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Population immunity to polioviruses in the context of a large-scale wild poliovirus type 1 outbreak in Tajikistan, 2010

Nino Khetsuriani[a,*], **Mark A. Pallansch**[b], **Shamsiddin Jabirov**[c], **Nargis Saparova**[d], **M. Steven Oberste**[b], **Kathleen Wannemuehler**[a], **Pavel Ursu**[d], **Steve Wassilak**[a], **Rebecca Martin**[e,1]

[a]Global Immunization Division, Center for Global Health, CDC, Atlanta, USA

[b]Division of Viral Diseases, Center for Immunization and Respiratory Diseases, CDC, Atlanta, USA

[c]National Center for Immunoprophylaxis, Tajikistan Ministry of Health, Dushanbe, Tajikistan

[d]WHO/Tajikistan, Dushanbe, Tajikistan

[e]WHO/Europe, Copenhagen, Denmark

Abstract

Background: A serosurvey to evaluate population immunity to polioviruses (PVs) in the context of the importation-related wild PV1 outbreak in Tajikistan in 2010 (461 confirmed cases among children and young adults) was conducted.

Methods: Serum specimens from a nationwide sample of 1–24 year-old persons selected through stratified cluster sampling ($n = 2447$) were tested for neutralizing antibodies to all three PV types. Samples with titers < 1:8 were considered seronegative. The serosurvey was conducted during the interval after mOPV1 supplementary immunization activities (SIAs) and before tOPV SIAs (targeting ages ≤ 15 years) implemented to control the outbreak. In the absence of pre-outbreak specimens, results for PV3 were used as a proxy for pre-outbreak PV1 immunity patterns.

Results: Overall, PV1 seroprevalence was 98.9%, PV2 seroprevalence was 98.8%, and PV3 seroprevalence was 86.9%. PV1 and PV2 seroprevalence exceeded 95% in all age groups and regions. PV3 seroprevalence was <90% in all age groups and regions, except 15–19 year-olds (91.7%) and Dushanbe (90.0%). PV3 seroprevalence was lowest among 1–4 (82.7%) and 5–9 (84.4%) year-olds, particularly among 1–4 year-olds in Kurgan-Tube (76.3%) and RRS (80.0%) regions. Birth cohorts immunized only through routine services (ages, 1–7 years) had lower PV3 seroprevalence than birth cohorts targeted by the SIAs during 1995–2002 (8–19 years): 82.5% versus 89.3%, $p < 0.001$.

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[1]Director, Global Immunization Division, Center for Global Health, CDC, Atlanta, USA.

[*]Corresponding author at: Team Lead for the European Region, Disease Eradication and Elimination Branch, Global Immunization Division, Center for Global Health, CDC, 1600 Clifton Road, MS-A04, Atlanta, GA 30333, USA. Tel.: +1 404 639 4671; fax: +1 404 639 8676. nck7@cdc.gov (N. Khetsuriani).

[3]Initially, a total of 2582 participants were enrolled but 123 were excluded for the following reasons: inferior specimen quality ($n = 100$), insufficient specimen quantity for testing ($n = 10$), no questionnaire provided ($n = 9$), and age >24 years ($n = 4$), resulting in 2459 eligible participants.

Conflicts of interest

None declared by any co-author.

Conclusions: Suboptimal (<90%) PV3 seroprevalence across wide age range suggests the outbreak resulted from accumulation of susceptibles due to suboptimal coverage over a long time period, particularly in the birth cohorts immunized only through routine services and in areas where the outbreak began (Kurgan-Tube and RRS). High PV1 seroprevalence indicates that mOPV1 SIAs with expanded target age (≤15 years) succeeded in closing the immunity gap and ongoing WPV1 transmission is unlikely. To accelerate outbreak control in areas which have been polio-free for long time, expanding SIA target age should be considered.

