

Contributions of AFP Contact Samples to the Sensitivity of the AFP Surveillance System in South-Sudan, 2012-2016

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Abstract

Background: South Sudan continues to witness recurrent conflicts, with the attendant risk of polio outbreaks in the country. For AFP surveillance, one stool specimen is required from at least three healthy children who made direct contact with an index AFP cases. This paper evaluates the contribution of contact sampling to the sensitivity of the AFP surveillance system in South-Sudan.

Method: This was a retrospective cohort study carried out in all states in South Sudan using the country's AFP surveillance dataset as at 2016.

Results: A total of 4687 contacts were identified for 1637 index AFP cases. Lakes (740) and Western Equatoria (700) provinces recorded the highest numbers of children contacts while Unity (200) and Central Equatoria (272) provinces recorded the least.

Proportion of children with zero OPV exposure amongst the index AFP cases was lowest in 2013 (1.7%) and highest in 2015 (3.7%). Amongst the AFP contact cases, the proportion of children with zero OPV exposure was highest in 2016 (2.0%) and lowest in 2013 (0.6%).

About 5.3% and 2.9% of the children in the 0-1 year age bracket for both index AFP and contact cases received zero exposure to OPV while 76.9% and 76.5% of the children in the aforementioned age bracket had received three or more doses of OPV. NPEV isolation rate stood at 19.4% and 15.1% for both AFP and contact cases respectively.

Conclusion: The collection of stool samples from contacts with index AFP cases has given the AFP surveillance system in South-Sudan added capacity to detect polioviruses. However, we recommend improved AFP case reporting and RI delivery services, particularly to the children in the 0-1 year age group.

Keywords: AFP contact sampling; Acute Flaccid Paralysis; South-Sudan.

Introduction

The incidence of poliomyelitis due to wild poliovirus (WPV) has decreased worldwide by 99% since the 1988 resolution of the World Health Assembly (WHA) to eradicate polio. The main strategies, which brought about this success, include improved routine immunization (RI) services, supplemental immunization activities (SIAs), adequate outbreak response capacity and a highly sensitive Acute Flaccid Paralysis (AFP) surveillance system [1-5].

Poliovirus surveillance involves a systematic isolation of WPVs from stool samples of AFP cases. An AFP surveillance system must be sensitive enough to pick at least three AFP cases per 100,000 children below 15 years of age. [3,6] For all AFP cases reported, adequate stool samples must be collected and transported to a World Health Organization (WHO) accredited laboratory via a reverse cold-chain transport system for polio enterovirus isolation. [4] Adequate stool sample collection occurs when

two stool samples are collected 24 hours apart within 14 days of paralysis onset and arrive at the laboratory within 72 hours from when the first stool sample was collected [7,8].

However, the sensitivity of the AFP surveillance system in South-Sudan is low. The country has had a long history with polio outbreaks due to large pockets of children remaining unimmunized, weak surveillance systems in some areas that fail to recognize viral importations before they take hold, mobile populations that are hard to access, and conflicts that create inaccessible areas. These conflicts began in 2013 and have lasted through to 2016 and 2017 [9].

The 2004-2005 polio outbreak in South-Sudan was attributed to viral importation while the 2008-2009 polio outbreak that resulted in 24 and 40 WPV cases in 2008 and 2009 respectively, was genetically linked to cases from the 2004-2005 outbreak [10]. This suggests that there were still undetected WPVs in circulation. By the end of 2009 however, South-

Sudan had met global certification standards for non-polio AFP rates ($\geq 2/100,000$) and stool specimen adequacy (80%) and had remained polio-free until a fresh outbreak was declared in 2013 following the confirmation of three WPV cases in Northern Bahr el Ghazal and Eastern Equatorial provinces [11].

From these reports, it is obvious that the risk of undetected polioviruses in circulation in the country remains high. To prevent the risks of future outbreaks, South-Sudan implemented certain strategies that include the addition of contact sampling from all AFP cases and the systematic collection of stool specimens in non-reporting or “silent” provinces to strengthen the sensitivity of the AFP surveillance system [6].

