RISK FACTORS FOR THE PERSISTENCE OF WILD POLIOVIRUS TRANSMISSION IN SINALOA, MEXICO, 1984–1986[1]

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INTRODUCTION

The Pan American Health Organization has set the goal of eliminating the transmission of wild poliovirus in the Americas by 1990. Mexico's current antipolio efforts, especially a National Vaccination Day strategy adopted in 1986, are directed toward this end. The aim of this National Vaccination Day strategy is to administer one dose of trivalent polio vaccine to every child under five years of age during each of two designated National Vaccination Days each year. The strategy enjoys broad national support as well as the support of international agencies (including PAHO) and the nongovernmental service organization Rotary International.

Figure 1 shows the great impact that Mexico's nationwide vaccination programs have had on polio. These programs, begun in 1973, were intensified in 1981. Subsequently, following the first National Vaccination Days on 18 January and 15 March 1986, the reported annual incidence of paralytic polio declined from two new cases per million inhabitants in 1983–1985 to 0.8 per million in 1986.

During the first three months of 1986, 11 new cases of paralytic polio in the state of Sinaloa were reported to the General Epidemiologic Directorate of Mexico's Ministry of Health and Welfare. An investigation was then conducted that supplemented individual case studies already done in order to identify the factors responsible for this high incidence of paralytic cases and to determine the coverage being provided by polio vaccination in this northwestern state.

[1] Based on a paper presented at the Annual Conference of the Epidemiologic Intelligence Service held in Atlanta, Georgia, USA, in April 1987. This article will also be published in Spanish in the *Boletín de la Oficina Sanitaria Panamericana*, vol. 105, 1988.

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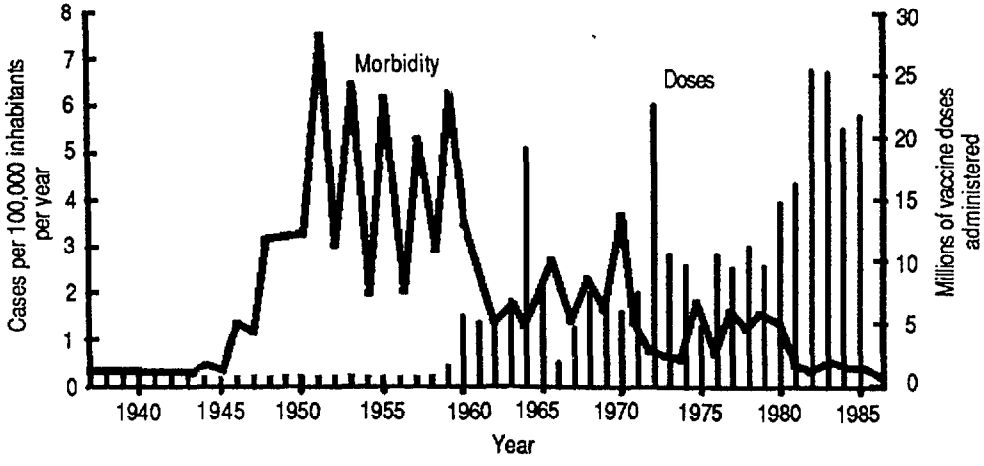
FIGURE 1. Polio vaccinations and morbidity in Mexico, 1937–1986.



Source: Secretariat of Health, General Directorate of Epidemiology and General Directorate of Preventive Medicine, Mexico

THE STUDY POPULATION AND METHODS

Initially, the eleven 1986 cases were studied individually; coverage surveys were conducted for about 30 children in dwellings near each case; and the clinical, epidemiologic, and laboratory diagnosis of each case was confirmed. Simultaneously, a thorough review was made of health facility vaccination records going back over the preceding five years, and also of available epidemiologic surveillance data on the frequency and distribution of the cases reported from 1980 to 1986—by the subjects' age, vaccination status, place of residence, and date of onset of illness.

