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Risk Factors Influencing Poliomyelitis Seroprevalence in Polio High Risk Areas of Afghanistan

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Abstract

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Doctoral Study Submitted in Partial Fulfillment

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Abstract

Afghanistan is one of the remaining polio endemic countries in the world. Nearly one million children under 5 years of age have missed polio vaccination in Afghanistan from May 2018 until January 2021. This quantitative study used the socioecological model as the theoretical framework and secondary data analysis of the 2020 polio serosurvey (N = 1384) to investigate various risk factors such as gender, parental education, family origin (language/location), wealth, distance to nearest health facility, and number of polio vaccine doses on the level of antibodies (i.e., seroprevalence) against all three types of polioviruses in children of two age groups, 6-11 months and 36-48 months, living in polio reservoir areas of Afghanistan. Almost every child (99%) was seropositive against polio virus Type 1 (PV1), 90% were seropositive for Type 2 (PV2), and 95% were seropositive for Type 3 (PV3). Gender, region, distance to nearest health facility, and oral polio vaccine status were significantly associated with level of polio antibodies against different types of polioviruses. Binary logistic regression revealed that children living in Kandahar non-catchment and catchment areas had a 58% and 53% reduction in the odds of PV1 antibody seropositivity, respectively, as compared to those living in Jalalabad. Similarly, children living in Kandahar and Behsud had a 61% and 73% reduction in the odds of PV2 antibody seropositivity, respectively, as compared to those living in Jalalabad. Identifying risk factors associated with polio seronegativity can help to inform targeted interventions and improve the overall effectiveness of polio eradication efforts.

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Dedication

The dissertation will be dedicated first to my respectful parents who with love and effort have accompanied me in this process, without hesitating at any moment of seeing my dreams come true, which are also their dreams. My beloved husband without whose constant support this paper was not possible. To my beloved children, Josef and Sally, who have been my constant source of inspiration and motivation throughout my academic journey. Your love, patience, and understanding have been the pillars of strength that kept me going, even during the toughest times. I dedicate this dissertation to my institution mentors under whose constant guidance I have completed this dissertation. They not only enlightened me with the academic knowledge but also gave me valuable advice whenever I needed it the most.

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Section 1: Foundation of the Study and Literature Review

Afghanistan is one of the remaining polio endemic countries in the world and forms one epidemiological block with Pakistan (Global Polio Eradication Initiative [GPEI], 2021a). Since the introduction of the GPEI in 1988, global eradication of the transmission of wild poliovirus (WPV) Types 2 and 3 has been declared (Kuehn, 2019), while WPV Serotype 1 (WPV1) transmission has never been interrupted in two neighboring countries, Afghanistan and Pakistan (GPEI, 2019).

Progress toward interruption of indigenous WPV transmission in Afghanistan has been impaired by decades of conflict and insurgency, leading to intermittent bans on house-to-house vaccinations, disruptions in supply chains, and the promotion of negative attitudes towards vaccination (Kalkowska et al., 2019; Verma et al., 2018). A World Health Organization (WHO) situation report indicated that nearly one million children under five years of age missed oral poliovirus vaccine (OPV) administration from May 2018 until January 2021 (Cousins, 2021; WHO, 2018).

The efforts to interrupt WPV1 transmission in these two countries have further been challenged by the emergence of circulating vaccine-derived poliovirus (cVDPV), biologically identical to WPV, resulting in paralytic polio cases; cVDPVs emerge when attenuated OPV strains undergo progressive genetic changes during prolonged circulation in under-immunized population (WHO, 2017).

In addition, the COVID-19 pandemic has had a significant impact on public health systems around the world, including efforts to eradicate polio in Afghanistan. The COVID-19 pandemic has had a notable impact on Afghanistan’s efforts to eradicate polio

including the suspension or delay of vaccination campaigns, disruption of surveillance activities, diversion of resources, and an increased risk of polio transmission due to social and economic instability caused by COVID-19 (Ahmadi et al., 2020).

Afghanistan had a 38% increase in WPV1 cases from 2018 (21 cases) to 2019 (29 cases) and a 93% increase from 2019 (29) to 2020 (56), with Kandahar province containing more cases than any other province (Martinez et al., 2020). Moreover, 69 cases of cVDPV Type 2 (cVDPV2) were detected in August 2020, of which a majority (62%) were in Nangahar province (Martinez et al., 2020).

The number of confirmed polio cases dropped from 54 cases in 38 districts in 2020 to four cases from only two districts in 2021 and two cases from two districts in 2022 (GPEI, 2022a).

The year 2021 was quite challenging for Afghanistan in terms of consistently implementing high quality supplementary immunization activities (SIAs) across the country and a significant number of children remained unreached. The security situation was varied, resulting from full-scale armed conflicts across the country that lasted till the middle of August followed by takeover by the Islamic Emirate of Afghanistan such as Taliban (GPEI, 2022a). The security situation since mid-August 2021 improved in general, but has not fully stabilized across the country, with ongoing security incidents including attacks on polio vaccination workers during the first quarter of 2022 (GPEI, 2022a). So far in 2023, Afghanistan did not report any polio cases.

Serosurveys to estimate population immunity in districts at high risk of polio importation are useful to gauge underlying gaps in population immunity to polio and

possibly to guide preparedness and response planning (Farag et al., 2020). The best way to monitor the population immunity against poliovirus is by determining the type-specific prevalence of antibodies against the virus (Biberi-Moroeanu et al., 1988). Seroprevalence surveys of polio antibodies have been used as a tool to evaluate risk of poliovirus outbreaks, as well as to assess polio program performance and identify population immunity gaps (Vivian et al., 2022). Another important use of serosurveys is to understand who is at higher risk of infection in different population groups, including by age and sex (Murhekar & Clapham, 2021). The seroprevalence studies provide information about the extent of transmission in the past and help to understand the future course of any outbreak (Murhekar & Clapham, 2021).

The polio serosurveys in young children in Egypt, Indonesia, and India have provided interesting country-specific results that have led to programmatic actions and an immunity benchmark for the eradication initiative (Bahl et al., 2014; El-Sayed et al., 2007; WHO, 2008). Scientific evidence about the existing level of seroprevalence, vaccination coverage, and its effectiveness in Afghanistan can further aid the country program in making informed decisions about polio eradication activities. Furthermore, scientific evidence will enable the national and international stakeholders to devise measures to further improve the quality and effectiveness of both routine and supplementary immunizations.

Background

Poliomyelitis is a highly contagious disease caused by poliovirus; an enterovirus that belongs to the *Picornaviridae* family (Mehndiratta et al., 2014). It has a diameter of

25 to 30 nm and its outer coat is composed of 60 protomers, each made of four virion proteins (i.e., VP1, VP2, VP3, and VP4) arranged in icosahedral symmetry. All four virions are made of eight strands of protein arranged in β sheet array forming a β barrel. Due to the intermingling of various proteins, loops are created, which serve as antigenic sites for combination with corresponding antibodies. Three serotypes of poliovirus have been recognized as Types 1, 2, and 3 (PV1, PV2, and PV3, respectively; (Mehndiratta et al., 2014) .

This life-threatening virus is very infectious and can spread through person-to-person contact (Centers for Disease Control and Prevention [CDC], 2021b). It enters the body through the fecal-oral route and spreads through contact with the feces or droplets from a sneeze or cough (less common) of an infected person. The dissemination of the virus in the feces is the reason for being a highly contagious disease (CDC, 2021b). An infected person can spread the virus to others immediately before and up to 2 weeks after symptoms appear (Roberts, 2020). An asymptomatic person can also pass the virus to others. Lack of personal hygiene and improper sanitation are the most important contributory factors for virus spread (CDC, 2021b).

Manifestations of poliomyelitis differ, ranging from asymptomatic to the most severe forms of debilitating paralysis (Mehndiratta et al., 2014). An estimated one out of four people with poliovirus infection will have flu-like symptoms (CDC, 2021b). However, one out of 100, or 1–5 out of 1000 can develop more serious symptoms that affect the brain and spinal cord (CDC, 2021b). Yet, paralysis is the most severe symptom associated with polio because it can lead to permanent disability and death (Mehndiratta

et al., 2014). Between 2 and 10 out of 100 people who have paralysis from poliovirus infection die as the virus affects the muscles that help them breathe (CDC, 2021b).

History of Poliomyelitis

Poliomyelitis existed since ancient times. Egyptian paintings from the period 1403–1365 B.C.E. showed children with withered leg and holding sticks (Blume & Geesink, 2000). In 1840, Jacob Heine and Karl Oskar Medin conducted the first systematic investigation of polio and developed the theory that the disease may be contagious, and polio was named as Heine-Medin disease (Baicus, 2012). Years after, in 1894, the first significant outbreak of infantile paralysis identified as polio was documented in United States. In 1900, paralytic cases started to appear in the United States (Baicus, 2012). Then, in 1907, a Swedish pediatrician, Ivae Wickman, identified the different clinical types of polio (Blume & Geesink, 2000). Following the work of Wickman, Karl Landsteiner and Erwin Propper, Austrian physicians, hypothesized that polio disease may be caused by virus in 1908 (Vashishtha & Kamath, 2016).

After that, in June 1916, a polio epidemic in New York, United States, raised concern and accelerated research into disease spread as more than 27, 000 patients were reported, with fatality exceeding 6000 in the United States (Blume & Geesink, 2000). After many studies and researches, several types of polio virus known as Type 1, 2 and 3 were identified by Sir Burnet and Dames MacNamara in 1931 (Baicus, 2012). Remarkably, in 1955, the first vaccine, an injectable and inactivated polio vaccine (IPV) was developed by Jonas Salk (Baicus, 2012; Blume & Geesink, 2000).

Subsequent to Salk's work, Albert Sabin developed a live oral vaccine known as OPV which rapidly became the vaccine of choice for most national immunization programs in the world (Baicus, 2012). Soon after the introduction of effective vaccines in the 1950s and 1960s, polio became under control and practically eliminated as a public health problem in industrialized countries (Vashishtha & Kamath, 2016).

However, between 1970 and 1980, polio was widespread in many developing countries, and it took somewhat longer for polio to be recognized as a major public health problem (GPEI, 2016). As a result, routine immunization with OPV was introduced worldwide as part of national immunization programs. In 1974, the World Health Assembly passed a resolution to create the expanded program for immunization (EPI) to vaccinate all children in the world and control the disease in many developing countries (GPEI, 2016). During that time, polio virus was paralyzing 1000 children worldwide every day (GPEI, 2016). Soon after, Rotary International launched the PolioPlus project in 1985 and established the GPEI in 1988, a global effort to immunize the world's children, and eradicate polio virus was initiated (Losey et al., 2019). Since then, more than 2.5 billion children have been immunized against polio in more than 200 countries (GPEI, 2016).

Prevention/Polio Vaccination

Unfortunately, there is no cure for polio (CDC, 2021b). However, it can be prevented by immunizing a child with the IPV or the live attenuated OPV in addition to herd immunity, which supplements to polio vaccination (CDC, 2021a; Roberts, 2020).

Interestingly, among those individuals who receive OPV, 95% develop immunity (CDC, 2021b).

It is necessary to understand that the population in whom the vaccine fails are still protected by the immunity of those around them (Roberts, 2020). However, not all those who receive the vaccine always produce appropriate levels of antibody against the antigen (CDC, 2021b). Regardless of the quality of vaccination services, the extent of this gap depends on the virus serotype and to some extent on the nutritional, demographic, and socioeconomic characteristics of the household (CDC, 2021b; Roberts, 2020).

Global Polio Situation

In the early 20th century, polio was considered the most feared diseases in developed countries, paralyzing hundreds of thousands of children every year (Vashishtha & Kamath, 2016). In 1988, when the World Health Assembly resolved to eradicate poliomyelitis globally, polio paralyzed more than 350,000 children across 125 countries (Bigouette et al., 2021). Today, only one of three WPV serotypes, WPV1, remains in circulation (CDC, 2021b). Despite such significant progress, circulation of indigenous WPV continues in Afghanistan, and WPV importation into polio-free areas has been a great challenge to global WPV eradication (Bigouette et al., 2021; GPEI, 2021a).

Prior to the COVID-19 pandemic, global incidence of polio cases had decreased by 99% and WPV was circulating in only two countries, Pakistan, and Afghanistan, but since then cases have been detected in several African countries. Globally, there were

140 cases of poliomyelitis caused by WPV in 2020, all detected in Afghanistan and Pakistan (Bigouette et al., 2021).

In addition to WPV, detection and circulation of vaccine-derived poliovirus (VDPV) cases have raised global concern. Between January 2020 and July 2022, a total of 1,985 cVDPV cases were identified in 34 countries (Elisha et al., 2021). Thirty-four different active poliovirus emergence groups (lineages) were reported through acute flaccid paralysis (AFP) surveillance or environmental surveillance (ES) in 2021(Rachlin et al., 2022). In 2022, to date, isolations of 14 cVDPV emergence groups have been reported from all three serotypes (Rachlin et al., 2022).

Poliovirus transmission has primarily been detected through surveillance of AFP, which is new onset of weakness in one or more limbs (CDC, 2022) . Since paralytic polio occurs in less than 1% of WPV-infected children, poliovirus can circulate undetected; therefore, endemic countries are challenged to rely solely on AFP surveillance to track transmission and achieve global eradication (Chen et al., 2020; Elisha et al., 2021). Hence, complementing AFP surveillance with environmental surveillance (ES; systematic sewage sampling and testing) and seroprevalence studies have been crucial for estimating temporal trends of poliovirus circulation, population immunity, and program effectives (Farag et al., 2020).

Problem Statement

Despite the ongoing global efforts to eradicate polio, WPV cases are still detected in Afghanistan and remained in polio endemic country in the world (GPEI, 2021a). Countries are classified by the International Health Regulations (IHR) as a state infected

with WPV1 or cVDPV2 with potential risk of international spread and large number of unvaccinated children (GPEI, 2021b; WHO, 2021). Afghanistan reported 26, 56, and four wild polio cases in 2019, 2020, and 2021, respectively (GPEI, 2021a).

Continued detection of WPV1 transmission though AFP surveillance and ES within Kandahar and Nangahar in 2020 highlighted a need to assess the immunity profile in Afghanistan among children to identify poliovirus seronegative populations in areas with continuous detection (Martinez et al., 2020)

There are so many Afghani children now susceptible to polio and outbreaks could erupt, particularly in areas with poor sanitation where the virus can thrive (Thompson & Kalkowska, 2021). Also, the unmonitored movement of people between Pakistan, which reported 147, 84, and one polio cases in 2019, 2020 and 2021, respectively, and Afghanistan threatens efforts to eradicate polio from Afghanistan (GPEI, 2021b).

In Afghanistan, the number of cases and infected districts have been on the rise since 2018. The number of infected districts increased from 14 in 2018 to 20 in 2019 and 38 in 2020 (Bigouette et al., 2021). Similarly, the number of cases also increased from 21 in 2018, to 29 in 2019 and 56 in 2020 (Bigouette et al., 2021). During 2020, WPV1 cases increased in number and geographic distribution compared with 2019 (GPEI, 2022b).