Keywords

Poliomyelitis; Poliomyelitis outbreaks; Polioviruses; Population immunity; Antibodies against polioviruses; Seroprevalence; Tajikistan

1. Introduction

In 2010, eight years after the European Region of the World Health Organization (WHO/Europe) had been certified free of poliomyelitis (in 2002) [1], the region's polio-free status was endangered by a major polio outbreak in Tajikistan, which spread to three other countries (Russian Federation, Turkmenistan and Kazakhstan). This was the first outbreak following the importation of wild poliovirus (WPV) into a polio-free WHO region and represented a major challenge for the Global Polio Eradication Initiative.

Tajikistan is a low income ex-USSR country in Central Asia (population, 7.4 million, 2009 estimate) with weak health infrastructure. The last confirmed WPV in Tajikistan prior to certification was detected in 1994, and the last polio-compatible case was reported in 1997 [1,2]. Despite the challenges posed by disruption of health care services, including immunizations, due to the civil war of 1992–1997, multiple rounds of successful nationwide supplementary immunization activities (SIAs) with trivalent oral polio vaccine (tOPV) through Operation MECACAR during 1995–2002 [3] led to interruption of WPV circulation in Tajikistan. No nationwide SIAs were held since 2002. Continued weakness of the national immunization program and lower than administratively reported OPV3 coverage found in surveys in 2005 and 2007 [4,5], raised concerns about potential gaps in population immunity and accumulation of susceptible individuals in Tajikistan. The risk assessment by the WHO European Regional Office in 2009 identified Tajikistan as country at high risk of poliovirus (PV) transmission in case of importation [6], but the lack of resources prevented conduct of SIAs at the time.

In 2010, Tajikistan experienced a large-scale explosive outbreak of poliomyelitis due to WPV type 1 (WPV1) of Indian origin with a total of 461 confirmed cases [2]. The initial cases occurred during February–March among children aged <5 years in the regions of Kurgan-Tube and Rayons of Republican Subordination (RRS). The outbreak subsequently spread throughout most of the country. Older children and young adults were also affected, with 106 (23.0%) cases reported among 5–14 year olds and 53 (11.5%) among adults aged 15 years. In response to the outbreak, massive immunization efforts, including 4 nationwide and 1 sub-national SIAs with type 1 monovalent oral polio vaccine (mOPV1) during May–August 2010, followed by 4 nationwide SIAs with tOPV during October 2010–

April 2011, were implemented.[2] Reported coverage was >98% for each SIA round [2]. The last confirmed WPV1 case had onset on July 4. The broad geographic spread and wide age range of cases suggested widespread suboptimal immunity to type 1 PV (PV1) and raised concerns about potential immunity gaps for type 2 (PV2) and type 3 (PV3) viruses as well.

To determine population immunity to PVs after the mOPV1 SIAs implemented to control the outbreak, and to validate and inform outbreak response strategies, a nationwide population-based serosurvey was conducted in Tajikistan in the fall of 2010. In addition, we attempted to infer the state of PV1 immunity before the outbreak to achieve a better understanding of the origins and epidemiology of the outbreak.

2. Methods

We conducted a nationwide serosurvey of persons aged 1–24 years (age groups – 1–4, 5–9, 10–14, 15–19, and 20–24 years) from all regions of Tajikistan. A sample size of 540 persons within each age group was determined assuming a seroprevalence of 50%, desired precision of ±5%, 0.95 probability of achieving that precision, and a design effect = 1.4. Participants were selected through stratified multi-stage cluster sampling. Twenty-five of 69 districts and cities were selected in the first stage via probability proportional to population size; settlements were randomly sampled within each selected district. Registries from health care facilities in these settlements were obtained and the participants were chosen by generating random numbers and selecting persons corresponding to these numbers in the list. Selection of participants was done independently for each age group. Total sample size allocated to each region was approximately proportional to the region's population size [7]. The final allocation of the proposed sample is presented in Table 1.

