Poliovirus circulation in the WHO European region, 2015–2022: a review of data from WHO's three core poliovirus surveillance systems

Thea K. Fischer,[a,b,h,*] Caroline K. Johannesen,[a,h] Kimberley S. M. Benschop,[c] Natasa Berginc,[d] Eugene V. Saxentoff,[e] Shahin Huseynov,[e] José E. Hagan,[e] and Heli Harvala[f,g]

[a]Department of Clinical Research, Nordsjællands Hospital, Hillerød, Denmark
[b]Department of Public Health, University of Copenhagen, Copenhagen, Denmark
[c]Center for Infectious Disease Control, National Institute for Public Health and the Environment, Bilthoven, Netherlands
[d]National Laboratory of Health, Environment and Food, National WHO Reference Laboratory for Polio, Ljubljana, Slovenia
[e]Vaccine-preventable Diseases and Immunization, Division of Communicable Diseases, Environment and Health, World Health Organization (WHO) Regional Office for Europe, Copenhagen, Denmark
[f]Microbiology Services, National Health Service (NHS) Blood and Transplant, London, United Kingdom
[g]Radcliffe Department of Medicine, University of Oxford, Oxford, United Kingdom

The Lancet Regional Health - Europe 2024;47: 101104

Published Online xxx
https://doi.org/10.1016/j.lanepe.2024.101104

Summary

Background The Global Polio Eradication Initiative (GPEI) has drastically reduced the global incidence of poliomyelitis since its launch in 1988 thanks to effective vaccines and strong global surveillance systems. However, detections of wild-type as well as vaccine-derived poliovirus (VDPV) still occur, also in the WHO European Region. This study aims to describe the poliovirus detection via the acute flaccid paralysis (AFP), clinical enterovirus, and environmental surveillance systems.

Methods In this study, we review data from annual reports from 2015 to 2022 from the World Health Organization (WHO)'s three core poliovirus surveillance systems in place in the WHO European Region: AFP, clinical enterovirus, and environmental surveillance systems.

Findings A total of 4324 reported samples were found positive for poliovirus: 477 from AFP surveillance, 394 from clinical surveillance and 3453 from environmental surveillance. Of these, 366 were VDPV, 3952 vaccine strains, and 6 were wild-type poliovirus. 709 were identified as type 1, 399 as type 2, and 1944 type 3, while 1272 samples contained more than one type. Temporal and spatial association of positive environmental samples with positive samples from AFP or clinical enterovirus surveillance was found in only eight countries.

Interpretation Analysis of poliovirus-positive samples from AFP, clinical enterovirus, and environmental surveillance revealed that type 3 poliovirus was the most prevalent type detected. Most poliovirus-positive samples were identified as vaccine strains. No information on sequences was available.

Funding This study was funded by WHO Regional Office for Europe and received financial support from the Bill and Melinda Gates Foundation.

Keywords: Enterovirus; Polio; Poliovirus; Surveillance; Public Health; Europe; Vaccine Derived Polio; Polio eradication; AFP; Environmental Surveillance; Clinical Surveillance

Introduction

The Global Polio Eradication Initiative (GPEI), launched in 1988, has been successful in reducing the incidence of poliomyelitis worldwide. At the initiation of the GPEI, more than 350,000 annual cases of polio were documented across 125 countries. Fast forward to 2023, the number of reported cases caused by wild-type poliovirus (WPV) had dwindled to a mere 12 cases in the whole

*Corresponding author. Nordsjællands Hospital, Opgang 58 plan 3, Dyrehavevej 29, 3400, Hillerød, Denmark.
E-mail address: thea.koelsen.fischer@regionh.dk (T.K. Fischer).
[h]Contributed equally.

Research in context

Evidence before this study

The global effort to eradicate polio has been openly sharing information on poliomyelitis cases, poliovirus detections, and poliovirus types through the Global Polio Eradication Initiative (GPEI) and WHO.

Poliovirus, often considered a relic of the past, is becoming increasingly relevant to monitor due to increased detection and reporting of vaccine-derived poliovirus (VDPV) in environmental samples (globally). Recent events in the European Region have highlighted the importance of vigilance with VPDV cases detected in environmental samples in London and two cases of paralytic VDPV in unvaccinated Israelian children according to the 2023 situational update from the European Centre for Disease Prevention and Control (ECDC), poliomyelitis remains a significant concern within the EU/EEA and the update underscored the necessity of continued surveillance and preventive measures to address the threat of polio.

ENPEN pen was launched in 2017 in response to the increase in emerging enteroviruses causing severe, polio-like illnesses in children across the globe. Sporadic detections of VDPV or Wild Polio Virus, Type 1 (WPV1) were noted via the ENPEN surveillance, and similarly captured via the World Health Organisation (WHO) surveillance systems.

With this, a collaboration between the WHO European regional office and ENPEN was established to investigate the detection of non-polio enterovirus and poliovirus in the existing surveillance systems, aiming to publish these findings.

In Europe, news on poliovirus detections and Acute Flaccid Paralysis (AFP) cases is shared with the media, and the national surveillance laboratories share their data with the WHO Regional Office for Europe. Thus, poliovirus circulation in Europe is documented, though it has not yet been analysed coherently and published in a collected, original study.

Added value of this study

With three coexisting poliovirus surveillance programs running in Europe, a formal investigation of their synergies has not been published. This study presents an analysis of three poliovirus surveillance systems, the detection of poliovirus in each system, their use in combination and the synergies between them. We find that poliovirus is detected in all systems but that temporal and spatial associations between environmental detection and clinically collected positive samples, such as AFP samples, are rare, possibly due to the incompleteness of systems for environmental surveillance.

