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The recent outbreaks and reemergence of poliovirus in war and conflict-affected areas

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SUMMARY

Background—Poliomyelitis is a highly infectious disease caused by poliovirus, which becomes difficult to manage/eradicate in politically unstable areas. The objectives of this study were to determine the movement and management of such polio outbreaks in endemic countries and countries with reoccurring cases of polio and to determine the effect of political instability on polio eradication.

Methods—In this study, the extent of polio outbreaks was examined and modeled using statistical methodologies and mapped with GIS software. Data on polio cases and immunization were collected for countries with polio cases for the period 2011 to 2014. Weekly data from the Global Polio Eradication Initiative were collected for selected countries. The recent virus origin and current movement was mapped using GIS. Correlations between immunization rates, the Global Peace Index (GPI), and other indicators of a country's political stability with polio outbreaks were determined. Data were analyzed using SAS 9.4 and ArcGIS 10.

Results—For several reasons, Pakistan remains highly vulnerable to new incidences of polio (306 cases in 2014). Overall immunization rates showed a steady decline over time in selected countries. Countries with polio cases were shown to have high rates of infant mortality, and their GPI ranked between 2.0 and 3.3; displaced populations, level of violent crime rating, and political instability also were ranked high for several countries.

Conclusion—Polio was shown to be high in areas with increased conflict and instability. Displaced populations living in hard-to-reach areas may lack access to proper vaccination and health care. Wars and conflict have also resulted in the reemergence of polio in otherwise polio-free countries.

Keywords

Poliomyelitis; Polio vaccination; War zones; GIS

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1. Introduction

Polio is a highly infectious disease caused by poliovirus, a virus that mainly infects young children. It invades the nervous system and may cause total paralysis.^{1,2} Polio reached epidemic proportions in the early 1900s in countries with relatively high standards of living. Polio was brought under control after the introduction of effective vaccines in the 1950s and 1960s. It was not until the 1970s that polio was recognized as a major problem in developing countries and routine immunization was introduced.^{3,4} In 1988, when the Global Polio Eradication Initiative began, polio was paralyzing more than 1000 children every day worldwide. As a result, more than 2.5 billion children were immunized against polio. Following this, the widespread use of oral polio vaccine (OPV) reduced the number of children paralyzed by polio from an estimated 350 000 in 1988 to just 1606 in 2009.⁴

Polio continues to circulate in several countries, with occasional spread to neighboring countries. Endemic countries include Afghanistan and Pakistan, the only two countries in 2015 never to have stopped polio transmission and global incidence.⁴ In 2014, Pakistan was one of the three countries in the world (the others being Nigeria and Afghanistan) where polio remained an endemic viral infection. Although the polio immunization campaign in the country started in 1974, efforts towards eradication officially started only in 1993. About 60 rounds of vaccination were performed in the country up until 2007, but the infection is still endemic.^{4,5}

On the African continent, early estimates of incidence were hampered by significant under-reporting. The decrease in reported cases has been accompanied by a reduction in the geographic extent of endemic areas, such that by 2006 only four countries had yet to stop poliovirus transmission worldwide, and in Africa only Nigeria was endemic for polio in 2014. Transmission has been persistent in these countries, and the onward spread to previously polio-free areas has presented a significant challenge to the Global Polio Eradication Initiative.⁶

In 2013, polio started to emerge in areas that had been polio-free for decades. The first suspected polio cases in Syria were identified in October 2013.⁴ Shortly afterwards, it was announced that wild poliovirus (WPV) had been isolated from 10 paralyzed children in Deir Ez Zor, one of the most fiercely contested areas of the country. By late November, 35 children had been paralyzed by polio in three separate governorates of the Syrian Arab Republic, which had previously not recorded polio for over a decade.⁷ In addition, World Health Organization (WHO) officials stated that the first Iraqi polio case was confirmed in March 2014 by the Ministry of Health of Iraq and had the same genetic fingerprint as the virus that paralyzed 27 children in eastern Syria in October. Both originated in Pakistan, one of the few countries in the world where polio has not been completely eradicated.⁸