Field teams visited residences of identified potential participants and enrolled them after providing the survey information sheet and obtaining verbal consent. A brief questionnaire including demographic information was completed and 3–5 ml of blood was obtained in serum separation tubes by venipuncture. Serum was separated and stored refrigerated at district level until delivered to the laboratory in Dushanbe, where serum was stored at −20 ○C until shipped by air on dry ice to the Centers for Disease Control and Prevention (CDC), Atlanta, for testing. Neutralization reaction to all three PV types [8,9] was performed at the Poliovirus and Picornavirus Laboratory, CDC. Specimens with antibody titers <1:8 were considered seronegative and specimens with titers ≥1:8 or higher were considered seropositive.

Statistical analysis was conducted using SAS v9.3 (Cary, NC, USA) and SUDAAN v10 (Research Triangle Park, NC, USA). Seroprevalence estimates and 95% confidence intervals (CI) were calculated taking into account the stratified cluster sampling design and weights scaled to approximate the population of each region by age group. Differences in seroprevalence across age groups and regions were assessed using Chi-square tests. Seroprevalence was also compared across age groups by their past history of SIAs. The

[2]The first two rounds of mOPV1 SIAs targeted children aged ≤5 years; subsequent mOPV1 rounds and the first two tOPV rounds targeted persons aged ≤15 years; the last two rounds of tOPV SIAs targeted children <5 years.

comparison groups included 8–19 year-olds who were targeted by SIAs during 1995–2002, and 1–7 year-olds who were born after the SIAs were discontinued following the certification of the Region as polio-free in 2002. Persons aged 20–24 years, born when WPVs were still circulating in Tajikistan and too old to be targeted by pre-certification SIAs, were excluded from this analysis. Differences in seroprevalence between these two age groups were assessed using Chi-square or Fisher's exact tests.

No direct estimation of PV1 immunity before the outbreak was possible in the absence of pre-outbreak specimens [10]. Because very little outbreak response supplementary vaccination with tOPV had been conducted in Tajikistan prior to the serosurvey, PV3 seroprevalence likely reflected pre-outbreak immunity levels. Therefore, we assumed that the pre-outbreak immunity profile for PV1 would follow overall trends for PV3 and used PV3 findings as a surrogate indicator for overall levels of population immunity to PV1 before the outbreak. This approach does not allow to quantitatively determine the pre-outbreak PV1 seroprevalence, but allows us to infer relative levels of immunity and trends across age groups and regions. A similar approach has been used in studies conducted in Oman [11] and in Jordan [12] after the WPV1 outbreaks. The surveillance data on the geographic and age distribution of WPV1 cases in Tajikistan reported in 2010 to WHO were used for comparison with serosurvey results.

The protocol was reviewed by the Human Subject Research Coordinator at the National Center for Immunization and Respiratory Diseases, CDC and determined to be a program evaluation in response to the 2010 polio outbreak, and therefore exempt from the Institutional Review Board approval. The survey protocol was reviewed and approved by the Tajikistan Ministry of Health.

3. Results

Overall, 2459 participants aged 1–24 years were enrolled (91.1% of the original target of 2700), and specimens from 2447 participants were available for PV antibody testing.[3] The distribution of the participants by age group and region is given in Table 1 and their demographic characteristics are given in Table 2.

Overall PV1 seroprevalence was 98.9%. PV1 seropositivity was >95% among all age groups and in all regions (Table 2). PV1-seropositivity was slightly lower among 20–24 year-olds (96.1%) than among younger age groups (99.2–100.0%) ($p < 0.01$). Residents of Gorno-Badakhshan Autonomous Oblast (GBAO) had slightly lower PV1-seropositivity (95.8%) than residents of other regions (98.4–99.5%), but differences across regions were not statistically significant.

Overall PV2 seroprevalence was 98.8%. Seropositivity to PV2 was >95% among all age groups and in all regions (Table 3). PV2 seroprevalence was higher among 5–19 year olds (99.3–99.8%) than among 1–4 year-old children, who had the lowest proportion of PV2-seropositives (96.6%), and among 20–24 year olds (98.3%) ($p < 0.01$). PV2 seroprevalence was lower among residents of GBAO (95.8%) than among residents of other regions (98.1–99.7%) ($p < 0.05$).