A ‘contact’ of an AFP case is defined as any healthy child below five years of age who was in direct contact with the index AFP case within one week before the onset of paralysis and/or within two weeks after the onset of paralysis [12,13]. The collection of stool specimen from these contacts improves the chances of detecting poliovirus through the AFP surveillance system and the sensitivity of the surveillance system in general. This paper evaluates the sensitivity of the surveillance system in South-Sudan through the collection of stool specimens from contacts of AFP index cases.

Method

Study Location

South-Sudan is a landlocked country located in north-eastern Africa. The country is bordered to the north by Sudan, to the east by Ethiopia, to the southeast by Kenya, to the south by Uganda, to the southwest by the Democratic Republic of Congo and to the west by the Central African Republic. It includes the vast swamp region of the Sudd, formed by the White Nile, locally known as the Bahr al Jabal [14].

This study consists of reports from the 10 states that make up South-Sudan between 2012 and 2016. The states include: Central Equatoria, Eastern Equatoria, Jonglei, Lakes, Northern Bahr el Ghazal, Unity, Upper Nile, Warrap, Western Bahr el Ghazal and Western Equatoria. The population of the people in this country was estimated at 13.1 million people based on United Nations estimates of July 2017 [15] (Figure 1).

Study Design

This was a retrospective cohort study carried out in all states in South Sudan using the country’s AFP surveillance dataset as at 2016.

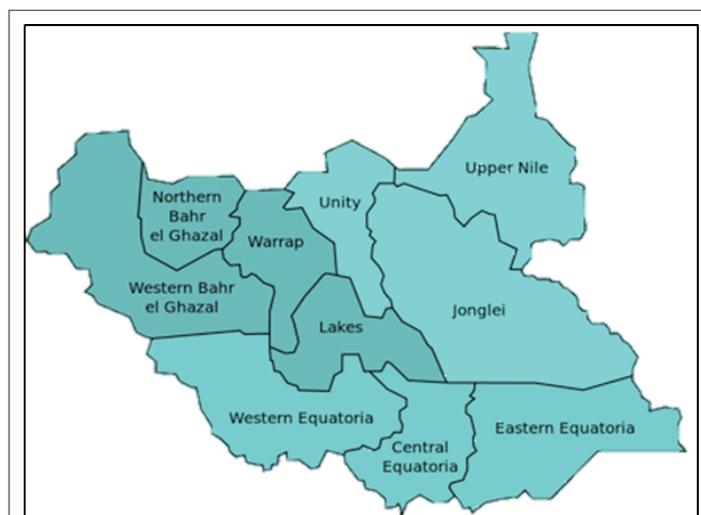


Figure 1: Map showing the provinces that make up South-Sudan [16].

AFP surveillance Network

The AFP surveillance system is based on both active and passive surveillance and it involves a combination of both health facility and community based case search.

The AFP surveillance system in this country is largely dependent on surveillance structures from WHO. South Sudan has 541 community-based informants and 1341 reporting sites that are divided into 308 high priority sites, 403 medium priority sites and 630 low priority sites. The priority level of the facility determines the number of visits by field surveillance officers. High priority sites/health facilities are visited weekly while medium and low priority sites are visited fortnightly and monthly.

Field assistants carry out initial case investigation once a true case of AFP is identified. They then notify field supervisors, who verify the case and supports the field assistant in the collection and transportation of the stool samples to the polio reference laboratory in Kenya for enteroviral isolation. The data manager receives the results; perform analysis and sends feedback to the WHO National focal persons and caregiver.

A true AFP case must show signs of sudden onset of weakness, floppiness or paralysis in one or more limbs of any child from zero to 15years of age.

Contact sampling

Based on the decisions of the Horn of Africa (HOA) and Technical Advisory Group (TAG) meetings on polio eradication in South-Sudan, one stool sample is required from at least three healthy children under five years who were in close contact with index AFP cases irrespective of the adequacy of the sample.