In my research, Kandahar and Jalalabad cities were selected for polio-serosurvey. The two cities were selected due to the frequency of positive environmental isolates identified at sampling sites within the cities (GPEI, 2021a). In addition, they are urban hubs for large population movement within the core polio reservoirs of the Northern and Southern Corridors of Afghanistan and Pakistan (Hsu, 2019).

In 2021, only four WPV1 cases were reported from Afghanistan (Rachlin et al., 2022). Twenty-one (35%) of 60 patients with WPV1 cases reported between January 2020 and November 2021 had never received OPV, 14 (23%) had received one or two doses, and 24 (40%) had received more than three doses; 23 (38%) had never received OPV through routine immunization but had received more than one SIA doses (Sadigh et al., 2022)

Regarding environmental samples, the number of WPV1 positive environmental samples decreased in 2020 to 35 compared to 56 in 2019 (GPEI, 2021b). In 2020, 303 cVDPV2 cases were reported from 96 districts of 24 provinces of Afghanistan (Rachlin et al., 2022). The ban on house-to-house vaccination that was imposed in May 2018 became more stringent in April 2019, which led to no polio vaccination campaigns from April to July 2019 (GPEI, 2021b).

Despite the sustained efforts, the security situation in Afghanistan limits vaccination teams from reaching high-risk populations; however, suboptimal campaign coverage in areas with no security limitations also contribute to continued circulation of WPV1 (GPEI, 2021a). Recent population movements between Pakistan and Afghanistan further contributed to the risk of transmission of WPV1 (GPEI, 2019). To finally achieve poliovirus eradication, it is important to maintain high program quality by identifying pockets of unimmunized children and intensifying efforts to reach all children with both poliovirus vaccines.

Purpose of the Study

The purpose of this quantitative study was to investigate various risk factors such as gender, parental education, family origin (language/location), wealth, distance to nearest health facility and IPV/OPV doses on the level of antibodies (seroprevalence) against all three types of polioviruses in children of two age groups, 6-11 months and 36-48 months, living in polio reservoir areas of Afghanistan. It is not known in this country whether there is an association between the aforementioned factors and the likelihood of being polio antibody seronegative. Most importantly, there has not been any household serosurvey conducted in the country before as previous surveys were health facility based serosurveys (Farzad et al., 2017; Hsu et al., 2019; Hussain et al., 2018).

Because of continued detection of WPV1 in Afghanistan, there is a need to better investigate these risk factors on population immunity levels and to guide targeted programmatic intervention to interrupt virus circulation. It is therefore essential to understand these relationships for achieving sufficient vaccination coverage. Analysis of seroprevalence surveys of polio antibodies is essential as such analysis has been used as a tool to evaluate risk of poliovirus outbreaks, as well as to assess polio program performance and identify population immunity gaps (Díaz-Quiñónez et al., 2018; Gofama et al., 2017)

Research Questions and Hypotheses

The following research questions and hypotheses were examined in this quantitative study.

RQ1: What is the effect of risk factors (gender, caretaker's education, wealth, family origin, and region) on the level of polio antibodies (seroprevalence; PV1, PV2, and PV3) in children, ages 6-11 and 36-48 months, living in polio high-risk areas of Afghanistan?

$H_0$1: There is no significant effect of the risk factors on the level of polio antibodies (seroprevalence) in children, ages 6-11 and 36-48 months, living in polio high-risk areas of Afghanistan.

H_a1: There is significant effect of the risk factors on the level of polio antibodies (seroprevalence) in children, ages 6-11 and 36-48 months, living in polio high-risk areas of Afghanistan.

RQ2: What is the effect of distance to health facility on the level of polio antibodies (seroprevalence; PV1, PV2, and PV3) in children, ages 6-11 and 36-48 months, living in polio high-risk areas of Afghanistan?

$H_0$2: There is no significant effect of distance to health facility on the level of polio antibodies (seroprevalence) in children, ages 6-11 and 36-48 months, living in polio high-risk areas of Afghanistan.

H_a2: There is significant effect of distance to health facility on the level of polio antibodies (seroprevalence) in children, ages 6-11 and 36-48 months, living in polio high-risk areas of Afghanistan.

RQ3: What is the effect of OPV/IPV doses (full, partial, and none) on the level of polio antibodies (seroprevalence) in children, ages 6-11 and 36-48 months, living in polio high-risk areas of Afghanistan?

$H_0$3: There is no significant effect of OPV/IPV doses on the level of polio antibodies (seroprevalence) in children, ages 6-11 and 36-48 months, living in polio high-risk areas of Afghanistan.

H_a3: There is significant effect of OPV/IPV doses on the level of polio antibodies (seroprevalence) in children, ages 6-11 and 36-48 months, living in polio high risk areas of Afghanistan.

Theoretical Foundation for the Study

The theoretical framework underlying this study was the socioecological model (SEM) of health. This model states that health is influenced by multiple factors such as individual, community, and the physical, social, and political environments (Townsend & Foster, 2013). According to the SEM, health is affected by the interaction between the individual, the group/community, and the physical, social, and political environment (Abisola et al., 2021).

The SEM was used to address the relevant risk factors that may affect public health practice related to immunity in children at the individual, interpersonal, community and public health policy levels, where behaviors may be shaped by the social environment. Serology results were categorized as the dependent or outcome variable. Key independent variables in this research were mapped to the five levels within the model as follows: (a) individual: age, gender, wealth, IPV/OPV dose history; (b) interpersonal: parent's education, family origin/language; (c) organizational (none-measured); (d) community: residence, distance to health facility; and (e) policy (none-

measured). The SEM provides a viable framework for vaccination programs to focus on specific positive actions at these foundational levels.

Nature of the Study

The nature of the study was a quantitative, cross-sectional study. In this study, an existing secondary data from the CDC was used. The CDC in collaboration with Aga Khan University (AKU) implemented a community-based cross-sectional polio serosurvey in Afghanistan. This survey quantified levels of serological protection (seroprevalence) against PV1, PV2, and PV3 in targeted areas within Kandahar city, Jalalabad city, and selected areas of neighboring Behsud district in Afghanistan.

This study involves secondary analysis of 2020 Afghanistan Household Seroprevalence Survey. The dependent variable is categorical: polio antibodies seroprevalence (seropositive or seronegative). The independent variables are categorical and continuous. The categorical variables are risk factors such as gender, ethnicity, immunization record, education level, wealth of the family, number of OPV/IPV doses, and regions, which are available in the secondary data set. The independent continuous variable is distance to nearest health facility.

Literature Search Strategy

For the present study, an open-ended search for literature with a focus on publications mostly ranging from years 2015 to 2022 was used. Some older reports were used for history of poliomyelitis disease and background to elaborate more on the progress of disease eradication. Emphasis was placed on peer-reviewed journals.

However, relevant national documents from the CDC, the GPEI, and the WHO reports were also used to supplement the literature review.

The following search engines were used for this study: Walden University Library, Pub Med, Science Direct, Research Gate, Google Scholar, and Dissertations and Theses at Walden University. The keywords searched were *vaccination status*, *vaccination coverage, poliovirus, seroprevalence, Afghanistan, serosurvey, polio immunity, polio eradication, access to health facility,* and *travel time to health centers*.

Literature Review Related to the Main Concept and Variables

SEM and Infectious Diseases

Given the importance and difficulty of research on infectious diseases, researchers have concluded that no single theory or method is sufficient to explain complexity of infectious diseases and the relationships between factors influencing disease outbreaks (Finucane et al., 2014). However, many scholars have relied on the SEM as a framework for exploring factors influencing diseases outbreak and prevention (Abisola et al., 2021; Lewis, 2005; Smith et al., 2005).

In Nigeria, Abisola et al. (2021), using the SEM framework, found that intrapersonal (caregivers' immunization knowledge, caregivers' welfare and love of child/ren), interpersonal (role of individual relationships and social networks), organizational (geographical and financial access to health facilities, health facilities attributes, staff coverage, and healthcare worker attributes), community (community outreaches and community resources), and policy-level (free immunization services) factors influence disease prevention, including childhood immunization uptake.

Similarly, the SEM gave an opportunity to significantly deepen understanding of HIV/AIDS as a transdisciplinary problem (Lewis, 2005).

Most importantly, in containment of the ebola epidemic in Liberia, the SEM framework was an important tool for guiding research and the design of communication activities and strategies to effectively impact on determinants of the intended behavior (Figueroa, 2017). In the United States, the SEM helped identifying risk factors for H1N1 influenza vaccine update (Kumar et al., 2012). The study found that intrapersonal, interpersonal, institutional, and the policy and community levels factors were significant predictors of vaccine uptake as well as of willingness to get the vaccine. The levels together explained 65% of the variance, suggesting that interventions targeting multiple levels of the framework would be more effective than interventions aimed at a single level (Kumar et al., 2012).

The SEM allows the identification of factors that may influence the health problems at various levels; therefore, this model aims to assist in the development of multi-level approaches to deal with complex public health problems (Cullinan et al., 2022). Addressing the infectious disease is complex due to the multiple and interrelated factors contributing to disease outbreaks. In an outbreak situation, using such a framework is critical, particularly when time is of the essence and lives are on the line.

Socioeconomic Factors–Educational Level and Wealth Index

In studies of risk factors influencing children immunity and seroprevalence, Farzad et al. (2017) argued that parental and household characteristics including parental education, occupation, and household wealth index are the most significant predictors of

seropositivity. Researchers have demonstrated that higher level of parental education strongly predict the likelihood of children with high level of antibodies to the polio virus. (Deshpande et al., 2014; Iliyasu et al., 2014; Izadi et al., 2015). Educated parents have been shown to have better health information and to be aware of risks associated with vaccine preventable diseases (Forshaw et al., 2017; Iliyasu et al., 2014). Several studies have shown that parents with a higher degree of education are more likely to completely vaccinate their child as compared to those with a lower level or no education (Asif et al., 2019; Raji et al., 2019).

In a systematic review and meta-analysis of 37 articles, Forshaw et al. (2017) reported that the odds of a child having complete vaccination were 2.3 times greater in children with educated parents as compared to children whose parents had no education. In Pakistan, in a study on factors that predict vaccination completion, parental education and higher socioeconomic status were significantly associated with immunization completion (Siddiqui et al., 2014).

Also, in a study of influence of education on the access to childhood immunization, Mora and Trapero-Bertran (2018) reported that children from families with greater educational attainment level have higher probability of being seropositive in immunization program. Burroway and Hargrove (2018) further supported the findings that caretakers' education, particularly that of the mother, has a robust association with better immunity profile at the individual and community level. Also, education is considered a protective factor for child health because it shapes women's capacity to take

advantage of better access to power, health information, and resources (Burroway & Hargrove, 2018).

In a polio serosurvey study in Kano, Nigeria, Iliyasu et al. (2014) demonstrated that children whose mothers had secondary or tertiary education tended to have more total doses of OPV, and lower seroprevalence was significantly associated with lower maternal educational status (Iliyasu et al., 2014). A similar study from Moradabad district in western Uttar Pradesh of India observed that parents' education duration was significantly associated with higher seroposivity (Deshpande et al., 2014). Farzad et al. (2017) documented that in Afghanistan, those children whose caregivers were educated were 1.59 times more likely to be seropositive and have a complete vaccination schedule than children whose parents had no education. Additionally, in a study to evaluate significant risk factors for seronegativity in Pakistan, Habib et el. (2013) reported that the educational status of the respondent is an additional factor influencing seronegativity. Also, results from the secondary analysis of Pakistan Demographic and Health Survey (PDHS), 2012–2013, showed that uneducated women had significantly higher probability (OR = 2.34, 95% CI [1.05, 5.18]; $p < .01$) of having a child with incomplete polio vaccination status (Khan et al., 2017).

Moreover, in Spain, in a seroprevalence study to assess influence of sociodemographic factors on seroprevalence, Lorenzo et al. (2019) reported that seroprevalence was significantly decreased with low education and socioeconomic status of family. Also, in a hospital and school based seroprevalence study in three regions of Ghana, Opar et al. (2019) documented similar findings that low seroprevalence of polio-

neutralizing antibodies is significantly associated with low school attendance of mothers ($p < .001$).

Interestingly, in Sistan-va-Baluchestan province from Iran, Izadi et al. (2015) assessed the impact of breastfeeding, father's education, and household crowdedness on seroconversion rate among infants with complete doses of OPV history (2, 4, and 6 months). Results showed that the father's education did not show statistically significant associations or even noticeable differences between seropositive and seronegative children (Izadi et al., 2015). Similarly, in Borno and Yobe States, Nigeria, the lack of association between parents' education and seroprevalence contrasts with previous seroprevalence surveys in Nigeria (Gofama et al., 2017).

Beside education, socioeconomic factors may also impact vaccination and hence immunity level of children. Scholars have reported that socioeconomic factors are among the key risk factors for WPV transmission and low immunity in children (Anello et al., 2017; Díaz-Quiñónez et al., 2018; Xu et al., 2020). In a seroprevalence of anti-polio antibodies in children from high-risk areas of Pakistan, Imtiaz et al. (2017) reported that polio seroprevalence was significantly different ($p < .001$) among geographic areas due to different socioeconomic status of families. In China, Xu et el. (2020) reported that low polio seroprevalence levels were associated with poor economical features in three different sites of Chongqing region. In Nigeria, from a nationally representative data of the Nigeria General Household Survey-Panel, Balogun et al. (2017) reported that in addition to maternal education, household economic status is an alternative pathway with indirect effect on children immunity and seroprevalence. In a similar study from a

population-based case-control study in Minnesota, Hammer et al. (2016) documented that immunity and vaccine coverage was lowest in children from the lowest socioeconomic status. Also, Khan et al. (2017) observed that household wealth remained a significant risk factor linked to low polio vaccination and seropositivity in children from Pakistan. Similarly, in Afghanistan, Farzad et al. (2017) reported that being rich is associated with high seroprevalence and complete immunization status. Additionally, Díaz-Quiñónez et al. (2018) found that children with low seroprevalence and fewer polio vaccine doses in Mexico were from lower socioeconomic strata. In this study, illiteracy (OR = 1.5; p = .002) and low household income (OR = 1.4; p = .0487) were risk factors associated with poliovirus susceptibility (Díaz-Quiñónez et al., 2018).

On the other hand, in a population-wide serosurvey against vaccine-preventable diseases in the Netherlands, van den Boogaard et al. (2020) reported that there is no consistent association between socioeconomic status of family and immunity profile of children. Iliyasu et al. (2016) also reported that there was no consistent relationship found between high seroprevalence (seropositivity) and socioeconomic status across the two polio serosurveys conducted in 2014 and 2013 in Nigeria.

Ethnoreligious Affiliation–Religious Beliefs and Tribe/Ethnicity

Beside education and socioeconomic factors, ethnicity has been identified as a significant risk factor that influences child's immunization status particularly for poliomyelitis (Farzad et al., 2017; Forster et al., 2017; Siddiqui et al., 2014). Scholars have argued that some ethnicity-related factors including religion, migration, and languages influence perceptions and decision-making toward immunization; therefore,

immunity status and uptake of some childhood immunizations will vary among different ethnic groups (Forster et al., 2017). In addition, some of the ethnic groups are highly marginalized, do not have legal resident status, are in a constant fighting or fleeing from natural disaster, and usually do not have economic opportunities (Siddiqui et al., 2014). As such, they do not have access to education and basic health care leading to lack of awareness about benefit of preventive health care and low immunity profile (Siddiqui et al., 2014).