Seroprevalence for PV3 (86.9%) was lower than for PV1 and PV2 (Table 3). PV3 seroprevalence was <90% in all age groups and in all regions, except the 15–19 year-old age group (91.7%) and Dushanbe (90.0%). Population immunity to PV3 was lowest among 1–4 (82.7%) and 5–9 (84.4%) year-olds (Table 3). Differences in PV3 seroprevalence were statistically significant across age groups ($p < 0.01$), but not across regions.

Of 2447 specimens tested, only eight (0.3%) were seronegative for all three PV types. Median antibody titer was 1:1024 (the highest dilution tested) for PV1, 1:256 for PV2, and 1:32 for PV3. The distribution of median titers by age group is given in Table 4.

The birth cohorts without previous history of SIAs had significantly lower seropositivity for PV2 (97.8%; 95% CI, 96.7–98.5%) and PV3 (82.5%; 95% CI, 78.1–86.1%), than birth cohorts targeted by the pre-certification SIAs: 99.7% (95% CI, 90.0–99.9%) for PV2, and 89.3% (95% CI, 86.0–92.0%) for PV3 ($p < 0.001$ for both). Seropositivity for PV1 did not differ significantly between the birth cohorts with and without past history of SIAs: 99.5% (95% CI, 98.3–99.9%) and 99.6% (95% CI, 98.8–99.8%), respectively ($p > 0.05$).

The analysis of the distribution of PV3 immunity profiles in each region by age group identified subgroups with particularly low seroprevalence. PV3 seronegativity was highest among 1–4 year-old children in Kurgan-Tube (23.7%; 95% CI, 20.3–27.4%), RRS (20.0%, 95% CI, 8.8–39.6%) and Kulyab (18.9%; 95% CI, 14.7–24.0%), and among 5–9 year-olds in Sogd region (24.8%; 95% CI, 15.4–36.4%) (Fig. 1). PV3 seroprevalence was low (40.0% seronegatives) among 20–24 year-olds in GBAO, but due to small sample size in this region the estimate had a very wide 95% CI (21.8–61.5%).

When the distribution of confirmed WPV1 cases by age group and region was compared to PV3 seroprevalence in respective groups, the age groups which accounted for the greatest proportion of cases in a given region, tended to be the age groups with lower PV3 seroprevalence (Fig. 1). Due to small numbers of cases in older age groups, this trend was more notable for younger age groups, particularly 1–4 year-old children in Kurgan-Tube and RRS regions where the outbreak began. Early in the outbreak (during February–March, 2010), 26 of 27 WPV1 cases occurred in these two regions, including 21 (77.8%) cases among 1–4 year-old children and 5 (18.5%) cases among children aged <1 year. Kurgan-Tube region, which had 23.7% PV3-seronegatives among children aged 1–4 years, reported 178 confirmed WPV1 cases in 2010; 95 (53.3%) cases occurred among 1–4 year-olds. RRS, with 19.9% PV3-seronegatives among 1–4 year-old children, reported 173 confirmed WPV1 cases, of which 76 (43.9%) cases occurred among 1–4 year-olds.

4. Discussion

The serosurvey documented very high seroprevalence to PV1 throughout Tajikistan by October 2010, suggesting that the immunity gap to PV1 that apparently led to the outbreak has been closed and that ongoing WPV1 circulation in the country is unlikely. This level of seroprevalence is consistent with reported high coverage (>98%) in the mOPV1 SIAs targeted to ages ≤15 years [2]. Additional contributors to high PV1 population immunity include widespread WPV1 circulation during the outbreak as well as routine vaccination of

children. Remaining susceptibility to PV1 is low, mostly observed among 20–24 year-old age group, not targeted by the SIAs in response to the outbreak.