Stool specimens must be collected during the period within one week prior to the onset of paralysis and/or within two weeks after the onset of paralysis. Stool specimens weighing 8grams (i.e. thumb size) must be collected into dry, leak-proof containers and stored in geostyle specimen carriers with frozen ice packs immediately after collection. The specimens are then sent to the laboratory along with the completed AFP C103 forms for children contacts for viral isolation.

Data Collection and Analysis

Epi-data v3.5.1 (EpiData Association, Odense, Denmark) was used for data entry and for analysis. Summarization of variables was done using ‘means’ for quantitative variables and ‘frequencies and proportions’ for qualitative variables. The differences in the baseline characteristics in socio-demographic characteristics were compared using a Chi square test. Multilevel logistic regression analyses were used to compare for any significant differences in socio-demographic and clinical variables.

Results

The collection of stool specimen from children who have made contact with index AFP cases increases the chances of detecting WPVs in the environment. A total of 4,687 children contacts were identified for 1,637 index AFP cases in South-Sudan between 2012 and 2016 (Figure 2).

Table 1 shows the distribution of AFP contacts between 2012 and 2016 by states in South-Sudan. Lakes (740), Western Equatoria (700), Warrap (682) and Eastern Equatoria (600) were the states with the highest numbers of children contacts while Unity (200) and Central Equatoria (272) states recorded the lowest in terms of children contacts

The yearly distribution of the OPV vaccination status of both index AFP and contacts cases between 2012 and 2016 were illustrated in table 2. The percentage of children with zero exposure to OPV amongst the index AFP cases ranged from 2.5%-3.7% while the percentage of children with three or more OPV doses ranged from 86.4%-91% and improved

yearly between 2012 and 2016. The proportion of children with zero OPV exposure amongst the index AFP cases was lowest in 2013 (1.7%) and highest in 2015 (3.7%). Also, the percentage of children who had received three or more doses of OPV amongst the index AFP cases was highest in 2016 (91%) and lowest in 2012 (86.4%).

Amongst the AFP contacts, the percentage of children without any OPV exposure ranged from 0.6%-2.0% between 2012 and 2016. The proportion of children with zero OPV exposure was highest in 2016 (2.0%) and lowest in 2013 (0.6%). Also, the percentage of children with three or more doses of OPV was highest in 2014 (94.4%) and lowest in 2013 (89.7%).

Table 3 illustrates the age distribution and OPV vaccination status of the index AFP and contact cases. About 5.3% and 2.9% of the children in the 0-1 year age bracket for both index AFP and contact cases respectively haven't received any form of OPV while 76.9% and 76.5% of the children in the aforementioned age bracket for both the index AFP and contacts respectively had received three or more doses of OPV.

The percentage of children in the 3-5 years age bracket with zero exposure to OPV was higher (3.4%) amongst the index AFP cases than in the AFP contact cases (0.6%) while the percentage of children with three or more OPV doses was higher (95.3%) amongst the AFP contact cases than in the index AFP cases (89.8%).

The Non-polio Enterovirus (NPEV) status of the index AFP cases and contacts were illustrated in table 4. A total of 317 and 709 stool specimens from the index AFP cases and contacts respectively were positive for non-polio enteroviruses, resulting in a 19.4% and 15.1% NPEV isolation rate for the AFP and contacts cases respectively. NPEV isolation rate ranged from 16.2%-20.9% and 11.1%-19.1% amongst the index AFP and contact cases respectively.

The distribution of the number of index AFP cases and contacts were illustrated in figure 3. The number of index AFP cases and contacts ranged from 913-1035 and 315-349 between 2012 and 2016. The highest number of index AFP cases and contacts were recorded in 2013, while the lowest number of index AFP cases and contacts were in 2014.

Table 1: Distribution of AFP Contacts between 2012 and 2016 by province in South-Sudan.