Globally, the majority of polio cases are from the Pashtun group that live both in Pakistan and Afghanistan (GPEI, 2021a). Siddiqui et al. (2014) reported that there are ethnic disparities in immunity profile of children in Karachi, Pakistan. This population-based survey showed that Pashtun (67%) and Bengali (48%) families had the lowest vaccine coverage as compared to other ethnic groups in Pakistan (Siddiqui et al., 2014). Also, from the polio antibodies seroprevalence study in the United States, Gregory et al. (2016) reported that there were differences by race/ethnicity and polio serotype among non-Hispanic Blacks and Whites as compared to Hispanic group. In India, ethnic violence and social marginalization also led to creation of ethnic disparities about polio immunity and vaccine efficacy (Hussain et al., 2015). In qualitative ethnography, Hussain et al. (2015) reported that Muslims experienced lower rates of child immunization and higher scores of child health inequality measures related to immunization coverage as compared to Hindu. In Kenya, a significant association between ethnicity and polio immunity was identified among children of different ethnic groups (Allan et al., 2021). It was found that Kikuyu children in the Coast, Western, Central, and Eastern regions had

74% higher odds of being immune to polio virus as compared to Somali children in the Northeastern region (Allan et al., 2021).

Geographic Factor–Region and Distance to Health Facility

There are clear geographic differences in health status of communities as regions have different history, environment, culture, and politics which can create disparities between regions (Finkelstein et al., 2016). In Democratic Republic of the Congo (DRC), in a polio serosurvey study, Voorman et al. (2017) reported that immunity to all three polio serotypes varied by province and was lowest in central DRC and higher in east and west indicating differences in socioeconomic and health status of these regions. Also, result showed that immunity to polio increased in urban areas (Voorman et al., 2017). On the other hand, Alfonso et al. (2022), from a nationally representative data, reported that while seroprevalence varied by place of residence and across provinces, it didn't reach significant level in DRC.

In China, Tan et al. (2018) reported some regional differences in Guangdong province. Seropositivity was lowest in west Guangdong as compared to other three surveyed regions indicating that children living in west were at higher risk of WPV or VDPV outbreak (Tan et al., 2018). In Afghanistan, Hsu et al. (2019) reported regional differences but only in immunity to type 3 virus. Although the study was not powered to provide provincial level estimates, Paktika from southern region had the largest proportion of PV1 seronegative children (Hsu et al., 2019). Another study from Afghanistan revealed that there are large discrepancies between urban and rural areas regarding immunization coverage (Shenton et al., 2018).

Travel time to immunizing health facility also appeared to be a barrier to polio vaccination and improved immunity profile of children. Few studies have examined associations between travel time to health facility and polio seropositivity; yet many have assessed influence of travel time on different vaccine coverage. In Ethiopia, Okwaraji et al. (2012) demonstrated that Children living more than 60 minutes from a health center were significantly less likely (adjRR = 0.85; $p < =.001$) to complete third dose of polio vaccination as compared to children living less than 30 minutes away from a health center. In this community-based study, travel time to health post was also significantly associated with BCG and measles vaccine coverage (Okwaraji et al., 2012). In Nigeria, Sato (2020) reported that an additional distance of 1 km to the nearest health facility reduced the likelihood that one receives a vaccine by about 5% [OR: 0.952, 95% CI = 0.935-0.969]. Also, a longer distance to closest clinic was associated with lower vaccine uptake and delayed timing of vaccination (Sato, 2020).

In Kenya, Morris et al. (2022) assessed the association of distance to nearest health facility to the third dose of the pentavalent vaccine as an indicator of completeness of child's immunizations schedule. Data showed that children living more than 60 minutes from the nearest health post had significantly lower odds of vaccination particularly in rural communities (Morris et al., 2022). In a similar study in Kenya, Noel et al. (2020) documented that travel time of more than 60 minutes significantly reduced immunization coverage and those children living more than two hours from immunizing health facilities were significantly less likely to be fully immunized. Additionally, in Nigeria, Sibeudu et al. (2017) further supported the finding that there is a negative

association between distance to health facility and immunity profile of children. Travel distance to health facility was found to be negatively associated with access to immunization in Anambra state (Sibeudu et al., 2017). Also, data from Demographic and Health Survey of nine sub-Saharan African showed that travel time to health post was significantly associated with full childhood immunization (Fenta et al., 2021).

Individual Factors–Age, Sex, and IPV and OPV doses

Gender-related barriers can also impose indirect effect on immunity profile. At the global level, there is no gender-based discrepancies in immunization coverage; however, in some areas particularly at the subnational level, male children tend to have better immunity as compared to female children (GPEI, 2019). Various seroprevalence and coverage surveys from Afghanistan showed discrepancies and similarities between both genders. Hsu et al. (2019) demonstrated that polio seroprevalence was similar between both genders in Afghanistan. Similarly, Hussain et al. (2018) reported that gender was not a risk factor for seronegativity; yet age was a significant risk factor in Afghanistan. In northern Nigeria, Iliyasu et al. (2014) found that while male gender had higher seroprevalence for all polio serotypes, gender differences did not reach statistically significance. Similarly, in DRC, seropositivity was not associated with the gender of the child (Voorman et al., 2017).

On the other hand, from a study in refugees resettling in Denmark, Hvass and Wejse (2019) documented that age and being male from Horn of Africa were associated with lack of immunity to poliovirus. In Guinea and Cote d'Ivoire, younger age groups were found to be at higher risk to type 2 poliovirus infection (Guindo et al., 2018). In

Niger, Ousmane et al. (2021) reported that immunity toward polio virus type 3 increased with age. Voorman et al. (2017) further supporting the idea of increased seroprevalence with older age groups.

Maintenance of population immunity against polio is critical through vaccination as poliomyelitis can be prevented using injectable IPVs and live attenuated OPVs (Voorman et al., 2017). In DRC, Voorman et al. (2017) reported that an additional OPV doses can increase polio immunity by 5%, 16%, and 5.5% for type 1, 2 and 3 serotypes. In Japan, high seropositivity was found to be associated with high OPV/IPV doses (Satoh et al., 2019). Also, in Nigeria, there was a significant association between seroprevalence and number of OPV doses received (Iliyasu et al., 2014). On the other hand, in Guinea-Bissau, Hansen et al. (2014) reported that OPV received at birth or with complete doses at six months of age did not contribute to higher antibody level.

Definition and Abbreviations

Endemic: A case that belongs to a particular people or country (Kalra et al., 2015).

Epidemic: A widespread occurrence of an infectious disease in a community at a particular time (Kalra et al., 2015).

Immunity: The body's ability to protect from an infectious disease and is gained through the presence of antibodies to that disease in a person's system (Voorman et al., 2017). These antibodies are disease specific and are proteins produced by the body to neutralize or destroy disease-carrying organisms (CDC,2021a).

Immunization: A process by which human body becomes protected against a disease through vaccination(CDC, 2021a).

IPV: Inactivated polio vaccine (IPV) to protect individuals against poliomyelitis. Individuals should get four doses in total to be considered fully vaccinated. It is taken at 2,4, 6 through 18 months old and 4 through 6 years old (CDC, 2021b).

OPV: Oral poliovirus vaccine (OPV) is the main vaccine used to eradicate polio. There are different types of OPV which can contain one, a combination of two, or all three polio serotypes of attenuated vaccine (Centers for Disease Control and Prevention, 2021a).

Outbreak: The occurrence of cases of disease in excess of what would normally be expected in a defined community, geographical area or season (Kalra et al., 2015).

Polio: Also referred to as poliomyelitis, this is an infectious disease caused by the poliovirus which attacks the central nervous system and cause permanent paralysis of lower limb (CDC, 2021b).

Seroprevalence risk factors: Scholars in this literature review have identified that seroprevalence of antibodies to different types of polio virus has been associated with age, gender, socioeconomic status and place of residence, in addition to the number of OPV /IPV doses received (Hsu et al., 2019; Iliyasu et al., 2016; Mohammad et al., 2021; Opare et al., 2019; Satoh et al., 2019; Vivian et al., 2022). In this study, similar variables will be examined in the Afghanistan polio serosurvey secondary data set to find out their relationship to seronegativity among children in Afghanistan high risk areas.

Seronegative: Seronegative means that the person has negative test result for the presence of a specific antibody in the serum of the blood and does not have the same antibodies that a person who is seropositive (Xu et al., 2020). Also, a seronegative person may have such low levels of antibodies in the body that a blood test does not detect the presence of either (CDC, 2021b).

Seropositive: Seropositive means that the person has specific antibody in the serum of the blood as detected by serological test (CDC, 2021b).In this study, seropositivity for poliovirus antibody defined as reciprocal titers of poliovirus-neutralizing antibodies ≥3.

Vaccine: A biological substance that is used to stimulate the body's immune response against diseases (CDC, 2021a). Vaccines are usually administered through needle injections, and some can be administered orally (Blume & Geesink, 2000).

Vaccination: The act of introducing a vaccine into the body to produce protection from a specific disease (Blume & Geesink, 2000).

Assumptions

Assumptions are important to be addressed as they can lead to drastically invalid results (Mishra et al., 2019) .The assumptions of this study include the following: The participants told the truth when they participated in the primary survey from which this secondary data study will be conducted; electronic data entry was conducted ethically, efficiently, and effectively with minimal errors; the missing data will be assessed to ensure the survey was not biased by the collector; and the vaccination documentation was accurate. Also, it is assumed that the secondary data used contained the expected

dependent and independent variables, and most importantly has enough cases and variables.

Scope and Delimitation

This study was based on the 2020 Afghanistan polio serosurvey dataset to investigate various risk factors such as gender, parental education, family origin (language/location), wealth, distance to nearest health facility and IPV/OPV doses on the level of antibodies (seroprevalence) against all three types of polioviruses in children of two age groups, 6-11 months and 36-48 months, living in polio reservoir areas of Afghanistan. The study was based on the secondary data analysis and there were no primary data collection or any contact with the participants involved in the dataset. Only the variables that are existed in the dataset were used.

This study was delimited to a quantitative cross-sectional study, there were no control groups for comparison or any intervention for temporal analysis. Also, the study was delimited by number of questions in the data collection tools and the sample size used for the serosurvey. The study was delimited to the information collected by the data collector and the time of data collection. There was time lag between collection and analysis of this secondary data. The study was delimited to the parents who reported having a child whose age was between 6 and 48 months at the time of information gathering.

Limitations

This study has several limitations including the use of secondary data collected by other researchers. Since data collected by the researchers was based on his/he objectives,

use of this secondary data may be biased. Another limitation is the quality of data, the data is already collected and hence any changes in the surroundings or other factors that may lead to the change in the data provided cannot be controlled. Missing data might impact the results as well since dataset cannot be modified to adjust for the missing information. There is possibility of having information bias resulting from recall capacities of respondents which further can influence the result as well. Moreover, using secondary data and cross-sectional study design, it is difficult to establish causality between dependent and independent variables.

Reliability and internal consistency for this study is more about how consistent the serosurvey instrument has been over time in measuring its constructs or characteristics (Kimberlin & Winterstein, 2008). Two previous polio seroprevalence surveys were conducted in Afghanistan in 2017 by the WHO, AKU, Care of Afghan Families (CAF) and the CDC using the same construct of this study (Hussain et al., 2018). Results from previous surveys has had consistent results with literature; hence, the instrument is considered reliable (GPEI, 2021a; Hsu et al., 2019; Hussain et al., 2018; Tan et al., 2018). The level of consistency of the instrument describes how accurate the study population were represented using the instrument repeatedly (Kimberlin & Winterstein, 2008). Finally, the findings from this study cannot be generalized to other population in Afghanistan but only to Kandahar and Jalalabad city as the study was limited to these two cites.

Significance and Potential for Positive Social Change

Results of this quantitative study can lead to changes in polio eradication strategies as well as help in assessing risk of future outbreaks of VDPVs in Afghanistan. Results can also help estimate population immunity in districts at high risk of polio importation and to gauge underlying population immunity gaps to poliomyelitis and possibly to guide preparedness and response planning. In addition, it can determine the relationship between risk factors associated with childhood vaccination coverage in Afghanistan.

Results can contribute to positive social change by providing valuable information to policymakers for improving vaccination coverage in Afghanistan and other developing countries. Results can also raise social awareness on the importance of polio vaccines by disseminating messages on vaccine efficacy and how globally polio could be eradicated from many countries because of vaccination. Through education, there will be individual level along with societal level changes. In this study, the changes include awareness, knowledge, policy and attitudes towards polio vaccination and consequently it could lead to positive behavioral changes at a larger scale.

Summary and Conclusion

This section described the importance of polio serosurvey to help identify gaps within immunization program. Polio is identified as a public health problem that need to be eradicated. The insufficient vaccination coverage coupled with conflict in Afghanistan has resulted in poor health outcomes. The purpose of the study, nature of the study, the research questions and hypotheses, assumptions, and detailed literature review were

presented. The section was concluded with a brief description of the significance and the potential for positive social change impact of the study. The next section will focus on the methodology used for this scientific inquiry. In this section, the population studied, the dataset used, the data management process, and ethical issues will be described.

Section 2: Research Design and Data Collection

Introduction

The purpose of this quantitative, cross-sectional study was to investigate various risk factors such as gender, parental education, family origin (language/location), wealth, distance to nearest health facility and IPV/OPV doses on the level of antibodies (seroprevalence) against all three types of polioviruses in children of two age groups, 6-11 months, and 36-48 months, living in polio reservoir areas of Afghanistan. In this section, I present the research design and rationale, methodology, study area, and population in Afghanistan, as well as the research data variables, the sampling procedure, and the sample size calculations. Subsequently, the inclusion and exclusion criteria are described. Finally, the research questions, hypotheses, data analysis plan, the statistical tests, and the summary are presented.

Research Design and Rationale

Research design is the framework of research methods and techniques chosen by a researcher to answer certain research problems (Das, 2022). The purpose of a research design is to provide a plan of study that permits accurate assessment of cause-and-effect relationships between independent and dependent variables (Carnahan et al., 2010). Moreover, research design allows researcher to confirm or deny the hypothesis (Carnahan et al., 2010). In this study, secondary data from a community-based cross-sectional survey was used. Cross-sectional study design has advantages and is preferred due to its ability to shed light on causal connections (Spector, 2019). The data used for this study

were collected between February and March 2020. The study is quantitative and the association between the dependent and independent variables was determined.

Research Methodology

In this subsection, I describe the methodology used in the study. The study area and population examined will be defined first. Next, the sampling techniques and ethical issues will be explained, followed by a restatement of the research questions. Finally, I will explain the statistical tests and the analyses that will be used.

Study Area and Population

In the original study, a community-based cross-sectional survey was conducted by CDC and AKU in two cities of Afghanistan: Kandahar and Jalalabad. Areas that fall into any environmental sampling sites were considered as catchment areas. All of Kandahar and Jalalabad were sampled, and the catchment area for the one environmental sampling site in Behsud district, which borders Jalalabad, was also sampled. Because of the geographic adjacency, the Behsud district was considered part of Jalalabad during sampling. There were four sampling sites in Kandahar and a part of the city that is not included in any catchment area. There were three environmental sites in Jalalabad and one in the neighboring Behsud district.