Population immunity to PV2 in Tajikistan was also high, likely attributable to routine vaccination of children, pre-certification SIAs (for 8–19 year olds), and effective spread of the type 2 polio vaccine virus from vaccinees to their contacts [10,13].

In contrast with PV1 and PV2 immunity, substantial susceptibility (>10% seronegatives) to PV3 was observed across a wide age range (all age groups except 15–19 year olds), particularly among 1–9 year olds, where approximately one in every 6 children was PV3-seronegative, and in all regions of Tajikistan.

Differences in seroprevalence for PV2 and PV3 across age groups were largely determined by the history of the exposure to pre-certification SIAs. Despite waning of antibody levels expected to occur over the almost 10-year period since the last SIAs [10], birth cohorts targeted by the pre-certification SIAs had significantly higher seroprevalence for PV2 and PV3 than those born after SIA discontinuation, demonstrating the profound impact of successful SIAs on population immunity against PV. The lack of differences by previous SIA history with regard to PV1 is likely due to the recent intense exposure to both WPV1 and mOPV1.

Suboptimal PV3 seroprevalence observed in the serosurvey in Tajikistan suggests the existence of a corresponding immunity gap to PV1 before the outbreak, and is consistent with the large scale, explosive outbreak affecting a wide age range with broad geographic spread. Based on the PV3 seroprevalence, PV1 immunity would have been particularly low in the area and age group where the early cases of this outbreak had occurred: among 1–4 year-olds in RRS and Kurgan-Tube. Upon WPV1 introduction into these regions, the PV1 immunity gap likely allowed imported virus to establish transmission, initiating the outbreak among the young children with subsequent spread to susceptible individuals in other regions and older age groups.

Taken separately, the overall level of PV3 population immunity found in this serosurvey would not have been considered alarmingly low for a polio-free setting. However, the 2010 outbreak in Tajikistan demonstrates that continuous PV transmission can occur in polio-free areas with relatively high population immunity, particularly when there are subgroups where susceptibility is concentrated. Therefore, to help prevent outbreaks in polio-free areas, it is necessary to achieve and maintain uniformly very high population immunity to all three PV types. Population-based data on immunity to PV prior to outbreaks are scarce in the published literature. However, until recently, wild PVs continued to circulate in certain areas of northern Indian states of Uttar Pradesh and Bihar despite very high overall OPV coverage with multiple rounds of SIAs, likely supported by pockets of susceptibles unreached by SIAs [14].

Despite comparable PV3 immunity gaps in all regions of Tajikistan, the outbreak did not spread to GBAO (no cases) and Sogd (only one reported case), suggesting that other factors prevented WPV1 introduction and transmission there. These factors likely include the relative geographic isolation of these regions of Tajikistan with particularly difficult

access during the winter months when the outbreak began, and very low population density in GBAO.

The serosurvey allowed retrospective validation of the polio outbreak response strategies in Tajikistan, taking into consideration actual susceptibility data. The operational decisions with regard to the choice of vaccine type (mOPV1 versus tOPV), frequency of SIA rounds, and target age groups for SIAs were made as the outbreak unfolded, on the basis of the epidemiologic data available in real time. The strategies chosen for the initial "acute phase" response included short-interval (2 weeks) SIA rounds with mOPV1 and expanding target age groups from ≤5 years to ≤15 years after the first two SIA rounds. In addition, four SIA rounds with tOPV were implemented beginning in October 2010. The wide age range of observed PV3 susceptibility is consistent with the wide age range of the PV1 immunity gap and supports the strategy of expanding the target age groups for outbreak response SIAs implemented in Tajikistan. Based in part on the Tajikistan experience, WHO expanded the target age to 15 years for outbreak response SIAs, as a recommended approach to polio outbreak control [15]. A number of polio outbreaks following importations after the long-term absence of PV circulation had high proportion of cases among older children and adults (Albania, 1996; Namibia, 2006; the Republic of the Congo, 2010–2011; and China, 2011 [16–20]), and also required wide age range campaigns to rapidly interrupt transmission. In addition, the PV3 results confirmed that nationwide tOPV SIAs to close potential immunity gaps and prevent potential future outbreaks from all three types of WPV were justified. The >99% coverage reported for each of the four tOPV SIAs [21], suggests that as a result of the tOPV SIAs, the PV3 immunity gap in Tajikistan has been reduced compared to the serosurvey findings.