Implications of all the available evidence

Based on the analysis of the three poliovirus surveillance systems and their synergies, we recommend more finely granulated environmental surveillance programs, including specific spatiotemporal coverage of the programs.

year,[1] with these occurring exclusively in the two remaining endemic countries of Afghanistan and Pakistan.[2] However, the number of vaccine-derived polio cases has jumped from just 32 cases in 2015 to 451 cases in 2023.[2]

Among the three WPV types, only WPV1 persists in circulation. WPV2 ceased circulating in 1999, and WPV3 has not been isolated since 2012.[3] The certification of global eradication of WPV2 in 2015 prompted the removal of the type 2 component from the oral poliovirus vaccine (OPV; Sabin strains) formulations in the subsequent year, though OPVs containing type 2 polio virus has been used for outbreak response in other WHO regions until 2022. Simultaneously, in a significant stride towards polio eradication, a few countries within the WHO European Region; Belarus, Georgia, and Poland transitioned from OPV to an inactivated poliovirus vaccine (IPV)-only vaccination strategy in 2016. The anticipation of a regional shift to an IPV-only vaccination strategy was expected to be fully implemented by the year 2020. However, the shift so far is taking longer than first anticipated and 11 Member States of the WHO European Region are still using OPV in routine immunization.[4] Robust clinical and syndromic surveillance of poliovirus circulation remains crucial until the conclusive eradication of poliovirus in endemic countries is achieved, coupled with the full transition from OPV to IPV.

Acute flaccid paralysis (AFP) surveillance has been the gold standard for surveillance of poliovirus since the beginning of the polio eradication initiative in 1988.[5] The occurrence of both acute and prolonged paralysis resulting from various enterovirus (EV) infections extends beyond poliovirus, encompassing various non-polio enterovirus (NPEV) types. Recognizing this broader spectrum, syndromic surveillance not only for AFP caused by poliovirus but also for acute flaccid myelitis (AFM) caused by NPEVs plays a crucial role in monitoring and understanding the dynamics of paralysis caused by the entire enterovirus genus. Many countries succeeding with polio eradication, have experienced epidemics from NPEVs associated with meningitis, meningoencephalitis, AFP and/or AFM cases. These present with manifestations clinically similar to polio, and with the potential for long-lasting sequelae such as Echovirus 30 (E30) epidemic,[6] EV-A71 epidemics of meningitis and brainstem encephalitis in Asia in 2008[7,8] and Spain in 2016,[9] and the EV-D68 epidemic in North America and Europe from 2014 onwards.[10,11]

Poliovirus infection manifests as poliomyelitis (abbreviated as polio) in only about 1 in every 200 unvaccinated individuals infected with the virus, with lower case rates in vaccinated communities. Since most poliovirus infections are asymptomatic, and infected individuals excrete substantial amounts of virus in their faeces for weeks, environmental surveillance can add value to clinical monitoring, especially in communities with sub-optimal immunisation levels. When applied correctly and functioning optimally, this method allows for the early detection of poliovirus circulation in an area before paralysis cases emerge, making it a valuable strategy post-eradication.[12] All components of poliovirus surveillance are supported by the Global Polio Laboratory Network (GPLN) for confirmatory testing using viral isolation, intratypic differentiation and genomic sequencing procedures in accordance with WHO guidelines.[13]

This study aims to describe the poliovirus detection via the AFP, clinical enterovirus, and environmental surveillance systems and compare the main outcomes from the 3 systems in the WHO European Region encompassing 53 countries[i].

We aim to evaluate the effectiveness of environmental surveillance in detecting poliovirus and predicting AFP cases and poliovirus-positive clinical cases. This strategic exploration is particularly relevant in the broader context of enhancing surveillance methodologies during the transitional phases of global changes in polio vaccination strategy and poliovirus eradication efforts.

Methods

Study population

The WHO European Region covers 53 countries from the Atlantic to the Pacific Ocean with a total population of 929 million in 2021.[14] The countries of the Region, their use of surveillance systems and preventive strategies are described in detail in Table 1. The sub-national administrative level of the Member States can vary substantially in size, from one municipality (e.g., in Andorra) to covering a whole country (e.g., England in the United Kingdom).

Data sources

The WHO data is based on the "Annual progress reports on polio eradication activities", which contain data on AFP, environmental surveillance, and clinical surveillance. The case-level data was collected through Online Laboratory Data Management System (LDMS) and centralized information system for infectious diseases (CISID). The data reviewed covers the years 2015–2022.

Surveillance systems

According to WHO guidelines, three types of surveillance systems for detecting the transmission of poliovirus are pivotal for reaching global polio eradication, based on the assumption that high-quality surveillance permits the timely detection of poliovirus transmission due to WPV, vaccine-derived polioviruses (VDPVs) and the circulation of Sabin-like viruses.[13] The surveillance is implemented in different combinations in countries throughout the WHO European Region.

Firstly, acute flaccid paralysis (AFP) surveillance

AFP surveillance is globally accepted case-based syndromic surveillance for AFP cases which confirms poliovirus by testing stool specimens in polio laboratories.[13] AFP cases are identified using both active and passive surveillance, and facility- and community-based detection methods.[15] In this study, AFP cases and contacts have been identified in accordance with the WHO guidelines[13] where the sensitivity limit is 1 case of non-polio AFP per 100,000 individuals younger than 15 years in a given year.

Secondly, environmental surveillance (ES)

ES is complementing AFP surveillance via systematic testing of sewage samples for poliovirus in specific settings.[16] ES is supplementary to AFP surveillance and can contribute valuable albeit non-clinical information. With ES it is expected that detection of circulating poliovirus can be achieved before the emergence of severe clinical or AFP cases, providing adequate sampling sites positioning and testing methodology is applied. Findings of non-polio enteroviruses validate the functionality of procedures of ES.[16] Effectiveness and representativity of ES are determined by the areas covered by the surveillance and the ability to detect enterovirus in the samples collected, and the probability of detected an infected case are, along with other factors, related to the population density in the sampled area.[16]

Lastly, clinical enterovirus surveillance (EVS)

Within polio-free regions or countries, clinical enterovirus surveillance can be used to complement or replace the AFP surveillance, especially when the AFP surveillance cannot meet the criteria for minimum detection of AFP cases.[13] This systematic clinical enterovirus surveillance aims to provide a supplementary data source on poliovirus circulation. In countries with no environmental or AFP surveillance, clinical EVS may be the only system confirming that poliovirus is not causing clinical disease.[15] Systematically testing for poliovirus in

[i]Albania, Andorra, Armenia, Austria, Azerbaijan, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Georgia, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Luxembourg, Malta, Monaco, Montenegro, Netherlands (Kingdom of the), North Macedonia, Norway, Poland, Portugal, Republic of Moldova, Romania, Russian Federation, San Marino, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Tajikistan, Türkiye, Turkmenistan, Ukraine, United Kingdom, Uzbekistan.