Next came a coverage survey designed to determine oral polio vaccination coverage by interviewing the mothers and guardians of children under five in the Sinaloa municipalities of Culiacán, Elota, and Guasave, and by examining these children's national vaccination cards. The three municipalities were chosen because the numbers of polio cases reported in them over the preceding five years indicated that they were high-risk areas. More specifically, it was decided that a cluster-sampling would be conducted in two stages, with the probability of selection being proportional to the size of the population in each city, town, and village covered. For this purpose, localities were selected at random from among those listed in the 1980 census. After that, dwellings within these localities were selected by systematic random sampling. The requisite sample size was 630 children under five years old distributed in 30 groups of 21. In actuality, 734 children within these 30 groups were selected, 678 of whom were over six months old.

The frame of reference for the sample was a 1980 census list showing the numbers of inhabitants per locality.

Various data—including age, vaccination status, date of vaccination, and whether vaccine had been administered on a National Vaccination Day—were determined for each child studied, and the source of the information (the person interviewed or the child's vaccination card) was noted.

Finally, a case-control study was performed in an effort to ascertain whether vaccination history, socioeconomic status, residential sanitation, or certain attitudes and beliefs constituted poliovirus transmission risk factors in the same areas where the coverage survey had been conducted. The cases studied in this survey were drawn from local records, and controls were selected from among children of about the same age as the study subjects with polio (± 3 months for the afflicted children under three years old and ± 6 months for those three to five years old). Only 18 of 30 eligible cases were included, because many of the afflicted children had moved or could not be found. An effort was made to obtain four controls for each case, two in homes neighboring that of the afflicted child and two others selected at random from the list of children compiled in the same locality for the National Vaccination Days.

The survey of attitudes and beliefs conducted as part of this effort was based on Likertt's technique of summarized ranges, in which the survey subject is presented with a favorable or unfavorable opinion on the matter involved (as if it had been expressed by a third party) and is asked whether he or she agrees or feels the opinion is true (or in some instances feels it is more or less true), or else whether he or she disagrees or feels it is not true. The options were read out in a different order for each respondent *(1)*.

For purposes of conducting these two surveys, a team of 10 interviewers was trained in advance and supervised in the field (only half of this team was used to administer interviews in the case-control survey).

The field data obtained were recorded on precoded questionnaires, fed into a data base of the Data Base Management III computer program, and analyzed with the Statistical Package for the Social Sciences (SPSS) program. Contingency tables were constructed, and null hypotheses were tested by the chi-square and Fisher procedures. Coverage was assessed by calculating the point estimate and its 95% confidence limit. To assess the variables considered most relevant, an additional paired analysis was made of case and control histories. Some variables were stratified to test for confounding variables. In addition, data on the controls were taken from the case-control study and analyzed to ascertain the distribution of test variables vis-a-vis the controls' vaccination status. The presence of interactions was determined by loglinear models *(2)*. Vaccine efficacy was estimated with two models, one based on the percentage of attributable risk *(3)* and the other on the model proposed by Smith et al. *(4)*. The attributable risk was estimated on a raw data basis *(5)* as well as on a matched-pair basis *(6)*.

Results

Of the probable paralytic polio cases reported in the state of Sinaloa from 1982 through 1985, 93.4% afflicted children under three years old (Table 1). It is also noteworthy that of those children afflicted in 1983–1985, 80% had received fewer than three doses of polio vaccine (Table 2). In addition, the geographic distribution of both the 1981–1985 cases (Table 3) and the 61 1983–1985 cases mapped in Figure 2 shows pronounced clustering in certain central or northern municipalities, mostly in ones that were readily accessible and had over 2,500 inhabitants (see Figure 2). Overall, the rates in Table 3 show that far higher numbers of probable cases per 100,000 inhabitants were reported in the municipalities of Guasave and Culiacán than were reported in the southern municipality of Mazatlán.

This clustering is even more apparent within smaller local "microregions." For example, Figure 3 indicates that in the 1980–1986 time frame polio cases tended to recur within the same localities in the municipality of Guasave. Thus, while the municipality of Guasave contained over 700 separate "microregions," 15 (39%) of the 38 paralytic polio cases reported from the area in 1980–1986 occurred in just five of these.