Civil unrest and war contribute to the spread of infectious disease. Troops and equipment, as well as displaced persons, are constantly moving from one place to another during wars, carrying with them infectious disease organisms and vectors. This is combined with the destruction of the physical and often economic infrastructure of the area. Wars spur widespread mass migrations. Migrants are stressed, often emotionally and physically, so

they may have low immunity to diseases endemic in the new area; in addition, they may bring with them diseases that are common in their former home but which are not endemic in the new area. This combination of conditions, especially in crowded makeshift refugee camps, may lead to disease epidemics.^{6,7}

Civil unrest and wars have a great impact on the spread of infectious diseases. The objectives of this study were (1) to determine the extent of polio spread and vaccination coverage in endemic countries, neighboring countries, and other countries where polio is reemerging; (2) to determine the correlation of polio outbreaks/spread with wars and civil unrest, using the variables vaccination coverage, infant mortality rate, Global Peace Index (GPI), percent of population displacement, level of violent crime, and level of political instability in the selected countries; and (3) to map the outbreaks of polio and visualize their movement across the selected regions.

2. Methods

Weekly data on WPV cases were collected to determine the association between polio outbreaks and civil unrest and wars in endemic countries (Pakistan, Afghanistan, and Nigeria) and countries with a reemergence of polio cases (Syria and Iraq). The years 2011 through 2014 were selected based on the availability of data for the selected variables for Afghanistan, Cameroon, Equatorial Guinea, Ethiopia, Iraq, Kenya, Nigeria, Pakistan, Somalia, and Syria, from the Global Polio Eradication Initiative (available at <http://www.polioeradication.org/Dataandmonitoring/Poliothisweek.aspx>). In addition, data on polio immunization coverage among 1-year-olds in the selected countries for the period 2011–2013 (2014 data were not available) were collected from the WHO Health Service Coverage (available at http://apps.who.int/gho/indicatorregistry/App_Main/view_indicator.aspx?iid=2443).

To determine the correlation of polio outbreaks in the endemic countries with wars and conflict, several variables were considered in the analysis, including the following: vaccination coverage, infant mortality rate (as a measure of population health and quality of living), GPI (a measure of the relative position of a nation and region in terms of peacefulness), population movement from endemic regions resulting from wars, level of violent crime, level of political instability, and the risk of outbreaks of poliomyelitis. The infant mortality rate – the number of infant deaths before age 1 year – is often used as an indicator to measure the health and wellbeing of a nation, because factors affecting the health of entire populations can also impact the mortality rate of infants (<http://www.cdc.gov/reproductivehealth/maternalinfanthealth/infantmortality.htm>).

The infant mortality rate – the number of infants dying before reaching 1 year of age per 1000 live-births in a given year – was obtained from the World Data Bank. Estimates were developed by the UN Inter-agency Group for Child Mortality Estimation (UNICEF, WHO, World Bank, UN DESA Population; data available at <http://data.worldbank.org/indicator/SP.DYN.IMRT.IN/countries?display=default>).

The GPI, developed by the Institute for Economics and Peace (available at <http://economicsandpeace.org/>),⁹ was used as another indicator of a country's political stability and to assess the social, political, and economic factors that influence its level of peace. In addition to the GPI, the percentage of displaced population, level of violent crime (rated with a score of 1–5), and level of political instability (rated with a score of 1–5) were also collected for the selected countries.