Country	Population	Polio vaccination coverage[a]	Vaccines in program 2020 (Only IPV or combined OPV/IPV)	AFP Surveillance	Clinical enterovirus Surveillance	Environmental Surveillance
Albania	2.832.439	98	OPV/IPV	Yes	Yes	
Andorra	79.034	97	IPV	Yes		
Armenia	2.777.971	98	IPV	Yes	Yes	
Austria	8.958.960	84	IPV	Yes	Yes	
Azerbaijan	10.412.652	88	OPV/IPV	Yes		Yes
Belarus	9.498.238	98	IPV	Yes	Yes	Yes
Belgium	11.594.060	98	IPV	Yes	Yes	
Bosnia and Herzegovina	3.210.847	75	IPV	Yes		
Bulgaria	6.687.717	91	IPV	Yes	Yes	
Croatia	4.008.617	92	IPV	Yes	Yes	Yes
Cyprus	1.260.138	96	IPV	Yes	Yes	
Czechia	10.495.295	94	IPV	Yes		Yes
Denmark	5.964.059	98	IPV		Yes	
Estonia	1.322.765	85	IPV	Yes	Yes	Yes
Finland	5.545.475	91	IPV			Yes
France	67.750.000	96	IPV		Yes	
Georgia	3.728.282	85	IPV	Yes	Yes	Yes
Germany	83.200.000	91	IPV		Yes	Yes
Greece	10.341.277	99	IPV	Yes	Yes	Yes
Hungary	10.156.239	99	IPV	Yes		
Iceland	372.520	92	IPV		Yes	
Ireland	5.056.935	93	IPV	Yes	Yes	
Israel	9.496.000	98	OPV/IPV	Yes	Yes	Yes
Italy	58.870.762	95	IPV	Yes		Yes
Kazakhstan	19.606.634	99	OPV/IPV	Yes	Yes	Yes
Kyrgyzstan	6.735.348	92	OPV/IPV	Yes		
Latvia	1.830.211	95	IPV	Yes	Yes	Yes
Lithuania	2.718.352	90	IPV	Yes	Yes	
Malta	535.064	98	IPV	Yes		Yes
Moldova	3.435.931	88	OPV/IPV	Yes	Yes	Yes
Monaco	36.686	99	IPV	Yes		Yes
Montenegro	626.485	80	OPV/IPV	Yes		
Netherlands	17.530.000	93	IPV		Yes	Yes
North Macedonia	2.085.679	84	IPV	Yes		
Norway	5.474.360	97	IPV	Yes	Yes	
Poland	41.026.067	91	IPV	Yes		Yes
Portugal	10.247.605	99	IPV	Yes	Yes	
Romania	19.892.812	85	IPV	Yes		Yes
Russian Federation	144.444.359	97	OPV/IPV	Yes	Yes	Yes
San Marino	33.745	92	IPV	Yes		
Serbia	7.149.077	92	IPV	Yes		
Slovakia	5.795.199	97	IPV	Yes	Yes	Yes
Slovenia	2.119.675	89	IPV	Yes	Yes	
Spain	47.519.628	93	IPV	Yes	Yes	Yes
Sweden	10.467.097	94	IPV		Yes	
Switzerland	8.796.669	96	IPV	Yes		
Tajikistan	10.078.507	97	OPV/IPV	Yes		Yes
Turkmenistan	85.816.199	99	OPV/IPV	Yes		
Türkiye	6.516.100	98	OPV/IPV	Yes	Yes	
Ukraine	36.744.634	69	OPV/IPV	Yes	Yes	Yes
United Kingdom	67.736.802	92	IPV		Yes	Yes
Uzbekistan	34.739.400	99	OPV/IPV	Yes		Yes

[a]Polio type 3 vaccination coverage among 1-year-olds.

Table 1: **Enterovirus positive samples and subtypes identified by AFP surveillance in the WHO European Region 2015–2022.**

enterovirus-positive samples[15] provides supportive evidence that the country is polio-free. Inclusion criteria for data from the clinical enterovirus surveillance into the WHO systems differ between countries. Some countries report all samples, while others report only samples testing positive for enterovirus, primarily focus on poliovirus-positive samples only, or only samples subjected to poliovirus testing.

Classification of poliovirus-positive samples

The poliovirus type is characterised using molecular techniques in accordance with the WHO diagnostic protocol. Samples reported to the WHO Regional Office for Europe's poliovirus surveillance are characterized in the WHO-accredited polio laboratories to describe the poliovirus type (PV1, PV2, and PV3) and the intratypic differentiation of poliovirus (vaccine strains (Vaccine or nOPV2), VDPV or wild-type virus). This study presents the aggerated findings based on poliovirus type and whether they were wild-type, vaccine strain or vaccine-derived viruses according to intratypic differentiation.

For analysis purposes, samples with more than one poliovirus type, e.g., typing results positive for both PV1 and PV3, are labelled as 'More than one type'.

Analysis

Information on samples was provided by the WHO Regional Office for Europe based on WHO surveillance systems for AFP surveillance, clinical enterovirus surveillance and ES covering the period of January 1, 2015, to December 31, 2022. All samples positive for any enterovirus from ES, AFP, and clinical enterovirus surveillance were included in the analysis. Distinction between samples from the same case or site were not possible. Multiple samples could be included from the same case or sample site. From the AFP surveillance, only samples from AFP cases were included, and samples from AFP contacts were omitted. Missing data is expected on poliovirus-negative samples, while complete reporting of existing data is expected for poliovirus-positive samples. Results were aggregated by surveillance system and country.