Vaccination coverage could account for most of these local variations. For example, a review of vaccination records showed a decline of vaccination coverage in the municipality of Guasave from 1984 to 1985, followed by a rise of morbidity in 1986 (see Figure 3). Thus, only 1,311 doses of vaccine were administered in Guasave in 1985—down from 3,267 in 1984. Farther south, in the locality of El Dorado (municipality of Culiacán), there was a similar but milder decline—from 772 doses in 1984 to 400 in 1985.

Clinical and laboratory studies of the 11 paralytic polio cases reported in Sinaloa State in 1986 yielded results compatible with the original diagnoses. Those diagnoses were confirmed by serology, isolation of the pathogen, or both in only three of the 11 cases (the organism most frequently obtained being

TABLE 1. Probable paralytic polio cases reported in Sinaloa State, 1982–1985, by patient age.

Age of patient (years)	Cases		
	No.	%	Cumulative %
<1	34	44.7	44.7
1	23	30.3	75.0
2	14	18.4	93.4
3	0	0	93.4
4	2	2.6	96.0
≥5	3	4.0	100.0
Total	76	100	100

TABLE 2. Vaccination status of patients with probable cases of paralytic polio reported in Sinaloa State, 1983–1985.

Vaccination status (No. of doses received)	Cases		
	No.	%	Cumulative %
0	23	33.3	33.3
1	16	23.2	56.5
2	16	23.2	79.7
3	10	14.5	94.2
>3	4	5.8	100.0
Total	69[a]	100	100

[a]The vaccination status of three of the 72 reported cases is unknown.

FIGURE 2. A map of Sinaloa State showing 61 of the 72 probable cases of paralytic polio recorded for 1983–1985 (black dots). Eleven cases are not shown because local health records listed their residences as variable. The location of named population centers is indicated by the circles shown.