The serosurvey findings highlighted both strengths and weaknesses of the immunization program in Tajikistan and emphasize the need to strengthen the routine vaccination delivery. Along with documenting the effect of successful mOPV1 SIAs, and long-lasting impact of the MECACAR campaigns, the serosurvey revealed weaknesses of routine immunization program judged by the lower seroprevalence for birth cohorts which had relied only on routine immunization to maintain population immunity, particularly among children aged 1–4 years. This conclusion is also supported by the low seroprevalence for diphtheria and tetanus identified from the present serosurvey reported elsewhere [22]. Achieving and maintaining high routine OPV coverage will be essential for sustaining high population immunity to PV and preventing future polio outbreaks.

The serosurvey had certain limitations. The specimens were collected after the outbreak; therefore only indirect judgment could be made with regards to PV1 immunity before the outbreak. Participant selection was based on health facility registries and unregistered persons could have been missed. However, this was mostly the case for adults, as the registries for children aged ≤15 years were updated to prepare for the SIAs rounds in response to the polio outbreak to include previously unregistered children. Also, a small sample size in some subgroups limited statistical power for comparisons across regions within age groups. Finally, collecting the data on vaccination status of the participants was not feasible during the short window of time for implementing the serosurvey as vaccination records were difficult to locate, particularly for older children and adults.

Recent polio outbreaks, resulting from importations from the remaining polio endemic countries to polio-free areas, are of serious concern for the Global Polio Eradication Initiative [15]. By rapidly controlling the 2010 outbreak, the European Region maintained its polio-free status [23]. However, pockets of susceptibles are still present in many countries, putting them at risk of future importation-related outbreaks. The risk of wild PV importation will remain until global eradication is achieved. Therefore, ensuring risk awareness and outbreak preparedness, along with very high immunization coverage and effective surveillance systems for early detection of cases will continue to be instrumental for preventing and rapidly containing future polio outbreaks and maintaining the polio-free status of the areas where WPV transmission has been interrupted.