Province	2012	2013	2014	2015	2016	Total
Central Equatoria	71(26.1)	65(23.9)	47(17.3)	60(22.1)	29(10.7)	272
Eastern Equatoria	97(16.2)	138(23.0)	107(17.8)	150(25.0)	108(18.0)	600
Jonglei	107(28.5)	88(23.4)	23(6.1)	63(16.8)	95(25.3)	376
Lakes	102(13.8)	149(20.1)	164(22.2)	152(20.5)	173(23.4)	740
Northern Bahr el Ghazal	81(16.6)	121(24.1)	96(19.6)	101(20.7)	90(18.4)	489
Unity	54(27.0)	43(21.5)	29(14.5)	44(22.0)	30(15.0)	200
Upper Nile	84(28.5)	77(26.1)	45(15.3)	28(9.5)	61(20.7)	295
Warrap	124(18.2)	129(18.2)	124(18.2)	166(24.3)	139(20.4)	682
Western Bahr el Ghazal	70(21.0)	77(23.1)	90(27.0)	49(14.7)	47(14.1)	333
Western Equatoria	126(18.0)	148(21.1)	171(24.4)	114(16.3)	141(20.1)	700

Table 2: Yearly distribution of the OPV vaccination status of AFP and contact, South Sudan; 2012-2016

Year	AFP Cases				AFP Contact cases			
	0 Doses (%)	1-2 Doses (%)	≥ 3 Doses (%)	Missing no. Of doses (%)	0 Doses (%)	1-2 Doses (%)	≥ 3 Doses (%)	Missing no. Of doses (%)
2012	11(3.4)	31(9.6)	280(86.4)	2(0.6)	7(0.8)	51(5.6)	826(90.2)	32(3.5)
2013	6(1.7)	36(10.3)	304(87.1)	3(0.9)	6(0.6)	65(6.3)	928(89.7)	36(3.5)
2014	10(3.2)	24(7.6)	277(87.9)	4(1.3)	10(1.2)	36(4.0)	846(94.4)	3(0.3)
2015	12(3.7)	29(8.8)	287(87.5)	0(0.0)	7(0.6)	57(6.1)	859(92.7)	5(0.5)
2016	8(2.5)	19(5.9)	292(91.0)	2(0.6)	18(2.0)	32(3.5)	853(93.4)	10(1.1)

Table 3: Age distribution and OPV vaccination status of AFP cases and Contacts, South Sudan; 2012-2016.

Age (years)	AFP Cases				AFP Contact cases			
	0 Doses (%)	1-2 Doses (%)	≥ 3 Doses (%)	Missing no. Of doses (%)	0 Doses (%)	1-2 Doses (%)	≥ 3 Doses (%)	Missing no. Of doses (%)
< 1	9(5.3)	29(17.2)	130(76.9)	1(0.6)	9(2.9)	61(19.6)	238(76.5)	3(1.0)
1 - 3	18(2.0)	75(8.4)	795(88.9)	6(0.7)	23(0.9)	128(5.0)	2410(93.3)	22(0.9)
3 - 5	19(3.4)	34(6.1)	501(89.8)	4(0.7)	10(0.6)	37(2.3)	1533(95.3)	29(1.8)
Missing age	1(6.3)	1(6.3)	14(87.5)	0(0.0)	6(3.3)	15(8.2)	131(71.2)	32(17.4)

Table 4: Non-Polio Enterovirus Status of AFP cases and Contacts, South Sudan; 2012-2016.

Years	Total no. Of AFP Cases		Contacts	
	Positive (%)	Negative (%)	Positive (%)	Negative (%)
2012	66(20.4)	258(79.6)	172(18.7)	744(81.2)
2013	73(20.9)	276(79.1)	129(12.4)	906(87.5)
2014	51(16.2)	264(83.8)	100(11.1)	796(88.8)
2015	60(18.3)	268(81.7)	177(19.1)	750(81.0)
2016	67(20.9)	254(79.1)	131(14.3)	782(85.6)
Total	317(19.4)	1320(80.6)	709(15.1)	3978(84.9)