The study enrolled children belonging to two age groups, 6-11 months and 36-48 months, residing in Kandahar, Jalalabad, and a specific area of Behsud district. The participants were included in the study after obtaining informed consent. The data were collected by teams during different time periods, from February 16 to March 19, 2020, in Behsud and Jalalabad, and from February 25 to March 19, 2020, in Kandahar. The study

area boundaries were defined using administrative level three units, which are the smallest operational units for polio microplanning and are locally known as “clusters.”

These areas were selected due to the frequency of positive environmental isolates identified at sampling sites within the cities (GPEI, 2019). In addition, they are urban hubs for large population movement within the core polio reservoirs of the Northern and Southern Corridors of Afghanistan and Pakistan (GPEI, 2019).

Data Collection

Each survey team consisted of a team lead and 12 data collectors, along with a social mobilizer, nurse/phlebotomist, and a data collector for each survey site. The composition of all teams followed a 1:2 male to female ratio. The inclusion of female team members was crucial for gaining access to every household since women adhere to the *purdah* or veil system, a religious and social practice that mandates veiling and prohibits males from entering the household without permission from the head of the household (Rasuly-Paleczek, 2021).

To navigate to the predetermined starting points, each team was provided with digital maps on GPS-enabled tablets that indicated pre-selected point locations requiring collection of serology samples. Data collectors with extensive knowledge of the terrain and populations were used wherever possible to act as intermediaries between AKU investigators and suspicious or hostile populations (Amalia et al., 2022).

Teams were instructed to select and survey the closest residential structure within a search radius of 60 m from the predetermined points provided. In addition to the 60 m search radius, a total of 400 replacement collection points were provided for each study

area in the event of refusals and/or to account for points located in non-residential areas. If there were no qualifying children in the enrollment age group (6-11 months and 36-48 months) or the household refused to participate, field teams attempted to enroll the next closest house within a 60-m search radius of the predetermined starting point provided (Kumar, 2007).

The field teams utilized ArcGIS Explorer (Version 20.2.0; ESRI, Redlands, California, United States of America), an Android application developed by ESRI. This application was used to navigate to preselected points during the survey. Explorer was selected as it can operate in areas without internet access, enabling the teams to carry digital maps on tablets directly to the field. Along with ArcGIS Explorer, the teams used Open Data Kit (ODK), an open-source software designed for collecting geotagged questionnaire data. Each questionnaire gathered details on patient demographics, socioeconomic status, and immunization history and status.

Informed consent was obtained from caretakers of all eligible participants. In case of refusal to participate, parents/caregivers were asked if they would agree to answer a few questions, for example, age of child, district and village of residence, population group (e.g., nomad, returnee, refugee, etc.), travel history, and OPV and IPV immunization status of the child (RI and SIAs). These data assisted in quantifying the possible effects of non-response on the survey results.

After obtaining informed consent, the questionnaire was administered, and the blood drawn at the home. Families were given a small incentive (i.e., food/vitamins or school supplies) for their participation in the study. The results of the analysis will be

shared with any families whose children are found to be seronegative for polio or other vaccine preventable diseases.

Spatial Sampling Methodology

To randomize enrollment, the sampling approach used spatially randomized predetermined starting points to identify households. Due to the density of structures, no building classifications were available (e.g., commercial vs. residential) via satellite imagery. Instead, random points were overlaid on maps within the study areas, and every predetermined starting point served as team starting locations (Kumar, 2007). The “create random points” tool available in ArcGIS Pro (ESRI, Redlands, CA) software was utilized to generate primary starting point locations. The tool creates a specified number of random points generated within a constraining polygon. Since the study area encompassed multiple constraining cluster polygons, the “dissolve” tool was used to obtain a single constraining feature for each study area (Amalia et al., 2022). The clusters in Kandahar were further stratified into ES catchment and non-catchment areas by the Afghanistan Ministry of Health (MoH). Non-catchment areas were included within the study to offer insights into ongoing circulation of poliovirus in areas lacking ES sites. Kandahar was the only study area that included non-catchment areas (50 clusters) as both Jalalabad and Behsud solely consist of catchment areas (see Figure 1).

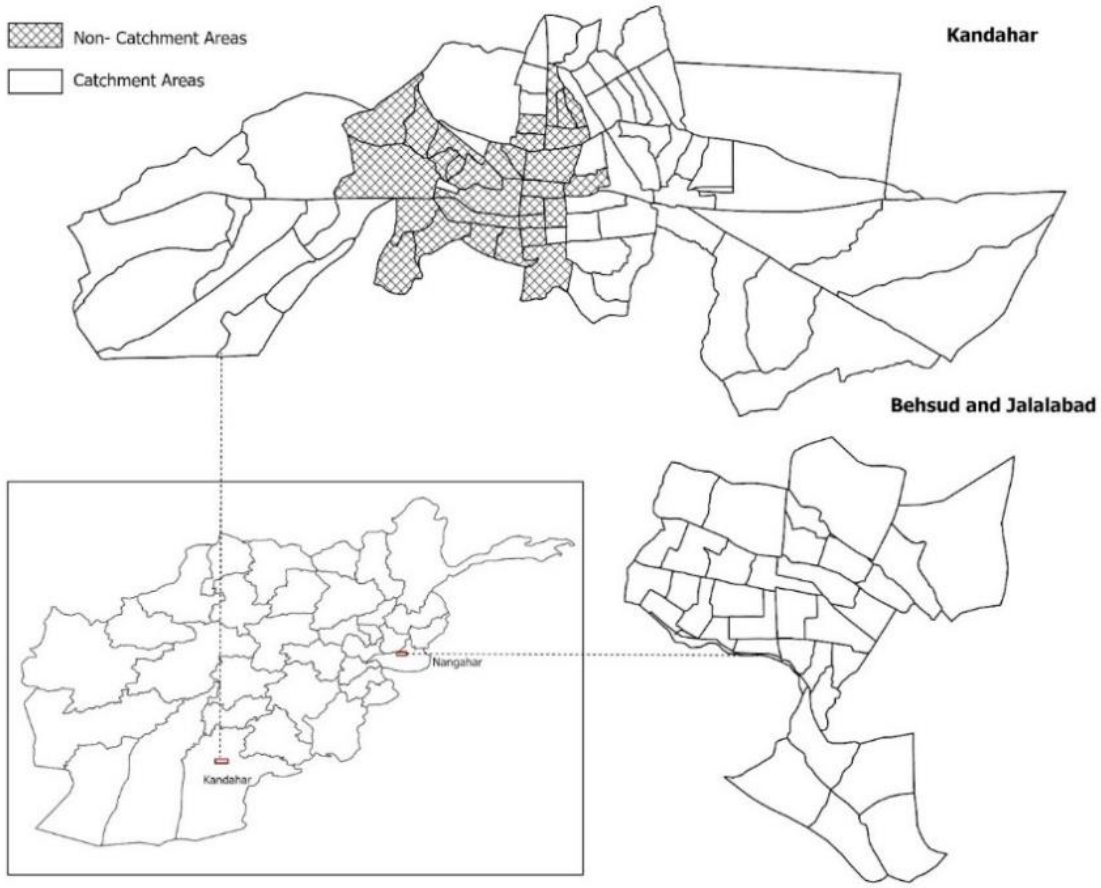
For city level estimates, 800 children were enrolled from each city. A sample size of 800 yields a precision of approximately +/-5% if the proportion was equal 50%, +/-4% if the proportion was 80%, or +/-3% if the proportion was 90%, with alpha level of 0.05 (Simple Asymptotic Formula; (Chan & Bohidar, 1998) .

The breakdown of the random point distributions is proportional to the population under 5 years of age in each strata area, as follows:

- Kandahar:
    - 350 geocoordinates randomly distributed among all clusters (an administrative unit designated by the polio program for use during vaccination campaigns) which fall into the catchment areas of environmental sampling sites
    - 450 geocoordinates randomly distributed among all clusters designated by the polio program not to fall into catchment areas of environmental sampling sites
- Jalalabad and Behsud district:
    - 782 geocoordinates randomly distributed among all clusters of Jalalabad (all of which are in environmental sampling site catchment areas)
    - 50 geocoordinates randomly distributed among the five clusters of Behsud district that fall into the catchment area of an environmental sampling site as designated by the polio program

Figure 1

Selected Areas for Polio Serosurvey



Inclusion and Exclusion Criteria

All children of two age groups, 6-11 months and 36-48 months, found to be living in the cities, either permanently or on a temporary basis as guests in the selected households were eligible for enrollment. Before enrollment in the study, a detailed history and examination were undertaken for each child to ascertain eligibility. Children with severe acute or chronic illness specifically immunodeficiency and neoplasms and on

chemotherapy were excluded. Only children without illnesses or with minor non-polio related illnesses were considered for enrollment.

Data Security

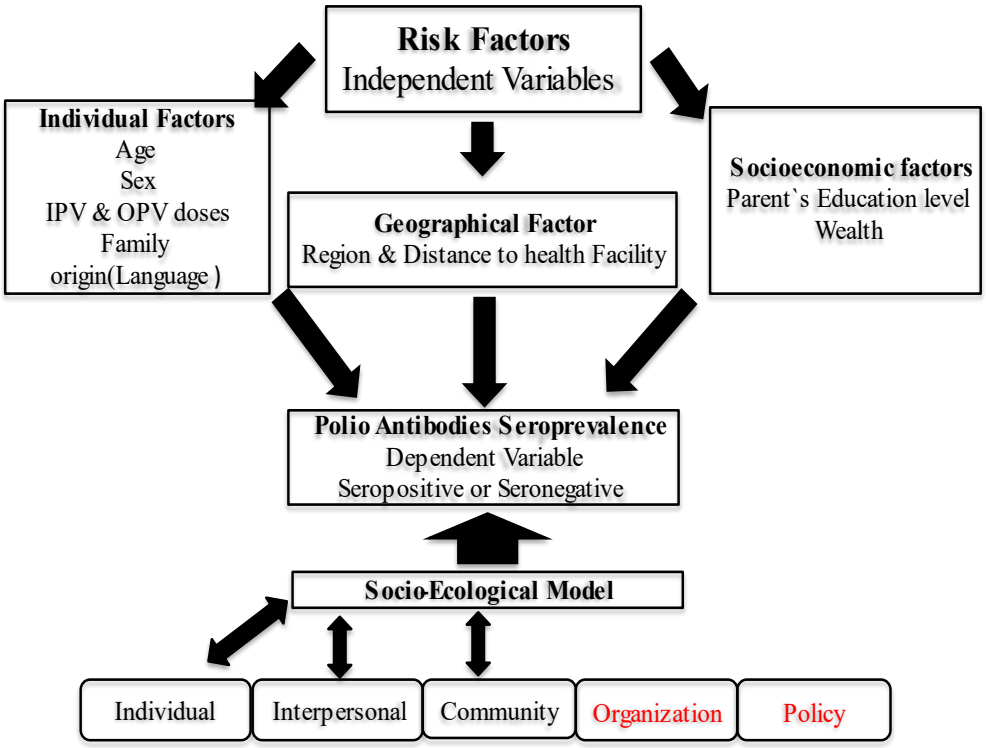
The study obtained approvals from the Ethical Research Committee of AKU and the Internal Review Board (IRB) of the Ministry of Public Health, Kabul, Afghanistan. All personal patient information was kept confidential, except for a senior project staff having access to identifier data, and data sets were analyzed anonymously. Codes were assigned to each enumerator in the field and every completed ODK questionnaire was submitted to a secure, password-protected server via an encrypted connection. To avoid loss of data and for completeness, all datasets were exported daily by the CDC and AKU.

Conceptual Framework

The conceptual framework of this present study in terms of dependent and independent variables is depicted in Figure 2. Seroprevalence was categorized as the dependent or outcome variable (seropositive and seronegative). Seropositivity is defined as reciprocal titers of poliovirus-neutralizing antibodies ≥3. Independent variables involved caretaker's factors (i.e., education level and wealth), child's factors (i.e., age, gender, IPV/OPV doses, and ethnicity), and geographical factors (i.e., region and distance to health facility). All the variables were collected by CDC and AKU as primary researchers for Afghanistan in 2020. The SEM was used to address the relevant risk factors that may affect the public health practice related to immunity in children at the individual, interpersonal, community and public health policy levels (Kolff et al., 2018; McLeroy et al., 1988).

Figure 2

Conceptual Framework



Data Variables and Description

The dependent variable used for this study was seroprevalence (seropositive and seronegative), which was evaluated for each poliovirus types (PV1, PV2, and PV3). Seroprevalence range of 3 and more is considered seropositive; otherwise, it is seronegative. Independent variables included: age, gender, ethnicity of the child; education level and wealth of parents; regions and distance to nearest health facility. The data set consists of three classes of variables: parents, children, and geographical variables. The age of each respondent was coded as the actual age, which were

categorized later into two groups based on the target (6-11 months and 36-48 months). The gender of each respondent was coded as male and female. Respondents' education level was coded into no formal schooling, primary school, secondary school certificate, high school certificate, graduated, masters, religious education, illiterate and other. Wealth index was estimated using ownership status of house as "yes" or "no". For each OPV/IPV vaccination status, the terms were coded as "yes," "no," or "do not know." If child was OPV vaccinated, the number of doses taken was recorded. The distance to health facility was coded in two variables: by distance in kilometers or by walking time in minutes. Language spoken (ethnicity) was evaluated as a predictor and categorized as Pashtu, Dari, Hazari, Uzbeki, Turkmeni, Nuristani, Balochi, Pashaee and Other. As for region, areas that were surveyed: Behsud (Jalalabad), Jalalabad city, Catchment area (Kandahar), Non-catchment area (Kandahar) were listed.

Research Questions

This study evaluated the following three research questions:

- RQ1: What is the effect of risk factors (gender, caretaker's education, wealth, family origin, and region) on the level of polio antibodies (seroprevalence; PV1, PV2, and PV3) in children ages 6-11 months and 36-48 months, living in polio high-risk areas of Afghanistan?
- RQ2: What is the effect of distance to health facility on the level of polio antibodies (seroprevalence; PV1, PV2, and PV3) in children ages 6-11 months and 36-48 months, in children of specific age groups living in polio high-risk areas of Afghanistan?

- RQ3: What is the effect of OPV/IPV doses (full, partial, and none) on the level of polio antibodies (seroprevalence) in children ages 6-11 months and 36-48 months, living in polio high-risk areas of Afghanistan?

Risk factors were independent variables. Seroprevalence was the dependent variable. Table 1 summarizes the study variables by research question.