We investigated any temporal and spatial relations between positive samples in the AFP surveillance and the ES and between positive-poliovirus samples, irrespective of the intratypic differentiation, in the clinical enterovirus surveillance and the ES at the country level and province level where applicable. To do this, all environmental samples positive for poliovirus, were identified. Then, the next positive AFP sample in the same country and, if any, in the same province was identified, and the number of days between collection of the samples was calculated. The same was done with positive samples from the clinical enterovirus surveillance. We defined an environmental sample as timely related to the detection of an AFP case or positive clinical enterovirus sample if collected in the 30 days preceding the detection of the AFP case or positive clinical enterovirus surveillance sample. For spatial relations, we defined that the environmental sample and the AFP case sample or positive clinical enterovirus sample should be detected in the same geographic area. When samples were timely related and occurred in the same province, we compared the characterisation results (virus type and variant) of the environmental samples and AFP case sample or positive clinical enterovirus sample.

All analysis was conducted using R studio version 2023.9.0.463.[17,18]

Role of the funding source

This study was funded by WHO Regional Office for Europe and received financial support from the Bill and Melinda Gates Foundation. The data was provided by the funding source. The work was conducted by the ENPEN study group in close collaboration, and input on the study design and the drafted manuscript allowed.

Results

AFP surveillance

Our review of the WHO Regional Office for Europe's AFP surveillance data provides outcomes in 44 (83%) of the 53 countries within the WHO European Region covering a population of more than 0.9 billion people (Table 1, Fig. 1). There were zero reported cases in

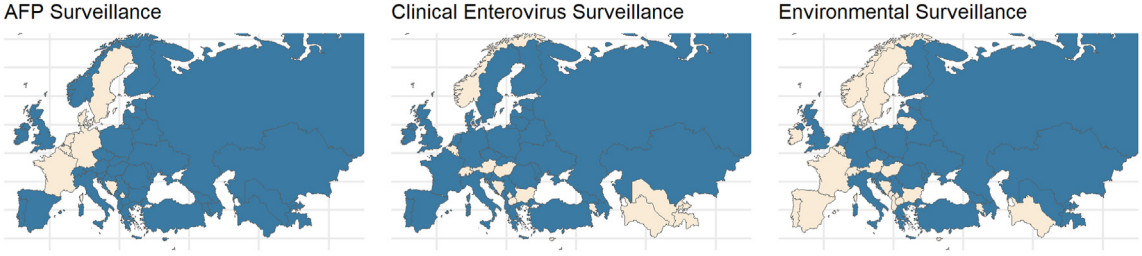

Fig. 1: Maps of participation in acute flaccid paralysis (AFP) surveillance, Clinical enterovirus surveillance, and Environmental surveillance in the WHO Europe region. Participating country Israel is not shown on the maps. Figure key: Blue, Participated with data to surveillance; Light yellow, Did not participate with data to surveillance.

Germany, while 43 countries provided data for AFP surveillance during the period, representing 81% of the total countries.

The AFP surveillance identified 477 poliovirus-positive samples from AFP cases in 24,954 tested samples from AFP cases (Table 2). The majority of AFP samples tested for poliovirus that was reported during the 8-year study period were from countries in the east of the Region led by the Russian Federation, Türkiye, and Ukraine, with 6429 (25.8%), 4206 (16.8%), and 2265 (9%) AFP samples, respectively. The prevalence of poliovirus-positive AFP samples was highest in the Russian Federation with 152 (2.4% positive) cases and in Tajikistan with 96 (5.8%) cases, while Türkiye reported only 28 (0.7%) poliovirus-positive AFP cases (Supplementary Table S1).

Characterisation of poliovirus type was available for all 477 samples from poliovirus-positive AFP cases. Among these, poliovirus type 3 was the most prevalent as a single detection, constituting 204 samples (43.1%) (Table 3) followed by type 2 in 102 samples (21.3%) and type 1 in 83 samples (17.3%). For 88 samples, multiple poliovirus types were reported. Overall, in single detection and multiple detection combined, 151 samples were positive for type 1, 118 for type 2 and 263 for type 3.

The AFP surveillance recorded no samples with WPV, thus all 477 samples were vaccine-related. Of these, 388 samples were vaccine strains (383 traditional vaccine samples, 5 samples were nOPV), and 89 samples were VDPV (Table 3). The majority, 78.4% (n = 69) of the 89 VDPV polioviruses identified were poliovirus type 2, while the vaccine strains most often were poliovirus type 3 (51.4%, 197/383).

During the study period from 2015 to 2022 in the WHO European Region, a general decline in the number of poliovirus-positive AFP samples was observed from 2017 to 2020 except in 5 countries, namely Kyrgyzstan, the Russian Federation, Türkiye, Ukraine, and Uzbekistan, (data not shown) where a general rise in poliovirus-positive samples from AFP cases was observed, and a notable peak occurred in 2021 (Fig. 2). It is noteworthy that throughout all the years of surveillance, the number of poliovirus-positive samples with vaccine-related variant type in the WHO European Region consistently remained high, and wild poliovirus was not reported in any samples collected from AFP case (Table 3).

Surveillance system	Samples positive for enterovirus (n)	Samples positive for Poliovirus	Samples from AFP-cases[a]
AFP	–	477	24954
Clinical enterovirus	11039	394	–
Environmental	8091	3453	–

[a]Contacts excluded from AFP surveillance samples.

Table 2: **Poliovirus cases identified and reported by surveillance systems in the WHO European Region 2015–2022.**

Surveillance system	Strain	Virus type				Total
		1	2	3	>1[a]	
AFP	Vaccine	71	28	197	87	383
	VDPV	12	69	7	1	89
	nOPV	0	5	0	0	5
	WPV	0	0	0	0	0
	Total	83	102	204	88	477
Clinical enterovirus	Vaccine	97	19	178	68	362
	VDPV	5	1	12	3	21
	nOPV	0	9	0	2	11
	WPV	0	0	0	0	0
	Total	102	29	190	73	394
Environmental	Vaccine	518	213	1510	939	3180
	VDPV	5	51	39	161	256
	nOPV	0	0	0	11	11
	WPV	1	4	1	0	6
	Total	524	268	1550	1111	3453
Total		709	399	1944	1272	4324

[a]More than one virus type detected in one sample.

Table 3: **Poliovirus characterization by surveillance system.**

Clinical enterovirus surveillance

The clinical enterovirus surveillance covers 28 of the 53 countries n the WHO Europe region (52.8%) (Table 1). A total of 11,039 samples were positive for enterovirus, including 394 samples positive for poliovirus (3.6%) from 15 countries (Table 2). Denmark reported the highest number of enterovirus-positive samples to the clinical enterovirus surveillance (4497 samples), with no samples positive for poliovirus. The Russian Federation and Ukraine reported the highest number of poliovirus-positive samples (Supplementary Table S2).