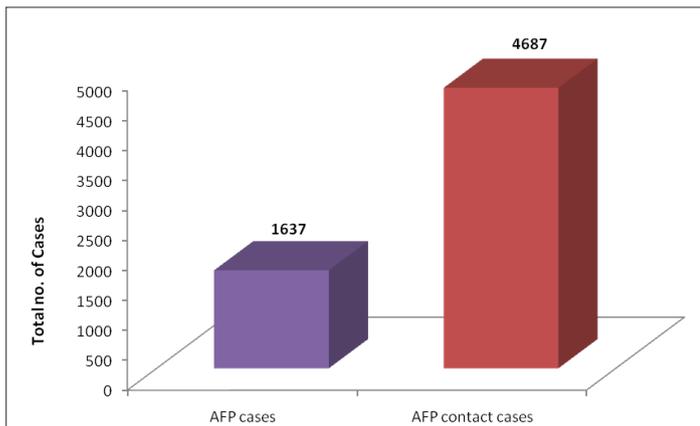


Figure 2: Distribution of Index AFP and Contact cases in South-Sudan, 2012-2016.

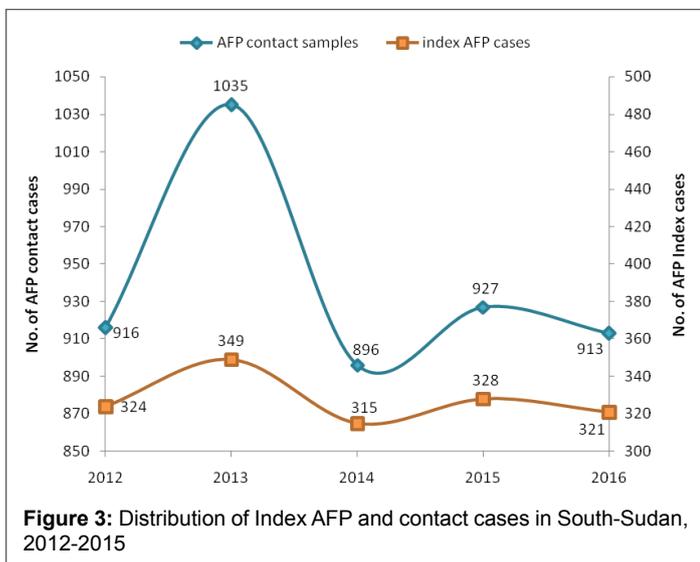


Figure 3: Distribution of Index AFP and contact cases in South-Sudan, 2012-2015

Discussion

The AFP surveillance system involves the identification, reporting, investigation and collection stool samples from AFP cases. An AFP case investigation is incomplete without adequate collection of stool specimens for viral isolation. Usually, one stool specimen is requested from at least three children below five years of age who were in direct contact with index AFP cases in situations where stool samples from such cases were not adequately collected (i.e. when the stool specimen of the index AFP case was not collected within 14 days of paralysis onset, improper stool specimen collection procedure, poor condition of sample due to leakages, desiccation, late arrival of sample at designated laboratory and inadequate cold-chain maintenance during stool collection, storage or transportation) [7].

In South-Sudan however, one stool specimen is requested from the aforementioned number of children contacts for all AFP cases whether stool specimen was collected adequately or inadequately. This is important particularly in South-Sudan because of the high levels of insecurity (i.e. recurrent conflicts) and the resultant frequency of polio outbreaks in the country [8]. Also, poliovirus spreads through oral-focal routes and in environments with poor sanitation as such, contacts of infected persons have a higher chance of being infected [17].

The collection of stool samples from children contacts therefore comes as an extra precautionary strategy put in place to enhance poliovirus isolation and prevent the risk of undetected polioviruses in circulation. In this paper, we assess the contribution of contact sampling to the sensitivity of the AFP surveillance system in South-Sudan.