Table 1

Study Variables by Research Question

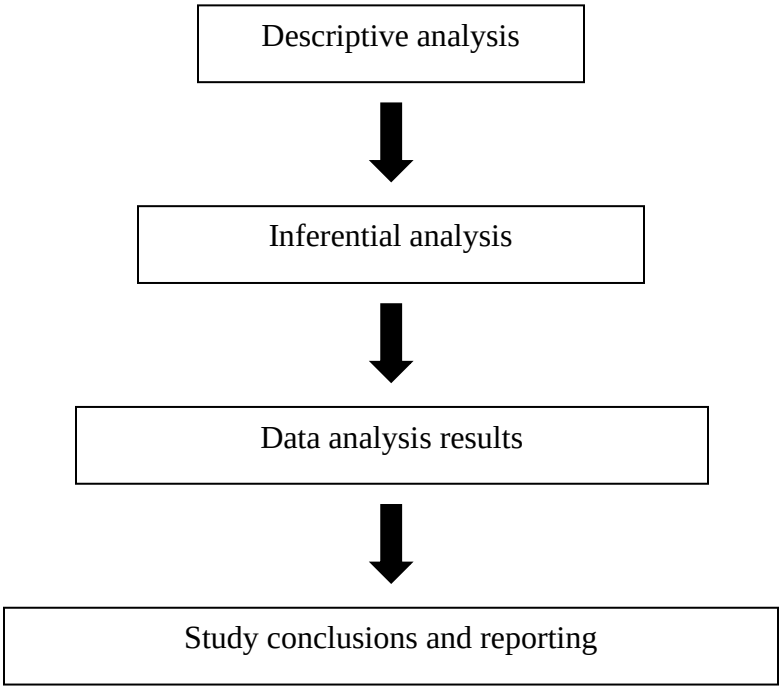
Research question	Dependent variable	Independent/predictor variables
RQ1: What is the effect of risk factors (gender, caretaker's education, wealth, family origin, and region) on the level of polio antibodies (seroprevalence) (PV1, PV2, and PV3) in children ages, 6-11 and 36-48 months, living in polio high-risk areas of Afghanistan?	Seroprevalence (binary)	Gender (nominal) Male = 1 Female = 2 Education (ordinal) Illiterate = 0 No formal schooling = 1 Primary = 2 SSC = 3 HSC = 4 Graduated = 5 Masters = 6 Religious education = 7 Declined/refused/unknown = 99 Wealth/ownership status (nominal) Owned = 1 Rented = 2 Living without paying rent = 3 Other = 88 Declined/refused/unknown = 99 Family origin/ethnicity/language spoken (nominal) Pashtu, Dari, Hazarai, Uzbeki, Turkmeni, Nuristani, Balochi, Pashaee, Other Region (nominal) Behsud Jalalabad = JB Jalalabad City = JC Kandahar Catchment Area = KC Kandahar Non-Catchment Area = KM
RQ2: What is the effect of distance to health facility on the level of polio antibodies (seroprevalence; PV1, PV2, and PV3) in children ages 6-11 and 36-48 months, living in polio high-risk areas of Afghanistan?	Seroprevalence (binary)	Distance to health facility from home (in kilometers; continuous) Distance to health facility from home by walking (in minutes; continuous)
RQ3: What is the effect of OPV/IPV doses (full, partial, and none) on the level of polio antibodies (seroprevalence) in children ages, 6-11 and 36-48 months, living in polio high-risk areas of Afghanistan?	Seroprevalence (binary)	Number of OPV doses taken by weeks (OPV0, OPV6, OPV10, OPV14; ordinal) Full = +4 doses Partial = 1-3 doses None = 0 doses IPV doses taken at Week 14 (nominal) Yes = 1 No vaccination = 0

Data Analysis Plan

The data plan involves the description and inferential analyses. This will be followed by data analysis results. Finally, the study conclusions and reporting will be presented. The four steps of the data analysis plan are summarized in Figure 3.

Figure 3

The Four Steps of Data Analysis Plan



Statistical Test and Analysis

SPSS (Version 25) was used to perform the statistical analysis of the secondary data of Afghanistan polio serosurvey 2020. Selection of the appropriate statistical methods is very important for the quality of the results (Mishra et al., 2019). Since each test has assumptions about the data, these assumptions were taken into consideration in this study when applying the appropriate test. In case of violation of the assumptions, it is

recommended to use data transformations, such as natural log or square root transformations, in order to address the violation (Mishra et al., 2019). A Chi-Square test of independence, with $p < .05$, was used to determine whether or not there is a significant association between independent and categorical variables (Mishra et al., 2019).

Similarly, logistic regression was applied to test the predictive ability or influence of the independent variables on the dependent variable (Parab & Bhalerao, 2010). Since the dependent variable is binary (seropositive/ seronegative), and there are more than two independent variables, Binary Logistic Regression can be applied so that all predictor variables will be tested in one block to assess their predictive ability while controlling for the effects of other predictors in the model (Tukur & Usman, 2016).

The rationale for including the above dependent variables was that they have been known to influence vaccination status and their effects were statistically significant in previous research (Bahl et al., 2014; Hussain et al., 2018; Setegn Muche et al., 2021). Hence, they were added to the binary logistic regressions model for the current research. In the binary logistic regression, odds ratio (OR) and a 95% confidence interval were used to interpret the results. Only data that were entered between February 25, 2020, to March 19, 2020, will be used for this study. Specimens with no laboratory bar code were excluded from the study and samples that has matching bar code were analyzed. Table 2 summarizes the statistical analysis by research question.

Table 2

Research Questions, Independent/Dependent Variables, and Statistical Tests

Research questions	Independent variables	Dependent variable	Inferential statistical analysis
RQ1: What is the effect of risk factors (gender, caretaker's education, wealth, family origin, and region) on the level of polio antibodies (seroprevalence) (PV1, PV2, and PV3) in children ages 6-11 and 36-48 months, living in polio high-risk areas of Afghanistan?	Risk factors Gender and ethnicity of the child, Education level & wealth of caretaker, Region	Seroprevalence • Seropositive • Seronegative	Chi-square test and binary logistic regression analysis
RQ2: What is the effect of distance to health facility on the level of polio antibodies (seroprevalence) (PV1, PV2, and PV3) in children ages 6-11 and 36-48 months, living in polio high-risk areas of Afghanistan?	Distance to nearest health facility (continuous)		Logistic regression
RQ3: What is the effect of OPV/IPV doses (full, partial, and none) on the level of polio antibodies (seroprevalence) in children ages 6-11 and 36-48 months, living in polio high-risk areas of Afghanistan?	OPV vaccine doses (full, partial, and none) IPV doses (Yes/No)		Chi-square test and binary logistic regression analysis

Threats to Validity

The reliability and validity of the data were evaluated by CDC data source. This study is a nonexperimental, quantitative, cross-sectional survey using spatially randomized predetermined starting points did not have the experimental design threats to internal validity (Slocum et al., 2022). The use of randomized sampling ensured random selection and predetermination of starting points minimized selection bias (Slocum et al., 2022). In addition, CDC has used three GIS measures to assess validity in navigating to pre-selected sampling points and enrolling a household: the percentage of household interviews where a GPS coordinate was successfully recorded, whether the GPS points of household interviews were within the correct cluster, and if enumerators enrolled a household near random starting point using 60m buffer. An additional analysis was done using normalized difference vegetation index (NDVI), an image ratio vegetation layer, to estimate sample points that may have fallen in agricultural areas with few houses (Huang et al., 2021). Importantly, this study will not attempt to establish a causal effect because immunity against poliomyelitis following the recommended vaccination schedule has already been established (CDC, 2021b). To ensure data were gathered correctly, consistently, and with continuous quality supervision, CDC in coordination with AKU had an extensive training program for supervisors and enumerators on survey implementation.

Summary

Section 2 of this research inquiry elaborated on the research design, a cross-sectional quantitative approach, and rationale of the study. The methodology, the study

area and population examined, sampling and sampling procedure, and operationalization of constructs were described. The independent and dependent variables, and the data analysis plan were also described. In the following section, results and findings will be presented.

Section 3: Presentation of Results and Findings

The purpose of this study was to examine various risk factors such as gender, care takers' education, family origin (language/location), wealth, distance to nearest health facility, and IPV/OPV vaccine status on the level of antibodies (seroprevalence) against all three types of polioviruses in children of two age groups, 6-11 months and 36-48 months, living in polio reservoir areas of Afghanistan. Based on the results and findings, evidence will be provided in this section about the risk factors that influence polio antibodies seroprevalence and factors that hinder polio eradication in Afghanistan. The study participants were from all four regions of Afghanistan that had been surveyed in the 2020 polio serosurvey. IBM SPSS (Version 25) was used to analyze the dataset to answer the research questions by testing the associated hypotheses:

RQ1: What is the effect of risk factors (gender, caretaker's education, wealth, family origin, and region) on the level of polio antibodies (seroprevalence; PV1, PV2, and PV3) in children, ages 6-11 and 36-48 months, living in polio high-risk areas of Afghanistan?

$H_0$1: There is no significant effect of the risk factors on the level of polio antibodies (seroprevalence) in children, ages 6-11 and 36-48 months, living in polio high-risk areas of Afghanistan.

H_a1: There is significant effect of the risk factors on the level of polio antibodies (seroprevalence) in children, ages 6-11 and 36-48 months, living in polio high-risk areas of Afghanistan.

RQ2: What is the effect of distance to health facility on the level of polio antibodies (seroprevalence; PV1, PV2, and PV3) in children, ages 6-11 and 36-48 months, living in polio high-risk areas of Afghanistan?

$H_0$2: There is no significant effect of distance to health facility on the level of polio antibodies (seroprevalence) in children, ages 6-11 and 36-48 months, living in polio high-risk areas of Afghanistan.

H_a2: There is significant effect of distance to health facility on the level of polio antibodies (seroprevalence) in children, ages 6-11 and 36-48 months, living in polio high-risk areas of Afghanistan.

RQ3: What is the effect of OPV/IPV doses (full, partial, and none) on the level of polio antibodies (seroprevalence) in children, ages 6-11 and 36-48 months, living in polio high-risk areas of Afghanistan?

$H_0$3: There is no significant effect of OPV/IPV doses on the level of polio antibodies (seroprevalence) in children, ages 6-11 and 36-48 months, living in polio high-risk areas of Afghanistan.

H_a3: There is significant effect of OPV/IPV doses on the level of polio antibodies (seroprevalence) in children, ages 6-11 and 36-48 months, living in polio high risk areas of Afghanistan.

Descriptive Analysis

Descriptive Characteristics of the Sample Population

Among the 1,412 respondents selected for the study, only 1,384 had serological laboratory results. Figures 4 and 5 show the distribution of the children who are

seropositive or seronegative to different types of polio virus (PV1, PV2 and PV3) and by age groups, respectively.

Figure 4 shows that overall, 99% of the children were seropositive against PV1, 90% were seropositive for PV2, and 95% were seropositive for PV3.

Figure 4

*Serological Protection Against PV1, PV2, and PV3 (*N = *1384)*

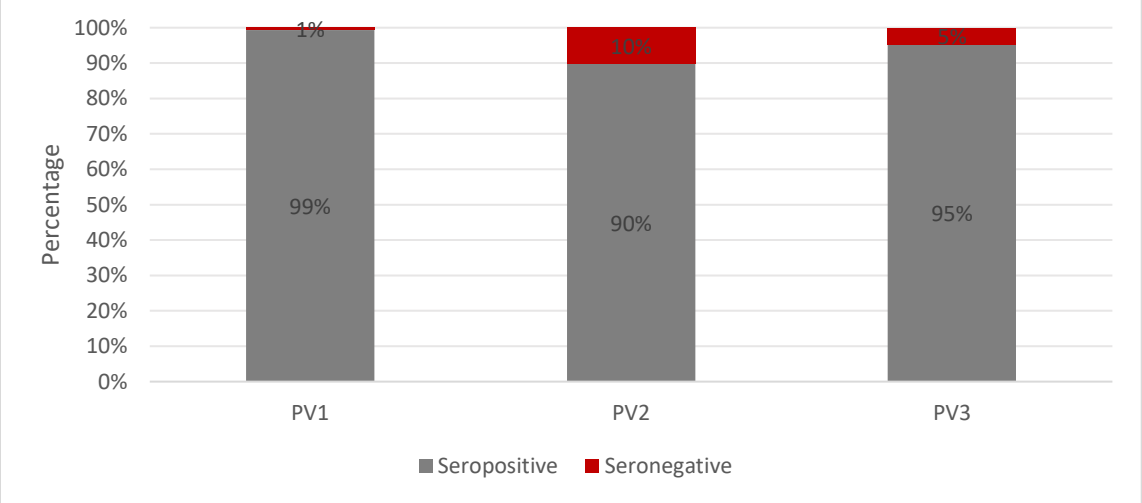


Figure 5 presents the overall results for seroprevalence by age group (x-axis) and poliovirus type (y-axis). Overall seroprevalence is high among the children that were sampled. It is quite high for PV1 and PV3 in both the older age group (100% and 95%, respectively) and in the younger age group (99% and 95%, respectively). As for PV2, the highest seronegativity was seen in both age groups as compared to PV1 and PV3 (12% and 9% in ages 6-11 months and 34-48 months, respectively).

Figure 5

*Serological Protection Against PV1, PV2, and PV3 by Age Group (*N = *1384)*

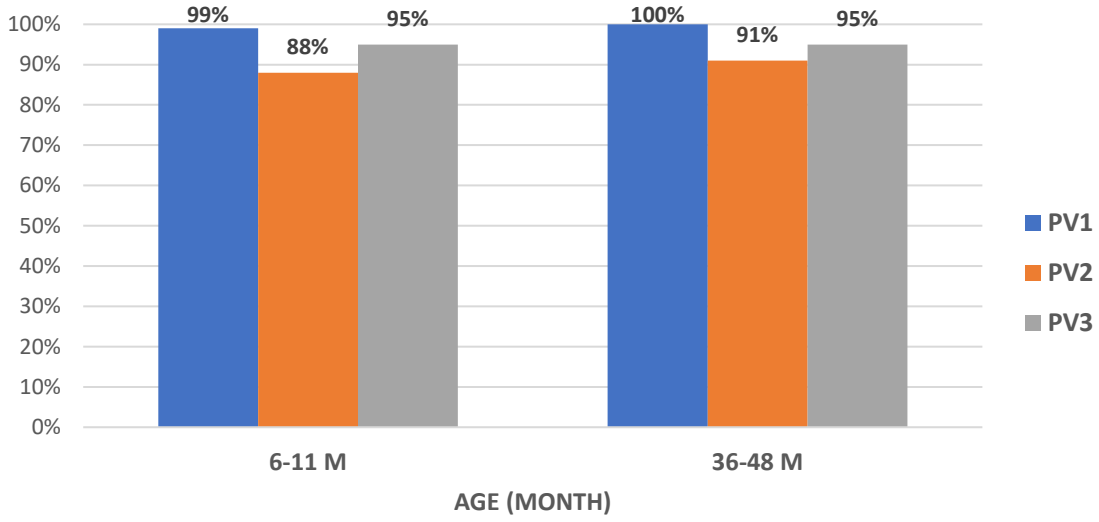


Table 3 shows the distribution of the children who completed or did not complete the polio vaccination as per Afghanistan's recommended schedule. Afghanistan's current immunization schedule classifies a child as fully vaccinated against poliovirus upon receiving a dose of OPV at birth in addition to taking OPV at 6, 10, and 14 weeks, and a dose of IPV at 14 weeks. Table 3 also shows that the majority of participants have taken the OPV birth dose (98.7%). Similarly, 98.6% ,98.2% and 98.2% have taken OPV first, second and third dose, respectively. In addition, only 2% did not take IPV at 14 weeks. Among the surveyed children, 1353 (95.8%) are fully vaccinated, 15 (1.1%) are partially vaccinated, and only 16 (1.1%) are not vaccinated against the polio virus.