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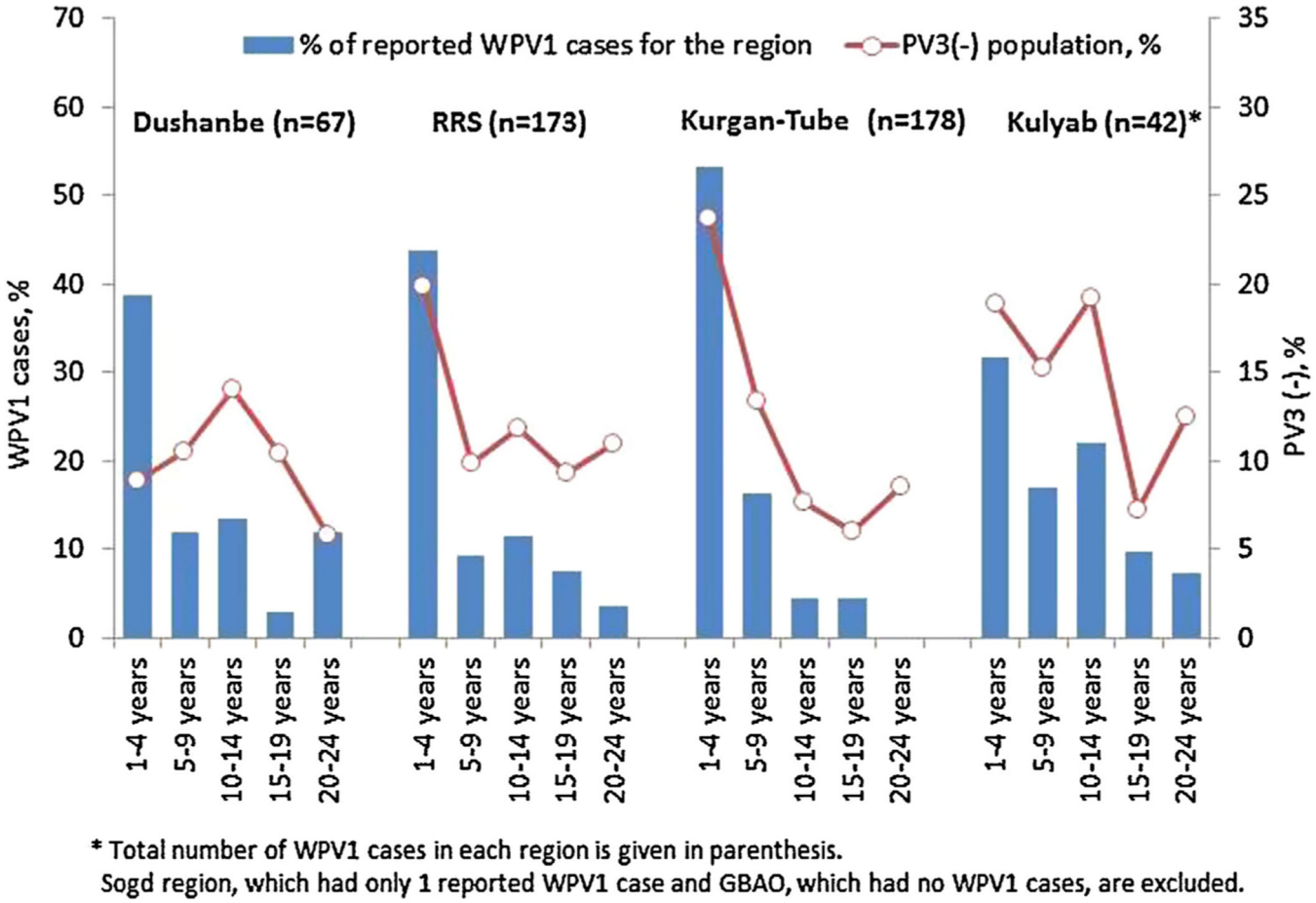

Fig. 1.

Reported WPV1 cases (per cent of all cases in the region) and proportion PV3-seronegative by region and age group, Tajikistan, 2010.

Table 1

Distribution of the proposed sample and serosurvey participants tested for poliovirus antibodies, by age group and region.

Age group	Dushanbe	RRS	Kurgan-Tube	Kulyab	Sogd	GBAO	Total participants nationwide
Proposed sample							
1–4 years	80	100	100	80	120	60	540
5–9 years	80	100	100	80	120	60	540
10–14 years	80	100	100	80	120	60	540
15–19 years	80	100	100	80	120	60	540
20–24 years	80	100	100	80	120	60	540
Total all ages	400	500	500	400	600	300	2700
Participants tested for poliovirus antibodies							
1–4 years	79	110	93	74	100	41	497
5–9 years	86	91	97	85	105	38	502
10–14 years	86	127	91	73	110	40	527
15–19 years	77	97	84	83	94	41	476
20–24 years	69	73	81	80	102	40	445
Total all ages	397	498	446	395	511	200	2447

Note: In accordance with the administrative division used by the health sector, the Kurgan-Tube and Kulyab zones of the Khatlon province were included as separate regions. RRS, Rayons of Republican Subordination; GBAO, Gorno-Badakhshan Autonomous Oblast.

Table 2

Distribution of demographic and risk factor variables among serosurvey participants tested for poliovirus antibodies.