A total of 4687 children contacts were identified for 1637 index AFP cases in South-Sudan between 2012 and 2016. This compares to the 1768 contacts identified for 568 index AFP cases in Somalia [18]. Even though the figures from Somalia were recorded during the polio outbreak of 2013, it highlights contact sampling as an important tool for expanding the reach to the targeted children thus improving the sensitivity of the AFP surveillance system.

Lakes, Western Equatoria, Warrap and Eastern Equatoria were among the states with the highest numbers of children contacts and AFP cases by implication while Unity and Central Equatoria state were among the least. Lakes state forms parts of the states least affected by the violence in South-Sudan. United Nation's Office for Humanitarian Affairs (UNOHA) estimates that over 395,000 people have been displaced from their homes and clustered in Internally Displaced Persons (IDP) camps since the beginning of the conflict in South-Sudan in December 2013, which has spanned through to 2016 and 2017 [19] Lakes Province has the highest number of IDP camps (91,800) based on UNOHA figures of 2014, even when it isn't among the most populated provinces. Therefore, it is possible that more children contacts (and index AFP cases by implication) were picked from this province due to easy access to the people in IDP camps and in the province in general.

In the case of Warrap and Eastern Equatoria, we believe that the relatively high population together with the number of IDP camps (Warrap: 3,200, Eastern Equatoria: 31,600) could have contributed the reasons for high numbers of cases since these provinces had been mildly affected by the violence based on UNOHA reports [12]. Even with the high numbers of IDP camps in Unity (65,000) and Central Equatoria (64,000), we believe that low numbers of AFP cases and contacts were found because of the population movements out of these provinces even when they have been averagely affected by the conflict in comparison to Lakes.

Our results further indicate that 5.3% and 2.9% of the index AFP cases and children contacts under the 1-year age group had zero exposure to OPV. This is in agreement with another study in China where 5% of the children under the same age bracket had zero exposure to OPV [4]. It also falls within the acceptable range of children population in the aforementioned age group without any OPV exposure [4]. The number of missing doses was more in the AFP contact cases than in the index AFP cases probably due to improper documentation on the part of the field officers during data collection.

Herd immunity is a form of immunity that occurs when the vaccination of a significant portion of a population (or herd) provides a measure of protection for individuals who have not developed immunity [20]. Polio herd immunity measures the average number of children with three or more doses of OPV. Even when the general herd immunity for both the index AFP and contact cases gradually improved from 2012 to 2016, the herd immunity for children under the one-year age bracket remained suboptimal.

In this study, the average herd immunity came approximately at 77% for both index AFP cases and contacts under the one-year age group. This is lower than the 82% average herd immunity recorded in Nigeria between 2011 and 2014 for the children in the same aforementioned age group and lower than the recommended 80-85% herd immunity threshold for poliomyelitis [2,21]. It is important to ensure high vaccination coverage for the children in this age bracket because they are the most susceptible to diseases. This suboptimal herd immunity for these children indicates weakness in the RI system. We recommend engaging in adequate

immunization planning that would improve the delivery of RI services and bridge the gap between the zero dose OPV children and those with 1-2 doses. This would increase herd immunity and better protect the populace against outbreaks from undetected polioviruses.

In total, NPEV isolation rate for the AFP and contacts cases from 2012-2016 stood at 19.4% and 15.4% respectively. These agree with one of AFP's surveillance indicators, which state that NPEVs must be isolated from at least 10% of stool specimen submitted to the laboratory [22]. It shows that the quality of the reverse cold chain is good and that the laboratories are able to perform routine isolation of enteroviruses. This data also indicates higher stool integrity from the index AFP cases in comparison to the contacts. We recommend that proper stool specimen collection procedure be adhered to at all times to maintain stool integrity for improved viral isolation rates. This increases the chances of detecting WPVs in the environment and enhances the sensitivity of the AFP surveillance system in general.

Results further indicate that the number of AFP cases and contacts were highest in the year 2013 but this number started to decline in 2014. This wasn't surprising as it coincided with the period where the conflict in the country began.