Characterisation of poliovirus types was available for all 394 samples (Table 3). In single detection, type 3 was most common (176 samples), followed by type 1 in 97 samples and type 2 in 19 samples. In 73 samples, more than 1 poliovirus type was detected. In total, 136 samples had a detection of type 1 poliovirus, 54 with type 2 and 213 had a detection of type 3, with single and multiple detections combined.

The intratypic differentiation of the poliovirus in the clinical enterovirus surveillance samples was vaccine-related in all 394 samples. Of these, 373 samples were directly from vaccine with 11 from nOPV and 21 were VDPV. Of the VDPV reported, 12 samples had poliovirus type PV3 (57.1%) (Table 3).

Environmental surveillance (ES)

The WHO European Regional data from ES for poliovirus covers 23 of the 53 countries (43.4%) within the

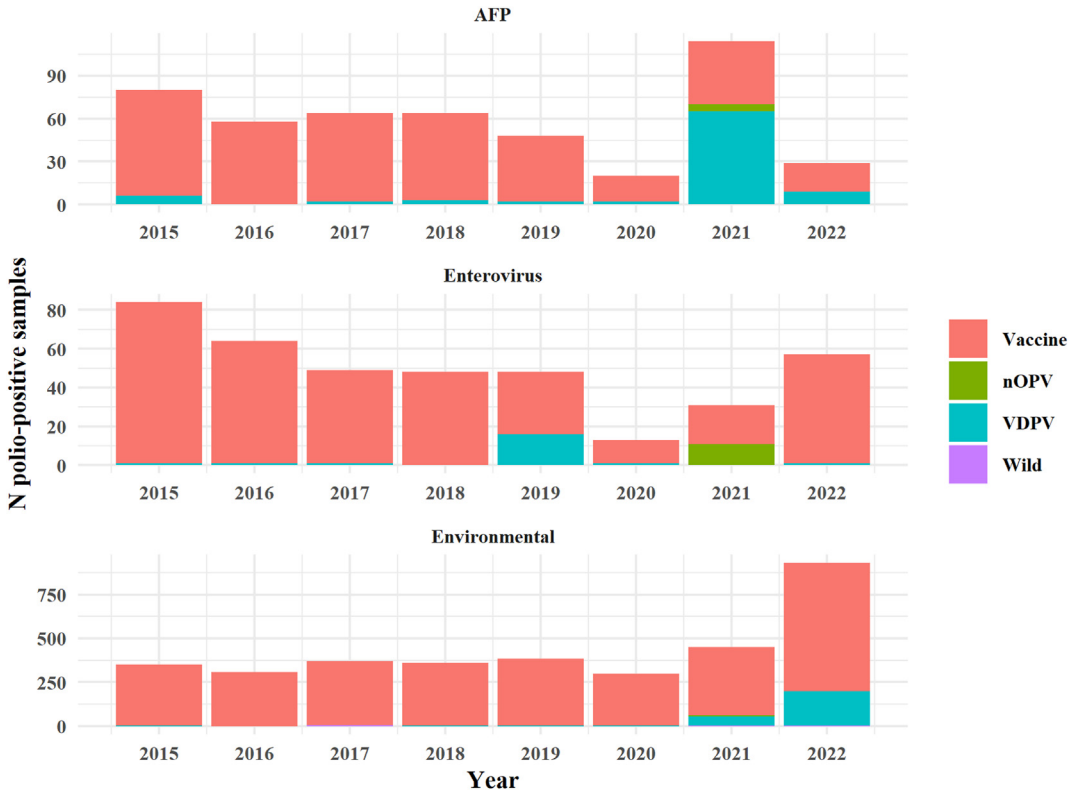

Fig. 2: Number of poliovirus-positive samples by surveillance system acute flaccid paralysis (AFP) surveillance, Clinical enterovirus surveillance, and Environmental surveillance during 2015–2022 in the WHO Europe region.

WHO European Region (Table 1). A total 8091 environmental samples tested positive for enterovirus of which 3453 (42.7%) samples tested positive for poliovirus (Table 2).

Of the 23 countries reporting on ES activities reporting of both polio-positive and non-polio-positive samples vary, and the positivity rates thus differ. Israel had the highest rate of poliovirus positive samples with poliovirus identified in 1536 (98.7%) out of 1556 enterovirus-positive samples. Italy reported the lowest non-null rate of poliovirus positive samples with only 3 out of 615 EV-positive environmental samples (0.5%) testing positive for poliovirus (Supplementary Table S3).

Type characterisations were available for all the positive samples (Table 3). The most common poliovirus type detected (single detection) in ES was type 3 detected in 1550 samples, followed by type 1 in 524 samples and finally type 2 in 268 samples. 1111 samples contained a mixture of poliovirus types. Counting single and multiple detection of types together, 723 samples were type 1, 172 samples were type 2 and 1333 were type 3.

All the 3453 poliovirus-positive environmental samples were characterized with intratypic differentiation with vaccine-related types. Of these 256 were VDPV (7.7%). In addition, 6 were WPV. In Netherlands, poliovirus wild-type 2 was detected 6 times in environmental samples and associated with an isolated well-contained incident, i.e. an industrial exposure of a single person, which did not lead to further transmission and outbreaks, and otherwhere described[19]). All VDPV had a confirmed characterisation of poliovirus type (5 PV1, 51 PV2, 39 PV3 and 164 with more than 1 virus type in the sample, Table 3).

Poliovirus types during the study period

During the study period, the number of positive samples and the distribution of poliovirus type was not constant by year and surveillance system. Fig. 3 shows the distribution of poliovirus types and sample numbers by year and surveillance system. In all systems, 2020 had a low number of positive tests, most distinctly in the AFP surveillance and the clinical enterovirus surveillance. Of interest, type 2 was present in all three systems until the switch from trivalent to bivalent oral polio vaccine in 2016. After that, type 2 seems to have disappeared but re-emerged in 2020 in the AFP surveillance and in 2021 in the clinical enterovirus surveillance and environmental surveillance. In 2021, type 2 poliovirus was the most common poliovirus type identified in poliovirus-positive samples from AFP cases.