The data were analyzed using SAS 9.4.¹⁰ Analysis of variance was used to determine the significance of differences in polio rates between the countries. Regression analysis was performed to determine the correlation between the polio rate and explanatory variables including immunization rate, infant mortality, GPI, percent of population displacement in the country, level of violent crime rating, and level of political instability rating. Geographical information system maps (GIS) were created using ArcGIS 10.0 to visualize the distribution of polio outbreaks in the endemic countries for the years 2013 and 2014.¹¹

3. Results

A significant difference ($p < 0.001$) in polio cases during the study period was found among the countries of Afghanistan, Cameroon, Equatorial Guinea, Ethiopia, Iraq, Kenya, Nigeria, Pakistan, Somalia, and Syria (Figure 1). The highest rates of polio cases were observed in Pakistan, with an average of 164 cases per year for the four study years; the highest number of cases occurred in 2014 ($n = 306$), a 62% increase since 2001 (Figure 2). However, no significant change in polio cases over time was observed for the selected countries ($p > 0.05$).

Immunization rates showed a decline over time; however this was not significant ($p > 0.05$). The rates were significantly different ($p < 0.001$) among the countries. Immunization rates in Cameroon and Kenya were the highest (84%), and these countries correspondingly had the lowest numbers of polio cases. Somalia and Equatorial Guinea, on the other hand, had the lowest rates of polio immunization (47.6% and 33%, respectively). Somalia was one of the countries with the highest rates of polio during the study period. In Syria, immunization rates dropped 30% from 2011 (75% in 2011 to 52% in 2013). Polio reemerged in Syria after decades of polio-free status, with 35 cases in 2013. Immunization rates remained constant in Pakistan; however, the polio rates showed a significant increase, pointing towards other contributing factors for the spread of the disease.

To determine the association of polio reemergence in countries due to conflict and war, several variables were examined, including the infant death rate in each selected country as a measure of the country's health and wellbeing, the GPI as an attempt to measure the relative position of the nation and region in terms of peacefulness, the percentage of displaced populations within the country, level of violent crime rating, and political instability rating. Polio-endemic countries tend to have high rates of infant mortality. In the present study, a significant variation ($p < 0.001$; Figure 3) was observed in infant mortality rates among the countries and over time. Somalia and Nigeria had the highest infant mortality rates (93/1000 infants and 78/1000 infants, respectively), while Iraq and Syria had the lowest rates (29/1000 infants and 13/1000 infants, respectively). The GPI and the other indicators of conflicts were

scored on a scale of 1–5; countries that are considered more peaceful have lower index scores. In this study, the GPI was high for most of the selected countries for the years 2013 and 2014; however, significant variation ($p < 0.001$; Figure 4) was observed among these countries. The GPI of all of the polio-endemic countries ranked between 2.0 and 3.4 for 2013 and 2014. The highest score was observed in Somalia. A summary of the data is shown in Table 1.

Similar results were observed for the other indicators of conflict, including the percentage of displaced population, level of violent crime rating, and level of political instability rating ($p < 0.001$; Figure 5). Somalia, Afghanistan, Syria, and Iraq ranked the highest in percentage of displaced populations. Syria was found to have the highest increase in percentage of displaced population between 2013 and 2014 (ranked 1.5 in 2013 and 5.0 in 2014). All countries, except Equatorial Guinea and Ethiopia, ranked between 4 and 5 for the level of violent crime, while all ranked between 3 and 5 for political instability, with Afghanistan, Somalia, and Syria having the highest rankings. The regression analysis showed a weak negative correlation ($R^2 = 0.0094$) between the number of polio cases and the immunization rate. A weak positive correlation was observed between the number of polio cases and the GPI ($R^2 = 0.07$) and political instability ($R^2 = 0.005$).

To visualize the distribution of polio outbreaks in the endemic countries for the years 2013 and 2014, GIS maps were created (shown in Figure 6). These maps help visualize the areas with high numbers of polio cases and determine its movement and change over time. The maps were created for the years 2013 and 2014 because the highest rates of polio occurred during that time and also because of the reemergence of polio in areas with no polio cases for decades, such as in Syria and Iraq.