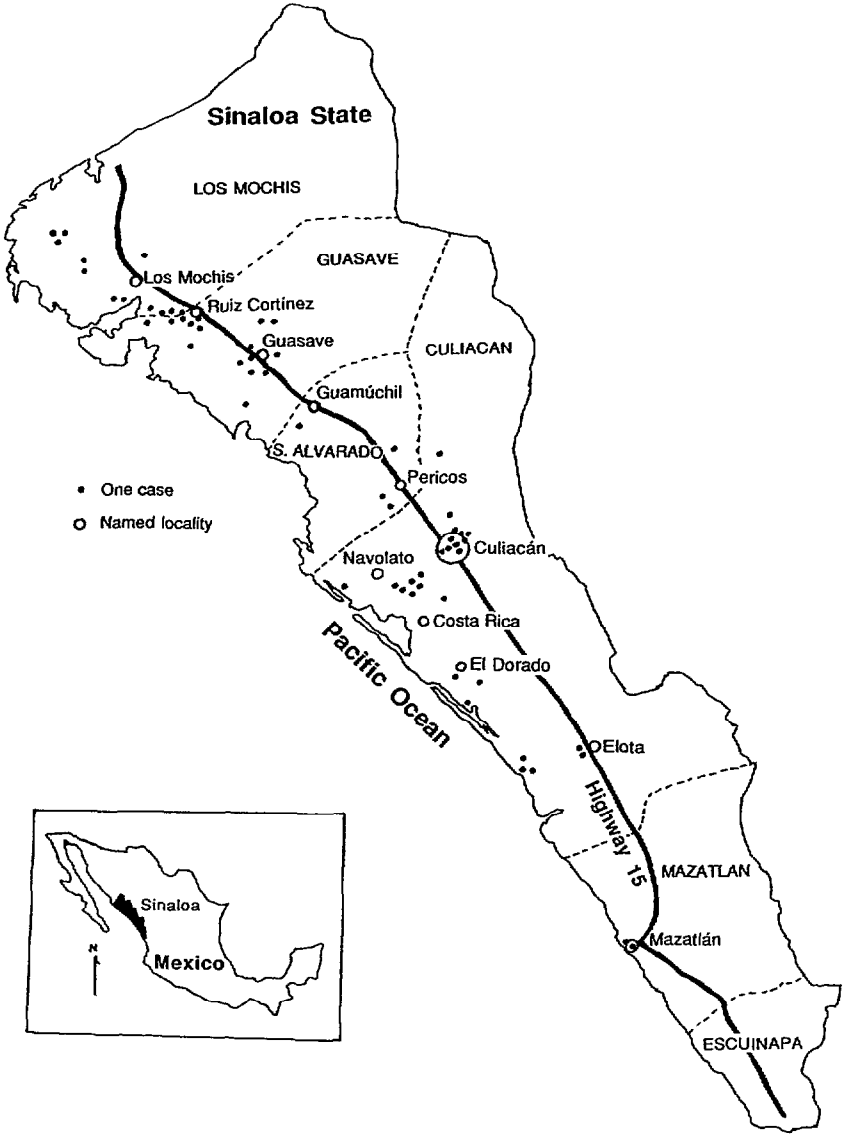


TABLE 3. Geographic distribution of probable paralytic polio cases reported in Sinaloa State by municipality, 1981-1985.

Year	Health area							
	Los Mochis	Guasave	S. Alvarado	Culiacán	Mazatlán	Escuinapa	Area unknown	Total
1981	3	1	1	4	1	0	0	10
1982	1	1	1	1	0	0	1	5
1983	6	19	1	11	2	0	6	45
1984	2	2	1	12	0	0	1	18
1985	3	3	0	4	1	0	0	11
Total	15	26	4	32	4	0	8	89
Rate[a]	3.6	7.7	2.3	4.4	1.2	0	–[b]	4.2

[a]Reported cases per 100,000 inhabitants per year.
[b]Population size unknown.

type 1 poliovirus); but in the other eight cases the clinical diagnosis was well established. Also, children under five years old residing near the victims' residences were found to have poor vaccination coverage, with as few as 10% having received three doses of vaccine. Indeed, a low level of local coverage in surrounding areas was a feature of all 11 of the study cases.

In the municipalities of Culiacán, Elota, and Guasave, 67.8% of the 734 study children under five years old were found to have received three or more doses of oral polio vaccine (Confidence Interval 0.05 = 64.9–70.7%) through the ongoing regular vaccination campaign, a percentage that rose to 91.3% ($C.I._{.05}$ = 88.4–94.2%) when vaccinations provided on the two National Vaccination Days were included. While the limited precision of estimates based on these 734 children docs not warrant inferences about smaller areas within the localities surveyed, a fairly obvious correlation was observed between low coverage in some areas during the ongoing vaccination campaign and meager results obtained in these same areas during National Vaccination Days (Figure 4). This correlation was found to have a coefficient of 0.56 and a value of $p < 0.001$. As Figure 4 indicates, the clusters of children studied were placed in three groups, as follows:

- Group 1, wherein at least 90% of the children had received three or more doses of oral polio vaccine, irrespective of supplementary vaccinations provided on National Vaccination Days;
- Group 2, wherein less than 90% of the children had received three doses through the regular program, although at least 90% had received three doses when those provided through the National Vaccination Days were included; and
- Group 3, wherein vaccination coverage was clearly inadequate, less than 90% of the children having received three doses of vaccine even when immunizations provided on National Vaccination Days were considered. Eleven of the clusters of children shown

FIGURE 3. Paralytic polio cases reported in localities within the municipality of Guasave, Sinaloa State, in 1981–1986, by reporting period.