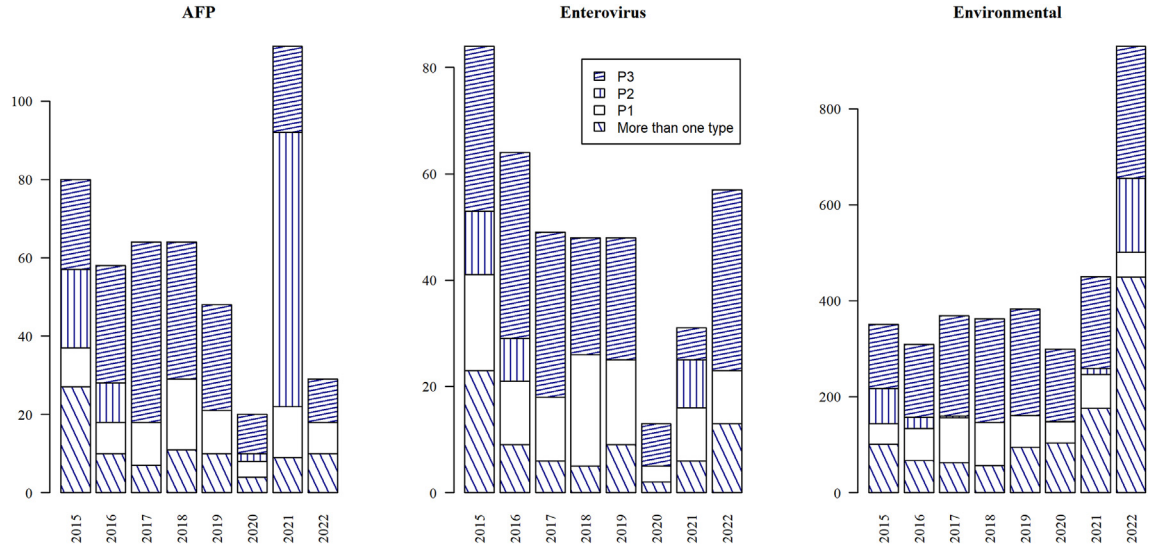

Fig. 3: Detection of poliovirus-positive samples by poliovirus type and surveillance systems acute flaccid paralysis (AFP) surveillance, Clinical enterovirus surveillance, and Environmental surveillance in the 2015–2022 WHO Europe region.

Combination of surveillance of poliovirus

In 13 countries in the Region, all three surveillance systems were running, with detection of poliovirus in at least one system in 10 countries. In 7 countries, poliovirus was detected in all three systems regardless of timing (Table 4). The combination of AFP and clinical enterovirus surveillance was present in 25 countries, with 13 countries detecting poliovirus in at least one system and 9 countries detecting it in both surveillance systems. with 16 countries detecting poliovirus in at least one of the two systems and 10 countries detecting it in both surveillance systems. Additionally, 17 countries had ES and clinical enterovirus surveillance in operation together, with 13 of these countries having detection of poliovirus in at least one surveillance system (Table 4).

Timing of poliovirus-positive environmental samples and AFP cases

We found 850 poliovirus-positive samples from ES that were followed by poliovirus-positive samples from AFP cases in the same country within 30 days. Investigation of the timing between the detection of poliovirus-positive samples from the AFP and the ES systems was possible only in the 17 countries where both systems were in place. In 10 of these countries, (Azerbaijan, Belarus, Georgia, Israel, Kazakhstan, Republic of Moldova, the Russian Federation, Tajikistan, Ukraine, and Uzbekistan) an ES detection occurred within 30 days of an AFP case.

Further, when investigating the temporal relationship at a provincial level, we saw that 71 of 87 provinces in the 10 countries with poliovirus-positive AFP cases and environmental samples did not have any reports of AFP cases positive for poliovirus collected after a poliovirus-positive environmental sample. We found a spatial as well as temporal concurrence of AFP cases and environmental tests positive for poliovirus in two countries (Israel and the Russian Federation). In these countries, six specific provinces out of 87 provinces (7%) in total reported a

Surveillance systems combination[a]	Countries with these surveillance systems	Countries with polio detected in at least one of the systems	Countries polio detected in the two/three systems	Countries with polio detected in AFP surveillance	Countries with polio detected in clinical enterovirus surveillance	Countries with polio detected in environmental surveillance
AFP + clinical enterovirus	25	13	9	11	9	–
AFP + Environmental	22	16	10	11	–	15
Environmental + Clinical enterovirus	17	13	11	–	12	12
AFP + clinical enterovirus + Environmental	13	10	7	8	9	9

[a]Countries with all three are included in the counts of the other combinations too.

Table 4: **Poliovirus detections in countries with multiple surveillance systems.**

positive environmental sample was collected within less than 30 days before the poliovirus-positive AFP-case. In the six provinces, 47% (546/1162) of all environmental samples were followed by a polio-positive AFP case. The rate of polio-positive samples from ES preceding a polio-positive AFP case with a maximum of 30 days in the 6 provinces was 3.3% (53 samples). While type 3 were dominant in the poliovirus-positive AFP samples that followed within 30 days of positive ES samples (92%) only 44% of these were preceded by a PV3 positive ES sample.

When restraining the analysis of environmental samples to VDPV positive-samples only, in Israel VDPV-positive environmental samples (12) was followed by an AFP sample within 30 days, with the VDPV-positive AFP samples (2) registered in February/March of 2022, concurrent with the described circulation of VDPV3 in Israel in 2022.[20]

Timing of poliovirus-positive samples from clinical enterovirus surveillance and environmental surveillance

Investigation of the timing between the detection of poliovirus-positive samples from the clinical enterovirus surveillance and the ES was possible in 24 countries. From 12 countries (Croatia, Czechia, Finland, France, Italy, Lithuania, Poland, Portugal, Spain, Tajikistan, Türkiye, and Uzbekistan), no poliovirus-positive clinical enterovirus surveillance samples were reported. In these countries, the rate of poliovirus-positive clinical enterovirus detection following environmental detection, therefore, was 0%.