4. Discussion

Significant progress has been made since 1988 when the global eradication of poliomyelitis was adopted. However, by 2012, the Global Polio Eradication Initiative was facing difficulties in endemic areas in three countries: northern Nigeria, eastern and southern Afghanistan, and the Federally Administered Tribal Area (FATA) and the Khyber Pakhtunkhwa (KP) of Pakistan.⁵

In this study, Pakistan was found to have had the highest rates of polio outbreaks for the past 10 years, with 306 cases in 2014 alone, accounting for 85% of all polio cases in the world. One of the major problems faced in endemic countries is vaccination refusal because of religious and cultural issues. Refusal of the OPV by the general public exemplifies the difficulties faced in multiple endemic areas, including Pakistan.¹² For example, in KP, Pakistan, the social unrest caused by the Lal Masjid siege in Islamabad in July 2007 led to mistrust between the local community and the national authorities. In 2011, the Central Intelligence Agency of the USA attempted to obtain DNA samples from the children in Abbottabad, KP, as part of the search for Osama bin Laden. The scheme involved vaccinating children against hepatitis B, and led to an erosion of public trust in immunization, reducing its rates in Pakistan.¹³ In addition, more than 40 vaccination staff have been killed (and counting) since July 2012, and as a result, local leaders have banned

immunization campaigns.¹⁴ Banning and refusal of polio and other vaccinations from the general population has led to increased rates of unimmunized children, thus increasing the probability of poliomyelitis.

Furthermore, in northern Nigeria, OPV refusals may have resulted from the disapproval of religious leaders and the perception that the vaccine is associated with birth control, as part of a foreign conspiracy, and is contaminated.⁵ This has led to increased rates of unvaccinated children.

Immunization rates during the study period showed a decline over time, although this was not significant. Countries with the highest polio immunization rates also had the lowest numbers of polio cases. In Syria, for example, polio reemerged after decades, with 35 cases in 2013. Vaccination rates fell from 91% of children before the war to an estimated 68% in 2012.¹⁵ WHO data on routine immunizations for polio show that a large proportion of the Syrian population were not vaccinated in the previous 2 years. Across Syria, coverage went down in 2012, and was as low as 50% in opposition controlled areas.^{16,17} It is estimated that there are 765 000 children inside Syria living in areas that are hard to reach. As a result of war, Syrian children must cope with war trauma, malnutrition, and stunted growth, alongside collapsing sanitation and living conditions. As well as polio, Syria has faced once-rare infectious diseases including measles, typhoid, hepatitis, dysentery, tuberculosis, diphtheria, and whooping cough. Many of these diseases have already traveled beyond Syrian borders, carried by millions of refugees.¹⁸

In addition to vaccination problems in some of the endemic countries, environmental and demographic characteristics related to crowding, population movement, and sanitation are also likely to play a role. Different population characteristics have major effects on routine immunization and on the numbers and sizes of outbreaks experienced by a country.⁶ Polio-endemic countries tend to have high rates of infant mortality. In the present study Somalia, Nigeria, and Afghanistan had the highest infant mortality rates, while Iraq and Syria had the lowest. In developing countries, infant mortality rates are high because these basic necessities for infant survival are lacking or unevenly distributed. Infectious and communicable diseases are more common.¹⁹ Low living standards may result in many diseases, especially among young children. Each year many children and adults die as a result of a lack of access to clean water and because of poor sanitation conditions. Most of the countries with low living standards are also dealing with wars or political unrest.

The GPI is a way to measure the peacefulness in a country; countries are ranked on a scale of 1–5, and those that are considered more peaceful have a lower index score. In this study, the GPI was high for most of the selected countries for the years 2013 and 2014. The GPI of all of the polio-endemic countries was between 2.0 and 3.3 for 2013 and 2014. Similar results were observed for the other indicators of conflict, including the percentage of displaced population, level of violent crime rating, and level of political instability rating. Somalia, Afghanistan, Syria, and Iraq ranked the highest in percentage of displaced populations. Syria was shown to have the highest increase in percentage of displaced population between 2013 and 2014. All countries except Equatorial Guinea and Ethiopia

ranked 4 to 5 for the level of violent crime, while all ranked between 3 and 5 for political instability. Afghanistan, Somalia, and Syria had the highest rankings.