Variable (no. with reported data available)	No.	Crude %
Sex (*n* = 2447)		
Male	1071	43.8
Female	1376	56.2
Ethnicity (*n* = 2406)[a]		
Tajik	2021	83.6
Uzbek	379	15.8
Other (mainly Russian)	16	0.6
Birth setting (*n* = 2384)		
Health care facility	1931	81.0
Home	453	19.0
Mother's education (*n* = 2423)		
High school or less	2065	85.2
More than high school	358	14.8
Father's education (*n* = 2403)		
High school or less	1489	62.0
More than high school	914	38.0

Note: The denominators for these descriptive variables vary because some participants did not answer all the questions.

[a] In the 2000 census, Tajiks comprised 79.9% and Uzbeks comprised 16.7% of the Tajikistan's population.

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Table 3

Population immunity for polioviruses by age group and region, population-based serosurvey, Tajikistan, 2010; estimates adjusted to account for sampling weights and survey design.

Poliovirus (PV) type	Variables	Tested, no.	Seropositive			Chi-square p-value[a]
			No.	%	95% CI	
PV1	Overall	2447	2417	98.9	98.3–99.3	
	By age group					
	1–4 years	497	490	99.0	97.9–99.6	<0.01
	5–9 years	502	502	100.0	N/A	
	10–14 years	527	525	99.9	99.8–99.9	
	15–19 years	476	473	99.2	95.6–99.9	
	20–24 years	445	427	96.1	93.8–97.6	
	By region					
	Dushanbe	397	393	98.9	97.4–99.5	0.26
	RRS	498	495	99.3	97.9–99.8	
	Kurgan-Tube	446	442	99.2	97.1–99.8	
	Kulyab	395	393	99.5	97.5–99.9	
	Sogd	511	503	98.4	97.3–99.0	
	GBAO	200	191	95.8	91.6–98.0	
PV2	Overall	2447	2412	98.8	98.4–99.1	
	By age group					
	1–4 years	497	479	96.6	94.8–97.8	<0.001
	5–9 years	502	499	99.3	97.8–99.8	
	10–14 years	527	524	99.6	98.2–99.9	
	15–19 years	476	475	99.8	98.6–100	
	20–24 years	445	435	98.3	97.0–99.0	
	By region					
	Dushanbe	397	396	99.7	97.9–100	<0.01
	RRS	498	494	99.3	98.3–99.7	
	Kurgan-Tube	446	436	98.1	95.8–99.1	
	Kulyab	395	388	98.3	97.1–99.0	

Poliovirus (PV) type	Variables	Tested, no.	Seropositive			Chi-square p-value[a]
			No.	%	95% CI	
	Sogd	511	507	99.3	98.5–99.6	
	GBAO	200	191	95.8	95.1–96.4	
PV3	Overall	2447	2125	86.9	84.2–89.1	
	By age group					
	1–4 years	497	414	82.7	78.8–86.0	<0.01
	5–9 years	502	431	84.4	78.7–88.8	
	10–14 years	527	459	87.2	83.0–90.4	
	15–19 years	476	437	91.7	88.0–94.3	
	20–24 years	445	384	87.5	83.6–90.6	
	By region					
	Dushanbe	397	357	90.0	84.4–93.7	0.57
	RRS	498	435	87.9	80.1–92.9	
	Kurgan-Tube	446	392	88.6	81.9–93.0	
	Kulyab	395	338	85.4	81.1–88.9	
	Sogd	511	431	84.5	80.9–87.5	
	GBAO	200	172	86.5	78.3–91.9	

[a] *p* values refer to the existence of differences in distribution of seroprevalence across age groups or regions.

Table 4

Median anti-PV antibody titers by age group, Tajikistan, 2010.

Age group	Median antibody titer		
	PV1	PV2	PV3
Overall	1:1024	1:256	1:32
1–4 years	1:1024	1:512	1:64
5–9 years	1:1024	1:256	1:32
10–14 years	1:1024	1:256	1:32
15–19 years	1:1024	1:256	1:32
20–24 years	1:64	1:64	1:16

1:1024 was the highest dilution tested, therefore the category “1:1024” includes titers 1:1024 and higher.