Table 3

*OPV/IPV Vaccination Status of Participants (*N *= 1412)*

Variables	*n*	%
OPV birth dose		
Not vaccinated	18	1.3
Vaccinated	1394	98.7
OPV first dose		
Not vaccinated	20	1.4
Vaccinated	1392	98.6
OPV second doses		
Not vaccinated	25	1.8
Vaccinated	1387	98.2
OPV third doses		
Not vaccinated	25	1.8
Vaccinated	1387	98.2
IPV		
Not vaccinated	28	2.0
Vaccinated	1384	98.0
OPV Status		
None	16	1.1
Partial	15	1.1
Fully vaccinated	1353	95.8

Individual Characteristics of the Children

The age group and gender of the children are depicted in Table 4. The proportion of age groups are almost equally distributed among the two groups: 6-11 months (49.3%) and 36-48 months (50.7%), respectively. Similarly, the proportion of the male respondents (50.8%) is almost equal to female (49.2%).

Table 4

*Age Groups and Gender of Participants (*N *= 1412)*

Variables	*n*	%
Age group		
36-48 months	716	50.7
6-11 months	696	49.3
Gender		
Male	718	50.8
Female	694	49.2

Socioeconomic Characteristics of the Caretakers

Table 5 is a descriptive analysis of the educational level and wealth index of the 1412 respondents' caretakers. The respondents with no education (illiterate) constituted the majority (49.5%), followed by primary education (16.9%), and no formal schooling (11.6%). Far fewer respondents held undergraduate and master's degrees (2.3% and 0.6%, respectively). The wealth index as indicated by home ownership in this study showed that the majority (82.6%) owned their houses.

Table 5

*Socioeconomic Characteristics of the Respondents (*N = *1412)*

Variables	*n*	%
Education level		
University graduated	33	2.3
High school certificate	43	3.0
Illiterate	699	49.5
Masters	8	0.6
No formal schooling	164	11.6
Others	1	0.1
Primary	239	16.9
Refused/unknown	36	2.5
Religious education	115	8.1
Secondary school certificate	74	5.2
Home ownership (wealth index)		
Yes	1166	82.6
No	245	17.4
Refused/unknown	1	0.1

Ethno-Religious Characteristics of the Respondents

The respondents also differed in ethnic background. Table 6 shows that the Pashtu group are the majority (87.3%), followed by Dari (12.4%), while other ethnic groups (Uzbeki/other) are the minority (0.4%, taken together).

Table 6

*Language Spoken (*N = *1412)*

Language	*n*	%
Dari	175	12.4
Other	1	0.1
Pashtu	1232	87.3
Uzbeki	4	0.3

Geographic Factors

The majority of participants were from Jalalabad (53.9%), followed by Kandahar non-catchment area (25.7%) and Kandahar catchment area (18.9%), whereas very few were from Behsud (1.5%; see Table 7). As for the distance to the nearest health facility, the average time of walking to the nearest health facility is 26.07 minutes and 6.74 kilometers (see Table 8).

Table 7

*Region (*N = *1412)*

Region	*n*	%
Kandahar (non-catchment area)	363	25.7
Behsud (Jalalabad)	21	1.5
Jalalabad	761	53.9
Kandahar (catchment area)	267	18.9

Table 8

Distance to Nearest Health Facility

Distance	*n*	Minimum	Maximum	*M*	*SD*
In minutes	1408	0	90	26.07	15.051
In kilometers	1407	0	68	6.74	8.083

Inferential Statistics

Inferential statistics are used to make reasonable predictions about the larger population. They make inferences and predictions based on a sample of data taken from the population in question (Hazra & Gogtay, 2016). As a result, inferential statistics help to draw conclusions based on extrapolations, and this is how they differ from descriptive statistics, which merely summarize the data that has been measured. In this study, the

inferential statistics applied included the Pearson chi-square statistics and binary regression analysis.

Bivariate Analysis

The chi-square test for independence, which is also called Pearson's chi-square test, is used to discover whether there is a relationship between two categorical variables. There are two assumptions that should be met for the results to be accurate (Avijit & Nithya, 2016). First, the selected two variables should be measured at an ordinal or nominal level; second, two variables should consist of two or more categorical, independent groups (Avijit & Nithya, 2016). In this study, all assumptions have been met and the test was used to determine the association between the independent variables, which include caretakers' socioeconomic factors (wealth index and educational level), language spoken (ethnicity), place of residence, the children's biological characteristics (gender) and child's polio vaccination status with the dependent variable (seroprevalence for three type of polio viruses: PV1, PV2, and PV3).

Binary logistic regression analysis was performed using SEM: individual factors (age, gender, IPV/OPV status, and family origin), socioeconomic factors (caretaker's education and wealth), and geographic factors (region and distance to health facility) as indicated in the research questions. Statistical analyses of each predictor variable in the research questions are presented in this section. Binary logistic regression was selected to determine whether the independent variables in the three research questions explained the dichotomous/binary nature of the dependent variable (polio antibodies seroprevalence).

The variables were tested separately with the seroprevalence status using binary logistic regression to determine the relationship between each variable and the seroprevalence status. The likelihood ratio tests were used for each variable to determine the statistical significance and the associated Chi-square value.

Pearson chi-square analysis was used to determine the relationship between the independent and dependent variables, while binary logistic regression analysis was conducted to measure the effect of this association (Avijit & Nithya, 2016). A summary of the bivariate analysis for all the risk factors of the present study and seroprevalence status is provided in Tables 9 to 20.

Results by Research Question

Results for RQ1

RQ1 was What is the effect of risk factors (gender, wealth, family origin, education, and region) on the level of polio antibodies (seroprevalence) (PV1, PV2, and PV3) in children ages, 6-11 and 36-48 months, living in polio high-risk areas of Afghanistan?

Gender was not associated with level of antibodies for PV1 and PV3 in both age groups. However, there was a significant relationship between gender and level of polio antibodies for PV2 among the 6–11-month group, χ^2 (1, N = 687) = 3.934, Cramer's V = .076, p = .047. Results of binary logistic regression with PV2 seroprevalence as the dependent variable and gender as the independent variable among 6-11 months age group showed a significant effect of gender on the level of PV2 antibodies, OR = 1.613, p = .049, 95% CI [1.003, 2.595]; younger females are 1.65 times at higher chance of being seropositive for PV2 antibody than males of same age group (Table 9 and 10).

Table 9

*Binary Logistic Regression for Gender and Seroprevalence PV1, PV2, PV3 Among Age 6-11 Months (*N = *687)*

							95% CI for EXP(B)	
Gender[a]	B	*SE*	Wald	*df*	Sig.	Exp(B)	Lower	Upper
Seroprevalence PV1	-.981	.840	1.363	1	.243	.375	.072	1.946
Seroprevalence PV2	.478	.243	3.882	1	.049*	1.613	1.003	2.595
Seroprevalence PV3	-.239	.384	.472	1	.492	.787	.398	1.558

[a] Male is the reference category.
* $p < .05$

Table 10

*Binary Logistic Regression for Gender and Seroprevalence PV1, PV2, PV3 Among Age 36-48 Months (*N = *697)*

							95% CI for EXP(B)	
Gender[a]	B	*SE*	Wald	*df*	Sig.	Exp(B)	Lower	Upper
Seroprevalence PV1	-16.461	2148.405	.000	1	.994	.000	.000	.
Seroprevalence PV2	.347	.269	1.664	1	.197	1.415	.835	2.400
Seroprevalence PV3	.389	.368	1.113	1	.291	1.475	.717	3.035

[a] Male is the reference category.

There was a significant association found between region and level of polio antibodies for PV1 among older children (36-48 months), χ^2 (3, N = 697) = 14.05134, Cramer's $V = .142$, $p = .003$. Region was a protective factor for level of PV1 antibodies, $OR = .206$, $p = .024$, 95% CI [1.052, .810], among 36–48-month group.

In addition, a significant association was seen between region and level of polio antibodies for PV2 among both age groups, χ^2 (3, N = 687) = 12.794, Cramer's $V = .136$, $p = .005$, and χ^2 (3, N = 697) = 10.742, Cramer's $V = .124$, $p = .013$, for age group 6-11 months and 36-48 months, respectively. Table 11 and 12 present the results of binary logistic regression and show that region has a significant impact on PV2 antibody level in

both age groups by indicating the *OR* = .703, *p* = .011, 95% CI [.534, .923] and *OR* = .630, *p* = .001, 95% CI [.474, .838] for 6-11 and 36-48 months, respectively.

Findings indicate that younger children who live in Kandahar City Non-catchment and Catchment area experience a 58% and 53% reduction in the odds of having PV2 antibody seropositivity as compared to those live in Jalalabad City respectively. Older age group children who live in Kandahar (catchment area) and Behsud experience a 61% and 73% reduction in the odds of having PV2 antibody seropositivity as compared to those children live in Jalalabad City respectively. As such, living in regions such as Kandahar city both Catchment and Non-catchment areas as well as Behsud are considered a risk factor for polio seronegativity. Wealth, family origin, and education showed no significant association with level of polio antibodies in either age group.

The results of the analysis showed that while some of the risk factors have significant effect on the polio seroprevalence of various serotypes, others were found to be nonsignificant. In this regard, the independent variables including gender and place of residence have a significant effect on polio seroprevalence status and therefore their null hypotheses were rejected. Conversely, the independent variables including wealth, family origin, and education do not have significant effect on polio seroprevalence status of children living in high-risk areas of Afghanistan, so their null hypotheses were failed to be rejected.

Table 11

*Binary Logistic Regression for Region and Seroprevalence PV1, PV2, PV3 among Age 6-11 M (*N = *687)*

Region	B	*SE*	Wald	*df*	Sig.	Exp(B)	95% CI for EXP(B)

							95% CI for EXP(B)	
							Lower	Upper
Seroprevalence PV1	-.267	.443	.362	1	.547	.766	.322	1.825
Seroprevalence PV2	-.352	.139	6.426	1	.011*	.703	.535	.924
Seroprevalence PV3	.075	.220	.117	1	.732	1.078	.700	1.661

* p < .05

Table 12

*Binary Logistic Regression for Region and Seroprevalence for PV2 among Age 6-11 M (*N = *687)*

							95% CI for EXP(B)	
	B	*SE*	Wald	*df*	Sig.	Exp(B)	Lower	Upper
Region[i]			11.429	3	.010			
Kandahar (non-catchment)	-.872	.274	10.120	1	.001*	.418	.244	.715
Kandahar (catchment)	-.754	.311	5.886	1	.015*	.470	.256	.865
Behsud	18.753	16408.711	.000	1	.999	139430864.	.000	.
Constant	2.450	.194	160.218	1	<.001	11.586		

* *p* < .05

[i]Jalalabad city is the reference category.

Table 13

*Binary Logistic Regression for Region and Seroprevalence for PV1, PV2, PV3 Among Age 36-48 M (*N = *697)*

							95% CI for EXP(B)	
Region	B	*SE*	Wald	*df*	Sig.	Exp(B)	Lower	Upper
Seroprevalence PV1	-1.579	.698	5.116	1	.024*	.206	.052	.810
Seroprevalence PV2	-.462	.145	10.213	1	.001*	.630	.474	.836
Seroprevalence PV3	.168	.230	.544	1	.465	1.183	.754	1.856

* *p* < .05

Table 14

*Binary Logistic Regression for Region and Seroprevalence for PV2, among Age 36-48 M (*N = *697)*

							95% CI for EXP(B)	
	B	*SE*	Wald	*df*	Sig.	Exp(B)	Lower	Upper
Region[i]			10.15	3	.017			
Kandahar (non-catchment)	-.479	.331	2.091	1	.148	.620	.324	1.186
Kandahar (catchment)	-.944	.331	8.144	1	.004*	.389	.203	.744
Behsud	-1.322	.679	3.789	1	.052*	.267	.070	1.009
Constant	2.708	.211	165.0	1	<.001	15.000		

* $p < .05$

[i] Jalalabad city is the reference category.

Results for RQ2

RQ2 was What is the effect of distance to health facility on the level of polio antibodies (seroprevalence) (PV1, PV2, and PV3) in children ages, 6-11 and 36-48 months, living in polio high-risk areas of Afghanistan?

There was a statistically significant association between distance to nearest health facility by walking in minutes and level of polio antibodies for PV3 among the older age group (36-48 M) [(χ^2 (2, N = 664)] = 33.122, Cramer's $V = .218$, $p < .001$)]. Results of binary logistic regression showed a negative significant effect of distance to nearest health facility on the level of polio antibody for PV3 with *OR* = .509, $p = .038$ (95% *CI*:.269, .963) (Table 16). As a result, distance to nearest health facility can be considered a protective factor for PV3 seroprevalence among older age group.

Table 15

*Binary Logistic Regression for Distance to HF and Seroprevalence for PV1, PV2, PV3 among Age 6-11 M (*N = *687)*

							95% CI for EXP(B)	
	B	S.E.	Wald	df	Sig.	Exp(B)	Lower	Upper
Distance (Minutes) for								
Seroprevalence PV1	-.535	.658	.662	1	.416	.586	.161	2.125
Seroprevalence PV2	-.031	.240	.017	1	.897	.969	.605	1.553
Seroprevalence PV3	-.371	.319	1.353	1	.245	.690	.369	1.289

Table 16

Binary Logistic Regression for Distance to HF and Seroprevalence PV1, PV2, PV3 among Age 36-48 M (N= *697)*

							95% CI for EXP(B)	
	B	S.E.	Wald	df	Sig.	Exp(B)	Lower	Upper
Distance (Minutes) for								
Seroprevalence PV1	-1.274	.914	1.941	1	.164	.280	.047	1.679
Seroprevalence PV2	.304	.310	.963	1	.326	1.355	.738	2.488
Seroprevalence PV3	-.676	.326	4.310	1	.038*	.509	.269	.963

* $p < .05$

Interestingly, in Pearson Chi-Square analysis, distance to nearest health facility in KM showed a significant association with PV1 seroprevalence in age group 6-11 [(χ^2 (2, N = 678)] = 12.317, Cramer's $V = .134$, $p = .002$)]. However, results of the binary logistic regression did not reach the significance level at α=.05, $OR = .211$, $p = .073$ (95% CI:.039, 1.155) (Table 17).

Being close to health facility increases the chance for older children to be protected (higher seroprevalence). As result, distance to nearest health facility has

significant effect on polio seroprevalence status of older children living in high-risk areas of Afghanistan and therefore null hypotheses was rejected.

Table 17

*Binary Logistic Regression for Distance to HF and Seroprevalence PV1, PV2, PV3 among Age 6-11 M (*N *= 687)*

							95% CI for EXP(B)	
Distance (KM) for	B	S.E.	Wald	df	Sig.	Exp(B)	Lower	Upper
Seroprevalence PV1	-1.554	.866	3.217	1	.073	.211	.039	1.155
Seroprevalence PV2	18.624	11340.78	.000	1	.999	12256101	.000	.
Seroprevalence PV3	17.718	11380.43	.000	1	.999	49502232	.000	.