The regression analysis in this study showed a weak negative correlation between the number of polio cases and the immunization rate: the lower the vaccination rate in a country, the higher the susceptibility to acquiring polio. In Pakistan, data showed an increase in immunization rates while polio cases remained the highest, indicating confounding or additional factors. The time lag between vaccination and the onset of the disease, accuracy of vaccination dosage, and the number of doses and the correct interval (effective vaccination requires several doses) are factors that may have affected the disease and vaccination coverage data, leading to the weak statistical correlation. The study results also showed a weak positive correlation between the number of polio cases and the GPI and political instability rating. Even though all countries with polio cases ranked high for GPI and the other variables, the limited data and the short time period of this study may have resulted in the weak correlation. Furthermore, several other factors may contribute to the susceptibility of a population to an outbreak, including genetic makeup, nutritional status, and socioeconomic and educational levels.

Countries that are polio-endemic may spread the virus to neighboring countries through travel or the movement of displaced populations. For example, there is evidence of the cross-border spread of poliovirus from Pakistan into Afghanistan. In addition, a poliovirus strain originating in Pakistan was detected in sewage samples from Egypt, Israel, the West Bank, and the Gaza Strip, which exploded into an outbreak in Syria in late 2013.^{14,20} Travelers could also bring the infection to other countries. For example, as a result of the Syrian war, hundreds of thousands of people are fleeing Syria and seeking refuge in neighboring countries and Europe. Because only 1 in 200 unvaccinated individuals infected with WPV will develop acute flaccid paralysis, infected individuals can spread the virus unrecognized.²⁰ In 2013, Eichner and Brockmann suggested that it might take more than 30 generations, nearly 1 year of silent transmission, before one acute flaccid paralysis case is identified and an outbreak is detected, although hundreds of individuals would carry the infection.²⁰

The GIS maps that were created in this study help to identify areas with high rates of polio and may predict the possibility of movement of the virus to neighboring countries. Vaccination campaigns and safety measures may be needed to reduce the threat to neighboring countries. Lebanon, for example, with more than a million Syrian refugees, many unregistered, and a creaking health system, is at highest risk.

Conflict, political instability, hard-to-reach populations, and poor infrastructure continue to pose challenges to eradicating the disease. Each country offers a unique set of challenges, which require local solutions. Poliovirus is mostly carried invisibly by children without symptoms, who are infected not only through drinking or eating something contaminated by feces, but also by coughing, sneezing, and kissing, particularly in crowded conditions. Children who do become paralyzed have already had the virus for 1–3 weeks. Each infected child means up to a thousand others are also silently spreading the infection.¹⁸ As a control measure, the WHO has mandated polio vaccination for everyone travelling to or from

Pakistan, Syria, and Cameroon, and encourages travel vaccinations for Afghanistan, Nigeria, and others.²¹ However, this may not be effective in the poor and conflict-ridden parts of Pakistan. Providing immediate health care to displaced families and others in these high-risk areas may better help control polio and other diseases in such areas. Clean water, increased nutritional measures, better sanitation, and easy access to health care contribute the most to improving health.^{14,21}

In 2013, the Global Polio Eradication Initiative launched its most comprehensive and ambitious plan for completely eradicating polio. It is a 5-year all-encompassing strategic plan that clearly outlines measures for eliminating polio in its last strongholds and for maintaining a polio-free world. The goal of the Global Polio Eradication Initiative is to complete the eradication and containment of all wild, vaccine-related, and Sabin polioviruses, such that no child ever again suffers paralytic poliomyelitis.²²

