service points increases.

relatively expensive. Alternative inexpensive and practical methods now include using GPS to create base maps and to locate facilities and roads.[27] We emphasise that the method used in this study is feasible and pragmatic in urban settings, requiring only minimum investment in basic GIS infrastructures.

This study had several limitations. We analysed the impact of outreach immunisation services only in a peri-urban area. The application of outreach services in other areas, especially in rural settings, was not investigated. The methods and impacts of outreach immunisation services in rural settings are different from those in urban areas. Further analysis on the application of outreach immunisation in rural areas is required. We did not set a control area for the comparison of the improvement of immunisation coverage with and without outreach immunisation services. However, our previous study has proved the effectiveness of the GMP+ by comparing intervention and control areas.[6] This study focused on the impact of access distance based on the preposition of our previous findings.

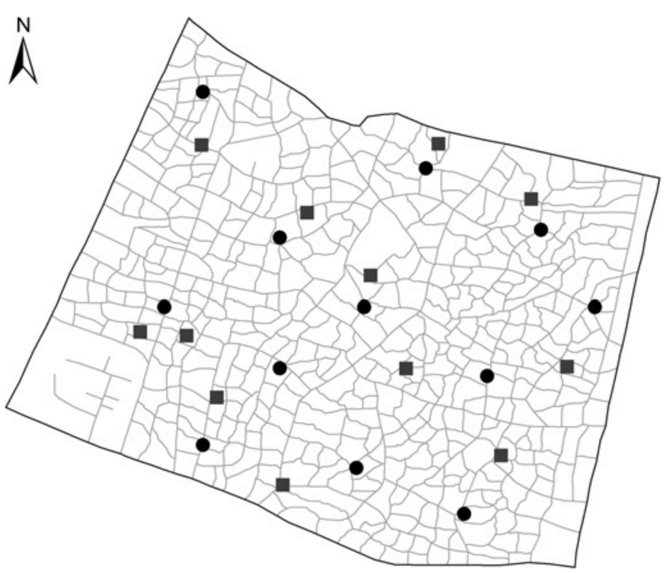

Figure 4 Distribution of current and optimal locations for 12 outreach service points. The squares (■) indicate location of the current 12 outreach service points and the circles (●) indicate location of the optimal 12 outreach service points.

What is already known on this subject

- Infant immunisation substantially contributes to reducing the burden of childhood illness and improving infant and child survival.
- Accessibility to immunisation services is a significant predictor of immunisation coverage.
- However, there have been few studies done on the impact of improving accessibility to immunisation services on immunisation coverage.

What this study adds

- Access distance to immunisation services was a critical determinant of immunisation coverage.
- The intervention of a community-based outreach immunisation programme played an important role in averting missed out immunisations.
- Optimal location analysis has the potential to minimise distances to the outreach service points and contribute to efficient decision making for service delivery.

In conclusion, access distance to immunisation services was a critical determinant of immunisation coverage in a peri-urban area. The intervention of a community-based outreach immunisation programme played an important role in averting missed out immunisations and can contribute to decreased vaccine-preventable diseases and child mortality. Optimal location analysis has the potential to minimise distances to the outreach service points and contribute to efficient decision making for service delivery.

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Competing interests None declared.

Ethical approval The study protocol was approved by the management committee of the Lusaka District Health Management Team, Ministry of Health, Zambia. Data collection via a questionnaire at the field level was conducted by verbal agreement.

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