Results for RQ3

RQ3 was What is the effect of OPV/IPV doses (full, partial, and none) on the level of polio antibodies (seroprevalence) in children ages, 6-11 and 36-48 months, living in polio high-risk areas of Afghanistan?

There was a statistically significant association found between OPV vaccination status and level of polio antibodies for PV1 in both age groups [(χ^2 (2, N = 667)] = 9.249, Cramer's V = .116, p = .010)] and [(χ^2 (2, N = 697)] = 19.572, Cramer's V = .168, p <.001)] for age group 6-11 and 36-48, respectively. From the binary logistic regression results, OPV vaccination status was considered a significant predictor for PV1 seropositivity in older age group with OR = 5.735, p = .007 (95% CI: 1.626, 20.237) (Table 17). Finding showed that the odds of being seronegative for PV1 antibodies is 33.9 %higher for unvaccinated children as compared to partial and fully vaccinated ones.

OPV vaccination status did not show any significant association with seropositivity of PV2 and PV3 in either age group.

Table 18

*Binary Logistic Regression for OPV Status and Seroprevalence for PV1, PV2, PV3 among Age 6-11 M (*N = *687)*

						95% CI for EXP(B)	
	B	S.E.	Wald	df	Sig.	Exp(B)	Lower	Upper
OPV Status for								
Seroprevalence PV1	1.072	.814	1.733	1	.188	2.922	.592	14.420
Seroprevalence PV2	-.086	.614	.019	1	.889	.918	.276	3.056
Seroprevalence PV3	.023	.838	.001	1	.978	1.023	.198	5.288

Table 19

*Binary Logistic Regression for OPV Status and Seroprevalence for PV1, PV2, PV3 among Age 36-48 M (*N = *697)*

							95% CI for EXP(B)	
OPV Status for	B	S.E.	Wald	df	Sig.	Exp(B)	Lower	Upper
Seroprevalence PV1	1.747	.643	7.372	1	**.007***	5.735	1.626	20.237
Seroprevalence PV2	.118	.461	.065	1	.798	1.125	.455	2.780
Seroprevalence PV3	.267	.553	.234	1	.629	1.307	.442	3.863

* $p < .05$

Table 20

*Binary Logistic Regression for OPV Status and Seroprevalence for PV1 among Age 36-48 M (*N = *697)*

								95% CI for Exp(B)	
PV1 Titer [a]		B	Std. Error	Wald	df	Sig.	Exp(B)	Lower Bound	Upper Bound
Seronegative	Intercept	-5.826	.708	67.68	1	<.001			
	Non-Vaccinated	3.523	1.265	7.752	1	.005*	33.90	2.838	404.939
	Partial	-14.749	.000	.	1	.	3.930E-	3.930E-	3.930E-7
	Fully Vaccinated	0[b]	.	.	0	.	.	.	.

[a] The reference category is: Seropositive.

[b] This parameter is set to zero because it is redundant.
* p < .05

As for IPV, Pearson analysis showed that there was a significant association with level of antibodies for PV1in both age groups [(χ^2 (2, N = 680)] = 9.192, Cramer's V = .116, p = .010)] and [(χ^2 (2, N = 697)] = 12.543, Cramer's V = .134, p =.002)] for age group 6-11 and 36-48, respectively. In addition, there was a significant association with level of antibodies for PV2 among the older group only [(χ^2 (2, N = 635)] = 6.227, Cramer's V = .095, p = .044)]. Results of binary logistic regression analysis for IPV are presented in Tables 21 and 22. Taking IPV at week 14 did not show any significant association with level of polio antibodies in either age group.

Taking OPV found to have a significant effect on the level polio antibody for PV1 serotypes and therefore its null hypothesis can be rejected. On the other hand, taking IPV failed to show any significant association with level of polio antibodies; as such, the null hypothesis for IPV was failed to be rejected, indicating that it is not likely to have a significant impact on polio seroprevalence.

Table 21

Binary Logistic Regression for IPV Status and Seroprevalence for PV1, PV2, PV3 among Age 6-11 M (N = 687)

							95% CI for EXP(B)	
	B	S.E.	Wald	df	Sig.	Exp(B)	Lower	Upper
IPV vaccine for								
Seroprevalence PV1	.490	1.663	.087	1	.768	1.632	.063	42.486
Seroprevalence PV2	-.207	.478	.188	1	.665	.813	.319	2.075
Seroprevalence PV3	-.043	.718	.004	1	.925	.958	.235	3.912

Table 22

Binary Logistic Regression for IPV Status and Seroprevalence for PV1, PV2, PV3 among Age 36-48 M (N = 697)

							95% CI for EXP(B)	
	B	S.E.	Wald	df	Sig.	Exp(B)	Lower	Upper
IPV Vaccine for								
Seroprevalence PV1	1.158	1.392	.693	1	.405	3.184	.208	48.702
Seroprevalence PV2	.132	.288	.208	1	.648	1.141	.648	2.007
Seroprevalence PV3	-.143	.379	.142	1	.707	.867	.413	1.822

Summary

This section summarized characteristic of study samples and presented results for each research questions. Overall, 99% of the children were seropositive against PV1, 90% were seropositive for PV2, and 95% were seropositive for PV3. The level of polio antibodies against different types of polioviruses was significantly associated with gender, region, distance to the nearest health facility, and OPV status. Additionally, living in Kandahar City Non-catchment and Catchment area was found to result in a reduction of 58% and 53% in the odds of having PV1 antibody seropositivity, respectively, compared to living in Jalalabad City. Furthermore, the odds of having PV2 antibody seropositivity were reduced by 61% and 73% for children living in Kandahar City and Behsud, respectively, as compared to those living in Jalalabad City. In the following section, interpretation and discussion of findings, social change implications of this study and recommendations for professional decisions and future studies will be presented.

Section 4: Discussion, Recommendations and Conclusion

The purpose of this quantitative, cross-sectional study was to investigate various risk factors such as gender, parental education, family origin (language/location), wealth, distance to nearest health facility, and IPV/OPV doses on the level of antibodies (seroprevalence) against all three types of polioviruses in children of two age groups, 6-11 months and 36-48 months, living in polio reservoir areas of Afghanistan. In this section, the discussion, recommendations, implication for social change, and conclusion will be presented.

The study results showed that 99% of the children were seropositive against PV1, 90% were seropositive against PV2, and 95% were seropositive against PV3. Gender, region, distance to nearest health facility and OPV status were significantly associated with level of polio antibodies against different types of polioviruses. Also, living in Kandahar City Non-catchment and Catchment area led to 58% and 53% reduction, respectively, in the odds of having PV1 antibody seroposivity as compared to living in Jalalabad City. Similarly, a reduction of 61% and 73% in the odds of having PV2 antibody seroposivity were seen for those children live in Kandahar City and Behsud, respectively, as compared to those live in Jalalabad City.

Discussion by Research Question

Findings for RQ1

RQ1 was What is the effect of risk factors (gender, wealth, family origin, education, and region) on the level of polio antibodies (seroprevalence; PV1, PV2, and

PV3) in children ages, 6-11 and 36-48 months, living in polio high-risk areas of Afghanistan?

In this study, the serological protection for PV1 and PV2 was higher in older age group (36-48 months) as compared to the younger one (6-11 months), whereas both age groups had similar serological protection against PV3. These findings are consistent with many other research studies, including a recent study from Afghanistan. Duintjer et al. (2014) found that older children and adults had higher levels of antibody to poliovirus after receiving the IPV compared to younger children, suggesting that older individuals had a stronger immune response to the vaccine.

A study conducted in Nigeria in 2018 found that children over the age of two had higher antibody levels to poliovirus after receiving the OPV compared to younger children (Iliyasu et al., 2014). Similarly, results from polio serosurvey studies in Pakistan, India, Guinea, Cote d'Ivoire, and Niger found that prevalence of neutralizing antibodies to the poliovirus was higher in older individuals compared to younger children, leading to improved immunity among the older age group (Guindo et al., 2018; Hvass & Wejse, 2019; Ousmane et al., 2021; Voorman et al., 2017; Yusuf et al., 2015).

Gender was not associated with level of antibodies for PV1 and PV3 in both age groups. However, there was a significant relationship between gender and level of polio antibodies for PV2 among the younger age group. Females were at 1.61 times more protected for PV2 seronegativity, $OR = 1.613$, $p = .049$, 95% CI [1.003, 2.595], as compared to males. This finding is in contrast with the reports of Hsu et al. (2019), Voorman et al. (2017), and Hussain et al. (2018) who found that polio seroprevalence

was similar between both genders in Afghanistan. Also, the finding is somehow inconsistent with a northern Nigeria study where female children were less likely to receive the polio vaccine compared to male children due to cultural beliefs that prioritize male children's health over female children's health (Iliyasu et al., 2014). Another study conducted in India found that girls were less likely to receive the vaccine due to limited mobility and lack of access to healthcare services (Lauridsen & Pradhan, 2011).

There is limited information on the specific association between gender and seronegativity (lack of immunity) to the different types of polioviruses (PV1, PV2, and PV3). However, gender can influence polio seroprevalence in several ways. Research has suggested that there may be some differences in polio vaccination coverage and seroprevalence between males and females. Factors such as social norms, cultural beliefs, and access to healthcare can all affect the risk of polio infection and impact the seroprevalence of the disease between males and females (Gupta et al., 2016; Lauridsen & Pradhan, 2011). These findings suggest that the association between gender and seronegativity for each type of poliovirus may vary by country and context, and further research is needed to better understand the role of gender in the receipt of the polio vaccine and the development of immunity to the different types of polioviruses.

In this study, education, wealth, and family origin showed no significant association with level of polio antibodies in either age group. The findings are not consistent with results from Farzad et al. (2017), Deshpande et al. (2014), Iliyasu et al. (2014), and Izadi et al.(2015), who demonstrated that parental and household

characteristics including parental education, occupation, and household wealth index are the most significant risk factors for polio antibody seronegativity.

Studies from various countries have consistently shown that higher levels of education are associated with lower rates of polio antibody seronegativity. Farzad et al. (2017) documented that in Afghanistan children whose caregivers were educated were 1.59 times more likely to be polio antibody seropositive. Similarly, in Spain and Ghana, scholars reported that polio seroprevalence was significantly decreased with low education and socioeconomic status of family (Lorenzo et al., 2019; Opare et al., 2019).

A study in Nigeria found that the children with educated mothers were 88% more likely to be fully immunized as compared to those with no educated parents (Muzammil et al., 2021). Similarly, in Afghanistan, mothers with higher levels of education were more likely to have their children fully immunized, with an odds ratio of 0.31 for those with secondary or higher education compared to those with no education (Muzammil et al., 2021).

Higher education has been associated with a reduced risk of poliovirus exposure and, as a result, a higher likelihood of seronegativity. This is because individuals with higher levels of education are often more likely to have access to resources and information that allow them to make informed decisions about their health and take steps to reduce their risk of exposure to infectious diseases. Additionally, higher education may be associated with improved socioeconomic status, which has been linked to better health outcomes, including a reduced risk of poliovirus exposure (Burroway & Hargrove, 2018).

Wealth as indicated by homeownership was not associated with polio seroprevalence in this study. This finding is consistent with some serosurveys where scholars reported that there is no consistent association between socioeconomic status of family and immunity profile of children (Iliyasu et al., 2014; van den Boogaard et al., 2020). However, researchers have documented that socioeconomic factors are among the key risk factors for WPV transmission and low immunity in children (Anello et al., 2017; Balogun & Guntupalli, 2017; Díaz-Quiñónez et al., 2018; Rachel et al., 2016; Xu et al., 2020). Hammer et al. (2016) reported that immunity to various vaccine preventable diseases was lowest among children with low socioeconomic status. Similarly, in Pakistan and Afghanistan, children with high antibody seroprevalence and complete immunization status were from rich families (Farzad et al., 2017; Khan et al., 2017).

Wealth has been shown to be positively associated with polio seronegativity, meaning that individuals with higher levels of wealth are more likely to have a negative serostatus, indicating a lack of exposure to the poliovirus (Simon et al., 2021). This may be due to several factors, including access to resources and information about the disease, better sanitation and hygiene practices, and the ability to take steps to reduce exposure, such as participating in vaccination campaigns.

Several reasons may contribute to the lack of significant association between wealth, education, and polio seropositivity in this study: access to vaccines regardless of an individual's education level and socioeconomic status, cultural beliefs, and practices; cultural beliefs and practices, such as resistance to vaccination, which may impact vaccine coverage regardless of an individual's education level; and health system

barriers. Barriers to accessing healthcare, such as transportation and cost, can impact vaccine coverage regardless of an individual's education and socioeconomic status.

Ethnicity has been identified as a significant risk factor that influences child's immunization status particularly for poliomyelitis (Farzad et al., 2017; Forster et al., 2017; Siddiqui et al., 2014). Globally, the majority of polio cases are from the Pashtun group that live both in Pakistan and Afghanistan (GPEI, 2021a). However, in this study, family origin as indicated by language spoken showed no significant association with polio seroprevalence although the majority were Pashtun (87.3%) followed by Dari (12.4%). It is important to note that while ethnicity may play a role, it is not the only factor in determining the prevalence of polio antibodies level. Other factors such as socioeconomic status, geography, disparities in access to health care, as well as cultural and religious beliefs play a significant role (Farzad et al., 2017; Hussain et al., 2015).

There was a significant association found between region and level of polio antibodies for PV1 among older children. In addition, a significant association was seen between region and level of polio antibodies for PV2 among both age groups. Findings indicated that younger children who live in Kandahar non-catchment and catchment area experience a 58% and 53% reduction, respectively, in the odds of having PV2 antibody seroposivity as compared to those living in Jalalabad. Older children who live in Kandahar (catchment area) and Behsud experience a 61% and 73% reduction, respectively, in the odds of having PV2 antibody seroposivity as compared to those children living in Jalalabad City. As such, living in regions such as Kandahar, both catchment and non-catchment areas, as well as Behsud is considered a risk factor for

polio antibodies seronegativity. This is not in consistent with Afghanistan's previous findings where Hsu et al. (2019) reported regional differences but only in immunity to PV3.

However, the results support the global concern that these regions are polio high risk areas that continuously report positive environmental isolates (GPEI, 2019). In addition, they are urban hubs for large population movement within the core polio reservoirs of the Northern and Southern Corridors of Afghanistan and Pakistan (GPEI, 2019).

Kandahar has had cases of polio in the past and polio cases continue to occur in Kandahar and other parts of Afghanistan (GPEI, 2021b). The reasons for the persistence of polio in Kandahar, and Afghanistan more broadly, include a lack of access to health services, low vaccination coverage, and ongoing conflict that makes it difficult for health workers to reach all populations with immunization services (GPEI, 2021a).

The region in which a population resides can have a significant impact on its polio seropositivity. Factors such as access to health care, vaccine availability, and cultural beliefs can vary widely between regions, leading to differences in polio seroprevalence.

Findings for RQ2

RQ2 was What is the effect of distance to health facility on the level of polio antibodies (seroprevalence) (PV1, PV2, and PV3) in children ages, 6-11 and 36-48 months, living in polio high-risk areas of Afghanistan?