In conclusion, this study found that polio was high in countries with political conflict and instability. Wars and conflict have resulted in the reemergence of polio in countries that were polio-free for decades, and may contribute to the spread of the virus to neighboring countries. The GPI was high for most of the studied countries during the study period. The GPI of all of the polio-endemic countries ranked between 2.0 and 3.3 for the years 2013 and 2014. Displaced populations and those living in hard-to-reach areas may lack the proper vaccinations and health care. Countries that are polio-endemic may spread the virus to neighboring countries through travel or through the movement of displaced populations. GIS maps may help to identify areas with high rates of polio and to predict the possibility of movement of the virus to neighboring countries.

Tackling the last 1% of polio cases has proved to be difficult. As long as a single child remains infected, children in all countries are at risk of contracting polio. Failure to eradicate polio from these last remaining strongholds could result in as many as 200 000 new cases every year, in the next 10 years, all over the world.

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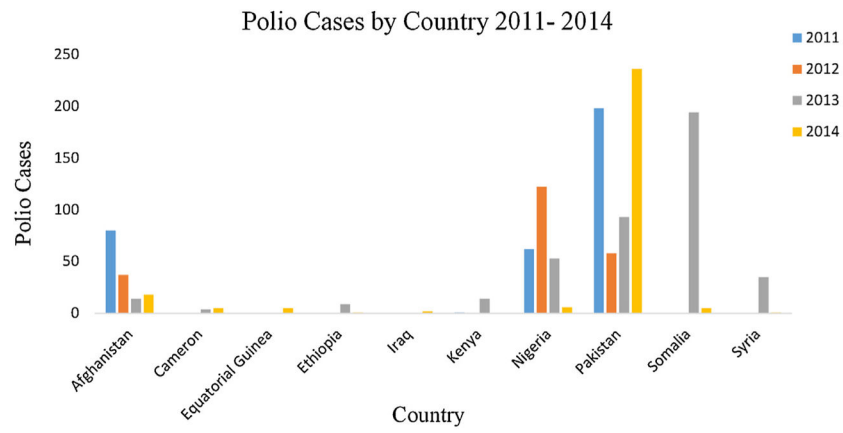


Figure 1. Wild poliovirus cases in endemic countries, 2011–2014. The highest rates were found in Pakistan.

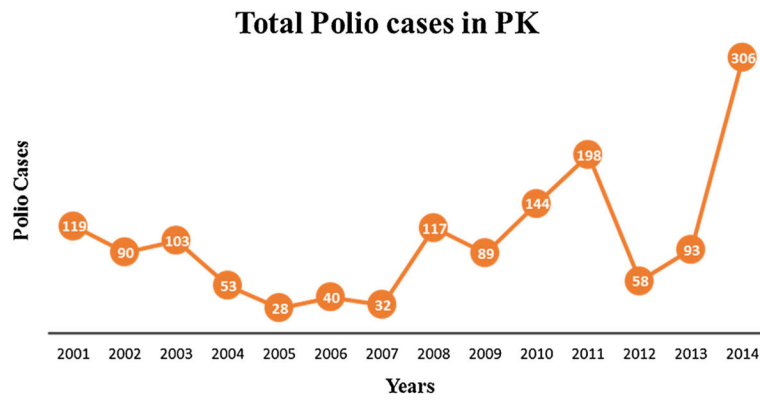


Figure 2. Polio cases in Pakistan 2001–2014. A significant increase was observed over time.