In 11 countries (Azerbaijan, Belarus, Georgia, Germany, Israel, Kazakhstan, Republic of Moldova, the Russian Federation, Slovakia, Ukraine, and the United Kingdom), an ES detection occurred before a poliovirus-positive sample from the clinical enterovirus surveillance. In Slovakia, all the environmental samples were collected more than 30 days before the corresponding clinical enterovirus samples.

The temporal and spatial occurrence was investigated at the provincial level in the 12 countries where environmental samples were positive for poliovirus within 30 days preceding a poliovirus-positive sample from the clinical enterovirus surveillance. In 8 countries, we identified provinces where poliovirus-positive environmental samples were detected in the 30 days preceding a poliovirus-positive clinical enterovirus sample, namely Georgia, Israel, Republic of Moldova, Netherlands, the Russian Federation, Ukraine, and the United Kingdom. Of 120 provinces reported to the surveillance systems for these countries, we found that poliovirus-positive environmental samples were detected in the 30 days preceding a positive-poliovirus clinical enterovirus surveillance sample in 20 provinces (16.7%).

Discussion

The WHO Europe polio program collects poliovirus surveillance data from 53 countries, aggregating information from various national surveillance systems. While data collection methods vary among countries, efforts are consistently made to adhere to WHO guidelines. Some countries report all samples, while others report only samples testing positive for enterovirus, primarily focus on poliovirus-positive samples only, or only samples subjected to poliovirus testing. Our analysis focuses on 45 countries participating in AFP surveillance, 28 countries in clinical enterovirus surveillance, and 23 countries in ES, examining data in detail from countries contributing to multiple systems.

ES received more reports of samples positive for poliovirus than the AFP surveillance and the clinical enterovirus surveillance (3453 vs. 477 and 394, respectively). In samples from countries still administering OPV (Albania, Azerbaijan, Israel, Kazakhstan, Kyrghyzstan, Moldova, Montenegro, the Russian Federation, Tajikistan, Turkmenistan, Ukraine, Uzbekistan) the poliovirus-positivity rate of ES was high (26%). Poliovirus type 3 was predominant in environmental samples. Notably, no instances were found where environmental detection of wild-type poliovirus (n = 6) was followed by an AFP case. Most poliovirus-positive environmental samples were vaccine-related or VDPV, while the wild-type poliovirus was detected 6 times in environmental samples and associated with isolated well-contained incidents that did not lead to further transmission and outbreaks.[19] The reoccurrence of type 2 in 2020–2021 highlights the ongoing threat of cases or outbreaks when imported strains spread in populations with low immunity against locally eliminated strains. The detections of poliovirus type 2 may reflect the use of OPV for outbreak response in other regions combined with international travel.

Our study has some limitations due to missing data. We compare the data by surveillance system, as the systems are not all in place in all countries. Overall, the data from AFP surveillance can be considered representative in participating countries, though concerns of the quality and numbers of surveillance investigations per population number and the efficacy of the surveillance can be raised between individual health districts within countries. The ES is recommended for implementation especially in areas where polio vaccination rates are low or other surveillance systems are challenged. This recommendation can challenge the representativeness of ES, a bias that should be considered if extrapolation is considered using this data. In addition, we have not been able to identify samples from the same case or environmental site. These two challenges mean that the number of poliovirus-positive samples cannot be translated to a case count or whole-country rates of poliovirus positivity based on environmental detections. Therefore, an estimation of the burden of disease is not feasible based on the results presented here. Instead, our results do provide

information on when and where poliovirus was detected in samples from the three surveillance systems, showing the significant spread in both time and place in Europe within the studied period. Furthermore, analyses were conducted based on sample reporting rather that case based reporting, which may have caused an overestimation of the data in some countries. In the WHO European Region, ES and enterovirus surveillance are adjunctive systems that complement and fill gaps in AFP surveillance by providing alternative mechanisms to detect potential circulation of poliovirus. In other regions, the surveillance system plays additional roles in transmission detection, as in Pakistan where WPV is endemic.[21] Our findings illustrate the interplay between the surveillance systems. We found a low probability that a poliovirus-positive environmental sample was predictive of an AFP case with poliovirus (1.0–4.4% of all samples in provinces where ES were predictive of AFP). Only when restraining the environmental samples to VDPV positive-samples, a predictive link was identified to the identification of VDPV circulation and an AFP case in Israel. This was concurrent with the described circulation of VDPV3 in Israel in 2022 In this atypical setting, ES had a secondary function of "early warning" surveillance and detected presence of virus before a clinical case was detected.[20] Our findings are consistent with a previous description of local experiences with ES, which also described large discrepancies between environmental detections and AFP cases,[22] while other experiences advised that the discrepancy followed limited ES in time and space.[23] We noted that ES was sporadic in many provinces. In six countries with poliovirus-positive AFP cases, no ES samples were reported to the WHO, reflecting that settings with active and sensitive AFP surveillance tend not to invest resources and effort in overlapping ES networks.

These observations reflect the strategic role of ES in Europe, as a complementary, rather than duplicative, surveillance mechanism to support detection of polioviruses potentially missed by AFP surveillance, which may either result from asymptomatic infections in the setting of high IPV coverage, incompletely implemented or poorly functioning AFP surveillance, or both. The limited predictive performance of ES in this setting is an expected reflection of the structure of this regional surveillance strategy. However, in settings where there is assessed to be higher risk of poliovirus introduction and circulation such as in Israel, co-surveillance could be encouraged, and ES and either AFP surveillance, clinical enterovirus surveillance or both should have functioned full-time, with systematic sampling and both passive and active surveillance of AFP cases.[13] In settings where AFP surveillance is functional and robust, and where risk of undetected widespread circulation is lower, ES could be used strategically to monitor areas with high-risk populations or environmental factors conducive to virus transmission. Conversely, in regions where AFP surveillance is weak or unrepresentative, ES could play a more dominant role, compensating for the surveillance deficit. Decision-making about the strategic implementation of ES and enterovirus surveillance as complementary systems to AFP surveillance, including spatiotemporal coverage, should be tailored to the context of poliovirus epidemiology and public health infrastructure each setting.