The collection of stool samples from children who were in direct contact with index AFP cases has no doubt given the AFP surveillance system in South-Sudan added capacity to detect the presence of polioviruses. We commend the efforts made so far by surveillance officers (especially in these times of conflict) and recommend that more efforts are made to improve AFP case reporting and RI delivery services, particularly to the children in the 0-1 year age group. This ensures that the populace is better protected from the risks of polio outbreaks.

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References

1. Abdel-Mannan OA, Harris MJ, Parker JA, Aly GS, El-Sayed NM (2010) Testing clinical surveillance of acute flaccid paralysis in Egypt post-eradication of poliomyelitis. *Trop Med Int Heal* 15: 1395-1400.
2. Bassey BE, Vaz RG, Braka F, Komakech W, Maleghemi ST, et al. (2016) Profiling the immunity status of children with non-polio acute flaccid paralysis who had not received any doses of oral polio vaccine in the South-South region, Nigeria 2011-2014. *Public Health* 139: 148-153.
3. Addo JK odoom, Ntim NAA, Sarkodie B, Addo J, Minta-Asare K, et al. (2014) Evaluation of AFP surveillance indicators in polio-free Ghana, 2009-2103. *BMC Public Health* 14: 687.
4. Wen N, Fan C-X, Fu J-P, Ning J, Ji Y-X, Luo H-M, et al. (2014) Enhanced surveillance of acute flaccid paralysis following importation of wild poliovirus in Xinjiang Uygur Autonomous Region, China. *BMC Infect Dis* 14: 113.
5. Centers for Disease Control and Prevention (CDC) (2011) Tracking progress toward global polio eradication-worldwide, 2009-2010. *MMWR Morb Mortal Wkly Rep* 60: 441-445.
6. Pomerai KW, Mudyiradima RF, Tshimanga M, Mucchekeza M (2014) Evaluation of the acute flacid paralysis (AFP) surveillance system in Bikita district Masvingo province 2010. *BMC Res Notes* 7: 252.
7. Landiwe KS, Lazarus RK, Ntombenhle J (1972) Evaluating the acute flaccid paralysis surveillance system in south-Africa, 2005-2009-an analysis of secondary data. *Pan Afr Med J* 14: 86.
8. Agrawal S, Singh H (2004) Acute Flaccid Paralysis. *Med journal Armed Forces India* 60: 84-85.
9. Polio global eradication initiative. South Sudan-GPEI.
10. Polio eradication initiative (2013) WHO EMRO. South Sudan, Countries , Polio eradication initiative.
11. World Health Organization. WHO EMR (2013) South Sudan declares polio outbreak a national health emergency . South Sudan-news.
12. Field Guide 1996 Revision Global Programme for Vaccines and Immunization Expanded Programme on Immunization. World Heal Organ.
13. World Health Organization, WHO-recommended standards for surveillance of selected vaccine-preventable diseases.
14. Metz HC (1992) Library of Congress. Federal Research Division., Thomas Leiper Kane Collection (Library of Congress. Hebraic Section). Sudan : a country study [Internet]. Washington, D.C.: Federal Research Division, Library of Congress.
15. United Nations (2017) South Sudan Population. Worldometers.
16. Wikkimedia Commons. File:SouthSudanStates.svg -Wikimedia Commons.
17. State Department of Health -DCHS -Communicable Disease Epidemiology W. Poliomyelitis Reporting and Investigation Guideline.
18. Moturi E, Mahmud A, Kamadjeu R, Mbaeyi C, Farag N, et al. (2016) Contribution of Contact Sampling in Increasing Sensitivity of Poliovirus Detection During A Polio Outbreak-Somalia, 2013. *Open forum Infect Dis* 3: ofw111.
19. Health Cluster (2014) South Sudan crisis.
20. CDC (2011) Progress Toward Poliomyelitis Eradication --- Nigeria, January 2010-June 2011. *MMWR Morb Mortal Wkly Rep* 60: 1053-1057.
21. Emily Willingham (2014) NOVA - What is Herd Immunity?
22. Polio global eradication initiative. Surveillance -GPEI.