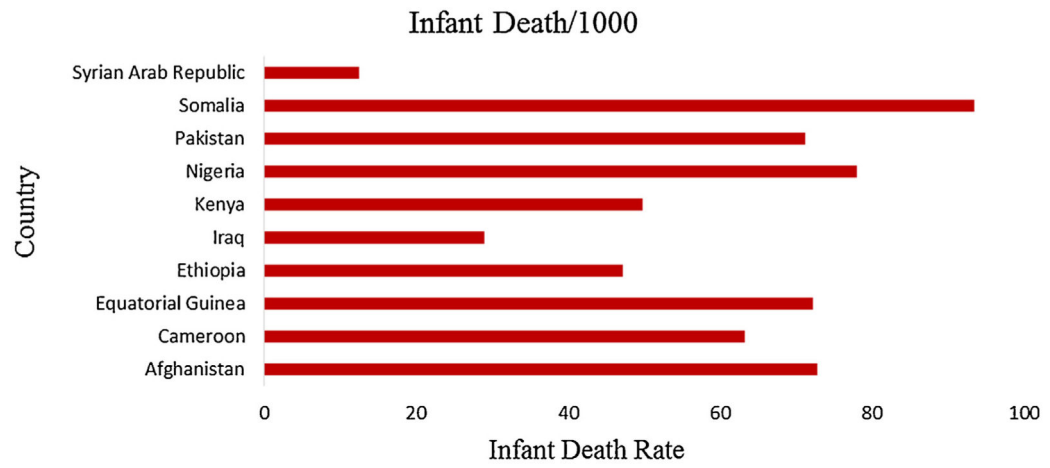


Figure 3. Average infant deaths per 1000 for the selected countries, 2011–2013. The highest rate was found in Somalia.

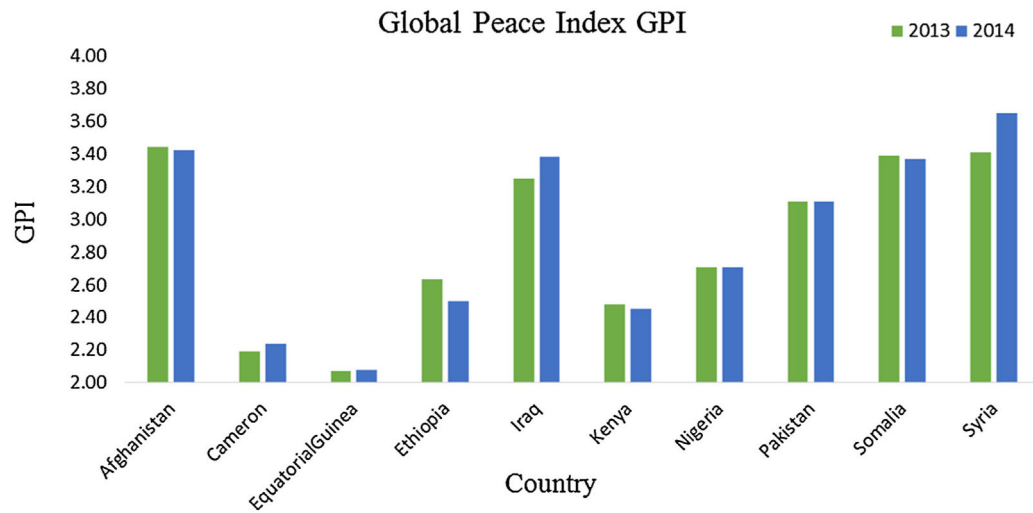


Figure 4. Global Peace Index for polio-endemic countries, 2013– 2014. A significant difference in GPI was observed between the selected countries, with the highest in Syria in 2014.

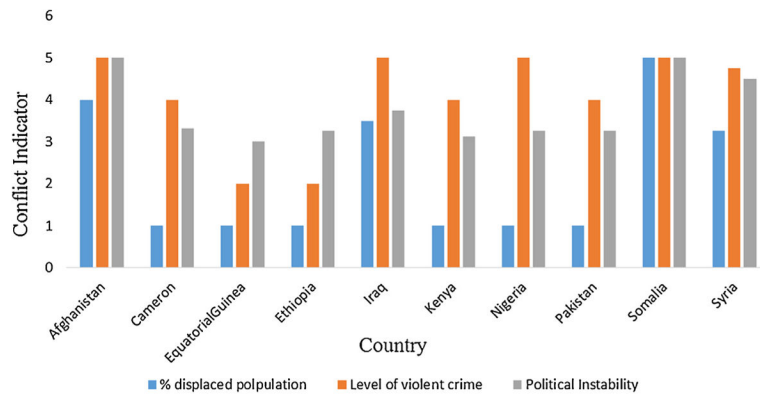


Figure 5. Indicators of conflicts in the selected countries; average for 2013–2014. All countries had high levels for the conflict indicators.