Contributors

TKF, KSMB, CKJ, and HH conceptualised the study and drafted the manuscript. EVS, SH, and JEH provided the data and advised on the study design. CKJ conducted data cleaning and analysis. KSMB and NB revised the drafts. All authors reviewed and approved the final manuscript.

Data sharing statement

The data used in this study is the property of the WHO Regional Office for Europe and will not be made publicly available in any format. Data may be made available for research purposes with inquiries directed to saxentoffe@who.int.

Disclaimer

The authors affiliated with the World Health Organization (WHO) are alone responsible for the views expressed in this publication and they do not necessarily represent the decisions or policies of the WHO.

Editor note

The Lancet Group takes a neutral position with respect to territorial claims in published maps and institutional affiliations.

AI statement

The authors have used Grammarly (Grammarly.com) to enhance the quality and accuracy of the language in this manuscript.

Declaration of interests

TKF is co-founder of ENPEN and declare conference and workshop attendance financed by The European Society of Clinical Microbiology and Infectious Diseases (ESCMID) and European Society of Clinical Virology (ESCV). CKJ and NB are members of ENPEN and declare conference and workshop attendance financed by European Society of Clinical Virology (ESCV). In addition, CKJ reports contracted work with WHO on polio- and non-polio surveillance. KSMB and HH are members of the European non-polio enterovirus network (ENPEN) and have no conflicts of interest to declare. EVS, SH, and JEH are employees of the WHO Regional Office for Europe and have no conflicts of interest to declare.

Acknowledgements

All WHO-EURO member states who have reported data on polio-virus surveillance.

Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.lanepe.2024.101104.

References

1 AFP/polio data. https://extranet.who.int/polis/public/CaseCount.aspx. Accessed June 4, 2024.
2 GPEI-polio today. https://polioeradication.org/polio-today/. Accessed June 26, 2024.
3 WHO. *Poliomyelitis (polio)*; 2024. https://www.who.int/health-topics/poliomyelitis. Accessed May 22, 2024.
4 WHO immunization data portal: global, regional and country immunization data at your fingertips. https://www.who.int/news/item/03-11-2022-who-immunization-data-portal–global–regional-and-country-immunization-data-at-your-fingertips. Accessed June 26, 2024.
5 History of polio – GPEI. https://polioeradication.org/polio-today/history-of-polio/. Accessed June 26, 2024.
6 ECDC. *Poliomyelitis situation update*; 2023. https://www.ecdc.europa.eu/en/publications-data/poliomyelitis-situation-update. Accessed May 22, 2024.

7 Yang F, Ren L, Xiong Z, et al. Enterovirus 71 outbreak in the People's Republic of China in 2008. *J Clin Microbiol*. 2009;47:2351–2352.
8 Huang S-W, Hsu Y-W, Smith DJ, et al. Reemergence of enterovirus 71 in 2008 in taiwan: dynamics of genetic and antigenic evolution from 1998 to 2008. *J Clin Microbiol*. 2009;47:3653–3662.
9 Casas-Alba D, de Sevilla MF, Valero-Rello A, et al. Outbreak of brainstem encephalitis associated with enterovirus-A71 in Catalonia, Spain (2016): a clinical observational study in a children's reference centre in Catalonia. *Clin Microbiol Infect*. 2017;23:874–881.
10 Cassidy H, Poelman R, Knoester M, Van Leer-Buter CC, Niesters HGM. Enterovirus D68 - the new polio? *Front Microbiol*. 2018;9:2677.
11 Benschop KS, Albert J, Anton A, et al. Re-emergence of enterovirus D68 in Europe after easing the COVID-19 lockdown, 2021. *Euro Surveill*. 2021;26:2100998.
12 Bubba L, Benschop KSM, Blomqvist S, et al. Wastewater surveillance in Europe for non-polio enteroviruses and beyond. *Microorganisms*. 2023;11:2496.
13 Global Polio Eradication Initiative. *Global guidelines for acute flaccid paralysis (AFP) surveillance in the context of poliovirus eradication*; 2023. https://polioeradication.org/wp-content/uploads/2023/03/Global-AFP-guidelines-pre-publiucation-version-2023.pdf. Accessed June 4, 2024.
14 The European Health Report 2021. *Taking stock of the health-related Sustainable Development Goals in the COVID-19 era with a focus on leaving no one behind*. Copenhagen: World Health Organization, Regional Office for Europe; 2022.
15 World Health Organisation. *Poliomyelitis*; 2018. https://cdn.who.int/media/docs/default-source/immunization/vpd_surveillance/vpd-surveillance-standards-publication/who-surveillancevaccinepreventable-18-polio-r3.pdf?sfvrsn=aa96984f_28.
16 Organization WH. Guidelines for environmental surveillance of poliovirus circulation. https://iris.who.int/handle/10665/67854; 2003. Accessed June 26, 2024.
17 RStudio Team. *RStudio*. Integrated Development for R; 2020.
18 R Core Team. R: a language and environment for statistical computing. https://www.R-project.org/.
19 Duizer E, Ruijs WL, van der Weijden CP, Timen A. Response to a wild poliovirus type 2 (WPV2)-shedding event following accidental exposure to WPV2, the Netherlands, April 2017. *Euro Surveill*. 2017;22:30542.
20 Circulating vaccine-derived poliovirus type 3 – Israel. https://www.who.int/emergencies/disease-outbreak-news/item/2022-DON366. Accessed June 25, 2024.
21 Cowger TL, Burns CC, Sharif S, et al. The role of supplementary environmental surveillance to complement acute flaccid paralysis surveillance for wild poliovirus in Pakistan – 2011–2013. *PLoS One*. 2017;12:e0180608.
22 Ivanova OE, Yarmolskaya MS, Eremeeva TP, et al. Environmental surveillance for poliovirus and other enteroviruses: long-term experience in Moscow, Russian federation, 2004–2017. *Viruses*. 2019;11:424.
23 Chen P, Liu Y, Wang H, et al. Environmental surveillance complements case-based surveillance of acute flaccid paralysis in polio endgame strategy 2019-2023. *Appl Environ Microbiol*. 2020;86:e00702–e00720.