The average travel time and distance by walking to the nearest health facility in this study was 26 (*SD*= ± 15) minutes and 6.7 (*SD* = ±8) kilometers. There was a

statistically significant association between distance to nearest health facility by walking in minutes and level of polio antibodies for PV3 among the older age group, *OR* = .509, *p* = .038, 95% CI [.269, .963]. As walking distance to the nearest health facility increases, odds of being polio antibody seronegative increases by 49%. This finding is consistent with similar studies from Ethiopia, Nigeria, and Kenya (Morris et al., 2022; Okwaraji et al., 2012; Sato, 2020). Okwaraji et al. (2012) and Morris et al. (2022) argued that children living more than 60 minutes travel time away from the nearest health facility were significantly less likely to complete their vaccination schedule as compared to children living less than 30 minutes from a health center. Additionally, Noel et al. (2020) demonstrated that travel time of more than 60 minutes significantly reduced immunization coverage and those children living more than 2 hours from immunizing health facilities were significantly less likely to be fully immunized. Similarly, Sato (2020) reported that an additional distance of 1 km to the nearest health facility reduced the odds that one receives a vaccine by 5%.

Study results suggest that children living a greater distance from the nearest health facility had an increased risk of being polio antibody seronegative. The distance to a health facility has been shown to have a significant impact on polio antibody seropositivity, with individuals living further from a health facility being more likely to have a positive serostatus, indicating exposure to the poliovirus (Sato, 2020; Setegn Muche et al., 2021). This may be due to several factors, including reduced access to health services, including vaccination programs, and reduced access to information about the disease and how to prevent it. Additionally, individuals living in remote areas may

face challenges related to transportation and infrastructure, making it more difficult for them to receive health services and protect themselves from such infectious diseases.

Findings for RQ3

RQ3 was What is the effect of OPV/IPV doses (full, partial, and none) on the level of polio antibodies (seroprevalence) in children ages, 6-11 and 36-48 months, living in polio high-risk areas of Afghanistan?

There was a statistically significant association found between OPV vaccination status and level of polio antibodies for PV1 in both age groups. Among the surveyed children, 95.8% were fully vaccinated, 1.1% were partially vaccinated, and only 1.1% (*n* = 16) were not vaccinated. The administration of OPV has been shown to be associated with reduced seropositivity for all three types of polioviruses (PV1, PV2, and PV3) (Blume & Geesink, 2000). OPV is a highly effective vaccine that provides immunity against the three types of polioviruses.

Findings showed that the odds of being seronegative for PV1 antibody is 33.9% more for unvaccinated children as compared to partial and fully vaccinated one. The study's finding is consistent with the report from Japan that antibody seropositivity is associated with high OPV/IPV doses (Satoh et al., 2019). Also, in Nigeria, there was a significant association between seroprevalence and number of OPV doses received (Iliyasu et al., 2014).

However, results revealed an absence of a significant effect of OPV status on seroprevalence of PV2 and PV3 serotypes. This finding differs from the report of Voorman et al. (2017) that showed an additional OPV doses can increase polio immunity

by 5%, 16%, and 5.5% for PV1, PV2 and PV3 serotypes. OPV is a live attenuated vaccine that provides immunity against all three types of polio virus (PV1, PV2, and PV3). However, in some cases, the vaccine may not provide full immunity against all three types. There are several reasons for this: mutations in the vaccine virus; over time, the vaccine virus can undergo mutations, leading to the emergence of new strains that are not effectively controlled by the vaccine, immune system responses; individuals with weaker immune systems may not respond to the vaccine, leading to lower levels of immunity; and dosing, which means the effectiveness of the vaccine can be impacted by the number of doses received and the timing between doses (Chan & Bohidar, 1998; Hansen et al., 2014).

Absence of significant association between IPV and seropositivity for all polio serotypes was also not consistent with other research. Studies have demonstrated that children who receive both OPV and IPV have lower rates of seropositivity for PV1, PV2, and PV3, compared to those who have not received the vaccine (John et al., 2014; Satoh et al., 2019). This indicates that the combination of OPV and IPV provides protection against all three types of polio virus, helping to reduce the risk of exposure and polio disease.

The lack of significant association between IPV and antibody seropositivity indicates that there is not always a strong correlation between receiving IPV and the presence of antibodies against poliovirus in an individual. Research documented that the time between the last vaccination and the antibody titer evaluation is a determinant of the

levels of persisting neutralizing antibodies and sometimes the antibody titer decreases over time regardless of persistent immunity (Vittoria et al., 2022).

However, several reasons could explain the lack of significant association between IPV and polio antibody seropositivity:

- Dosage - The number and timing of IPV doses received by an individual can impact the level of seropositivity;
- Individual factors - variations in the immune system and genetics of individuals can influence the response to the vaccine and the level of seropositivity;
- Environmental factors - exposure to poliovirus through contaminated food, water, or other sources can also impact the level of seropositivity (Bianchi et al., 2021; John et al., 2014).

Interpretation of the Findings in the Context of the Theoretical Framework

Interpreting findings in the context of the SEM can help to identify potential intervention strategies that can be tailored to the specific needs and context of the target population. It can also provide a comprehensive and nuanced understanding of the factors that influence polio antibody seronegativity and can inform the development of effective intervention strategies that address multiple levels of influence. The results of this study provide evidence for the validity of the SEM, as they demonstrated how the various independent variables are connected to the different levels of the model, including

- Individual factors: age, sex, IPV/OPV doses, and family origin
- Geographic factors: region and distance to health facility

- Socioeconomic factors: caretaker's education and wealth.

The analysis supports previous literature by showing the relationship between individual and geographic factors influencing immunity profiles of children leading to pockets of seronegative children (Anello et al., 2017; Balogun & Guntupalli, 2017; Sato, 2020; Setegn Muche et al., 2021). Consistent with the SEM, polio seroprevalence is significantly associated with individual and geographic factors such child's age, gender, IPV/OPV status as well as region and distance to health facility. Various authors have analyzed a secondary dataset and found that polio antibody seroprevalence is significantly related to individual factors like sex, IPV/OPV, age and geographic factors such as place of residence and distance to nearest health facility (Anello et al., 2017; Balogun & Guntupalli, 2017; Burroway & Hargrove, 2018).

Individual factors such as gender and age can play a significant role in the development and maintenance of immunity to the polio virus, and their relationship to polio immunity can be understood through the lens of the SEM.

At the individual level, age is an important factor in polio immunity. Polio is more common in children under the age of 5, with younger children being more vulnerable to severe symptoms and complications (Duintjer et al., 2014; Fenta et al., 2021). As individuals age and are exposed to the virus through vaccination or natural infection, they develop immunity to the virus (Fenta et al., 2021). Gender can also play a role in polio immunity, as research suggests that females may have a stronger immune response to the virus compared to males (Klein & Flanagan, 2016).

However, the relationship between individual factors and polio immunity cannot be fully understood without considering the broader context of the SEM. The model considers various levels of influence on health behaviors and outcomes, including individual, interpersonal, community, and societal factors. At the interpersonal level, social networks and relationships can influence individual health behaviors, including vaccination status. At the community level, access to healthcare and vaccination programs can affect vaccination rates and overall polio immunity levels (Abisola et al., 2021).The SEM also highlights the importance of addressing systemic factors that can affect polio immunity.

In summary, individual factors such as gender and age can have a significant impact on polio immunity, but this relationship is shaped by broader contextual factors at the interpersonal, community, and societal levels. Understanding and addressing these systemic factors is essential for promoting higher levels of polio immunity and improving overall public health. Distance to health facilities and place of residence can be a barrier to accessing healthcare services, which can ultimately impact seroprevalence and immunity at the individual and community levels. Thus, improving geographic factors of a child including access to health facility and place of residence may improve immunity profile of children in Afghanistan.

Implications for Social Change

Polio serosurvey is a method used to determine the prevalence of poliovirus antibodies in a population, which helps to assess the effectiveness of polio vaccination campaigns and identify areas where further efforts are needed to eradicate the disease

(Vivian et al., 2022). Identifying risk factors associated with polio seronegativity can help to design targeted interventions and improve the overall effectiveness of polio eradication efforts. There are some social benefits associated with identifying risk factors for polio seroprevalence particularly in Afghanistan:

- Targeted interventions: Identifying specific risk factors for seroprevalence, such as high prevalence of polio antibody seronegative children, can help to target interventions to the areas and populations that need them the most. By identifying populations or areas with low immunity profile, health officials can focus their efforts on increasing coverage in these areas and reducing the risk of polio transmission.
- Cost-effectiveness: Identifying risk factors can help to focus resources on the most high-risk populations and areas, which can improve the cost-effectiveness of polio eradication efforts.
- Equity: Identifying and addressing risk factors associated with seroprevalence, can help to reduce health disparities, and promote equity in health. It is important to note that while identifying risk factors is a crucial step in improving the effectiveness of polio eradication efforts, it is not enough on its own. The risk factors need to be used to inform targeted interventions and these interventions should be implemented and evaluated for their effectiveness. Polio disproportionately affects children under 5 years of age and certain population groups or gender. Eradicating polio can reduce the disease burden on individuals, families, and communities, as well as on

healthcare systems. Results of this study can help identify these groups, and target vaccination and other interventions to them, thus reducing disparities and promoting equity in health.

- Economic benefits: Eliminating polio can also have economic benefits, such as reducing healthcare costs and increasing productivity.
- Better understanding of the epidemiology of polio: Identifying risk factors can help to improve our understanding of how polio is transmitted and what factors contribute to its persistence in certain populations. By identifying risk factors, it is possible to monitor changes in the risk profile of a population over time and evaluate the effectiveness of interventions.

Recommendations

Gender, region, distance to nearest health facility, and OPV status were found to be significantly associated with polio seronegativity among the surveyed children in Afghanistan. It is important to consider the impact of gender on polio seroprevalence when designing and implementing polio eradication efforts. This can include targeted communication and community engagement efforts that address cultural barriers and promote equal access to healthcare for both males and females and ensuring that the health workers are female to make it easy for the female population to reach out to them. In some cultures, it may be considered inappropriate for women to seek medical treatment from male health workers. By having female health workers available, women may be more likely to seek out medical care for their children.

To address the regional disparities and improve polio seroprevalence across all regions, it is important to adapt strategies and interventions to the specific context and needs of each region. This may include focusing efforts on high-risk areas, increasing community engagement and education efforts, and building stronger healthcare infrastructure in remote and hard-to-reach areas. Additionally, involving regional authorities, community leaders, and healthcare workers in the process can help to build trust and support for vaccination in the community.

To address the influence of distance on polio seroprevalence, it is important to consider these factors and design interventions accordingly. This could include providing mobile vaccination clinics, increasing outreach and education efforts in remote areas, and addressing socioeconomic barriers to accessing healthcare. Additionally, it is important to consider cultural and linguistic diversity of the population to ensure that interventions are culturally appropriate and effective. Addressing these challenges and increasing access to polio vaccines is critical to the goal of global polio eradication.

In addition, there are several recommendations that can be implemented to reduce the number of seronegative children in a population:

- Increase vaccination coverage: One of the most effective ways to reduce the number of seronegative children is to increase vaccination coverage. This can be done through regular vaccination campaigns, as well as targeted efforts to reach high-risk populations and areas.
- Improve accessibility to vaccination services: Strategies such as mobile vaccination clinics, outreach efforts, and community engagement can help to

make vaccination services more accessible to children in remote or hard-to-reach areas.

- Address vaccine hesitancy: Vaccine hesitancy, or resistance to vaccination, can be a significant barrier to increasing vaccination coverage. Strategies to address vaccine hesitancy may include community engagement, education, and awareness campaigns, and addressing misinformation about vaccines.
- Ensure the quality of vaccination services: The quality of vaccination services is crucial for the success of vaccination campaigns. This includes ensuring that vaccines are stored and handled properly, that health workers are trained to administer vaccines, and that vaccines are provided to children in a safe and appropriate manner.
- Address socioeconomic barriers: Socioeconomic barriers such as poverty, lack of access to education, and lack of transportation can make it difficult for children to be vaccinated. Addressing these barriers can help to increase vaccination coverage and reduce the number of seronegative children.

Limitations

The present study used secondary data analysis from 2020 Polio serosurvey, and the study sample population was limited to two cities of Afghanistan and not representative of the entire Afghanistan population. Therefore, the findings can only be generalized to Kandahar and Jalalabad cities because there might be other factors influencing polio seroprevalence in other parts of the country which might have different sociocultural characteristics.

Although secondary data can be a useful resource for research, using secondary datasets usually has some limitations, including the fact that the data may not be directly relevant to the research problem or may not reflect the current situation. Bias is another limitation of this study; the data may be biased towards certain perspectives or may reflect the agenda of the data collector. One of the main independent variables of this study was the OPV/IPV status of child which was determined mainly from parents' recall without further validation with vaccination card. Majority of responses from caretakers reported completion of OPV/IPV as per schedules from memory with the attendant effect of recall bias leading to perhaps over-or underestimation of the number of vaccine doses received. The present study was conducted in 2022 from a 2020 data set which presents a two-year time lag in which situation in Afghanistan is different now particularly with impact of COVID-19 pandemic and the Taliban being in power as compared to before, so this must be considered before applying the findings and recommendation of the present study in practice.

Conclusion

The findings from the present study revealed that: there is association between geographical factors (regions and distance to health facility); child factors (gender and OPV status) and level of polio antibodies of various serotypes among under 5 years children in Afghanistan.

Afghanistan is one of only two countries in the world (along with Pakistan) where polio remains endemic. The country has been fighting polio for decades, and despite

significant progress made in recent years, the country still faces challenges in eradicating the disease completely.

Although overall polio epidemiology in Afghanistan seems to have slightly improved during the year 2021, 2022 and so far in 2023. There is a concern that polio cases may be underreported in Afghanistan, particularly in areas that are affected by conflict and insecurity. The conflict and instability in Afghanistan have made it difficult to reach all children with polio vaccines, particularly those in remote and hard-to-reach areas. In addition, the COVID-19 pandemic has also had a significant impact on the polio response in Afghanistan, as routine immunization services have been disrupted, and polio campaigns have been suspended in many areas by the Taliban.

The GPEI is a partnership involving various stakeholders, such as national governments, the WHO, Rotary International, the U.S. CDC, and UNICEF, among others, with the common goal of eradicating polio worldwide. It is crucial for all partners of the GPEI to continue supporting Afghanistan in its efforts to eradicate polio. Each partner has a critical role to play in supporting polio eradication efforts in Afghanistan and other countries where the disease is still endemic.

National governments must prioritize polio eradication efforts and ensure that all children receive the polio vaccine. The WHO and other health organizations can provide technical expertise and support to help improve vaccine coverage and surveillance for polio. Rotary International and other civil society organizations can mobilize resources and raise awareness about the importance of polio eradication. The CDC and other

partners can provide financial support and technical assistance to help strengthen health systems and improve vaccine delivery.

Overall, addressing polio in Afghanistan in the context of the Taliban will require a multi-faceted approach that involves negotiation, engagement, coordination, and sustainable solutions. By working together and prioritizing the needs of vulnerable communities, we can help to ensure that all children in Afghanistan have access to polio vaccines and other essential health services.

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