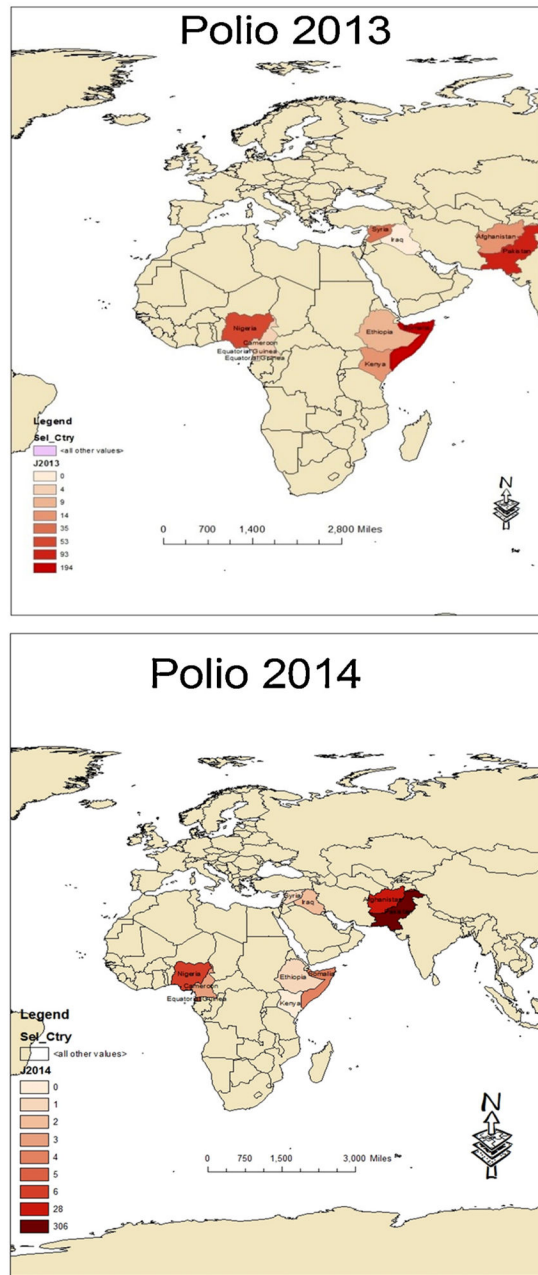


Figure 6. GIS maps of polio cases in endemic countries, 2013–2014.

Table 1

Mean values of the variables studied for the selected countries, 2011–2014.

Country	% displaced population	Level of violent crime	Political instability	GPI	Infant deaths/1000	Polio cases
Afghanistan	4.0	5.0	5.0	3.43	72.75	16.0
Cameroon	1.0	4.0	3.32	2.225	63.25	5.0
Equatorial Guinea	1.0	2.0	3.0	2.08	72.25	2.5
Ethiopia	1.0	2.0	3.25	2.57	47.25	5.0
Iraq	3.50	5.0	3.75	3.32	29.0	1.0
Kenya	1.0	4.0	3.135	2.47	49.75	7.0
Nigeria	1.0	5.0	3.25	2.71	78.0	30.0
Pakistan	1.0	4.0	3.25	3.11	71.25	165
Somalia	5.0	5.0	5.0	3.38	93.5	100.0
Syria	3.25	4.75	4.5	3.53	12.5	18.0

GPI, Global Peace Index.