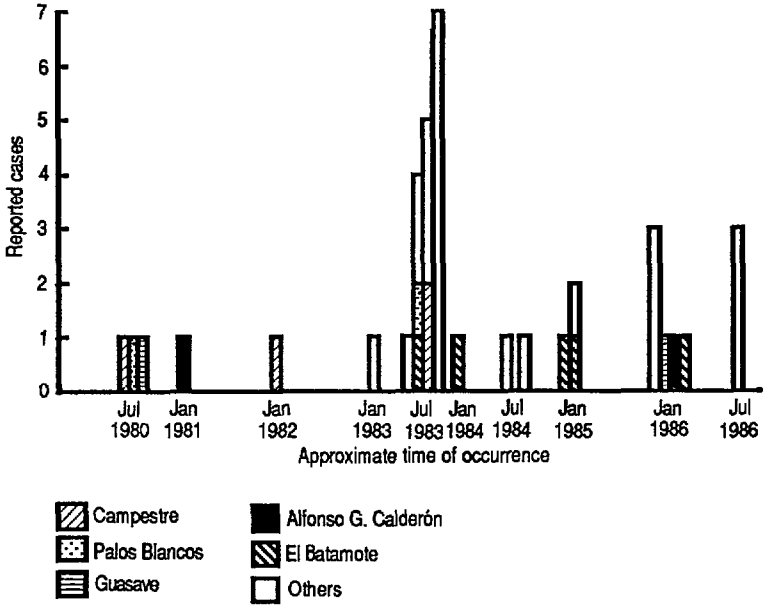
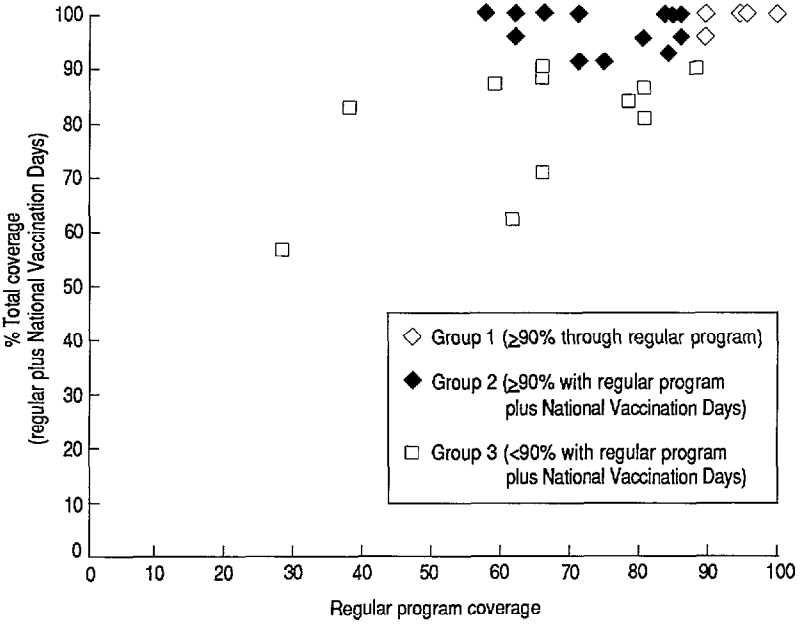


FIGURE 4. Vaccination status of the groups of children surveyed in three high-risk Sinaloa municipalities (Culiacán, Elota, and Guasave) in 1986. The horizontal axis shows coverage (% receiving ≥ 3 doses) provided by the regular program, while the vertical axis shows coverage (≥ 3 doses) provided by the regular program plus National Vaccination Days.



in Figure 4 fell within this group; it appears that the vaccination status of these Group 3 clusters was not greatly affected by the National Vaccination Days.

Another important point is that children under one year of age were found to have a significantly higher probability of being unvaccinated (odds ratio 2.8, C.I.$_{.05}$ = 1.7–4.8) than other children under five years old (Table 4).

The clinical efficacy of the oral trivalent polio vaccine used in Sinaloa over the preceding three years (1984–1986) was estimated using the aforementioned WHO model. Applying the vaccination coverage estimate of 67.8% in the municipalities of Culiacán, Elota, and Guasave, and the fact that about 30% of the eighteen 1984–1986 cases selected for study in those three jurisdictions had been completely vaccinated (≥ 3 doses), the model indicates that the vaccine's efficacy was most probably between 80% and 90% (Figure 5). Using Smith's alternative model *(4)*, vaccine efficacy was found similar to that indicated by the WHO model (Table 5, footnote a). Also, both the crude and paired analyses estimated the attributable risk at about 60% (C.I.$_{.05}$ = 31.9–81.1%), a finding that does not differ significantly from the previously cited risk and one that provides an interpretation of the direct protective effect of the vaccine.

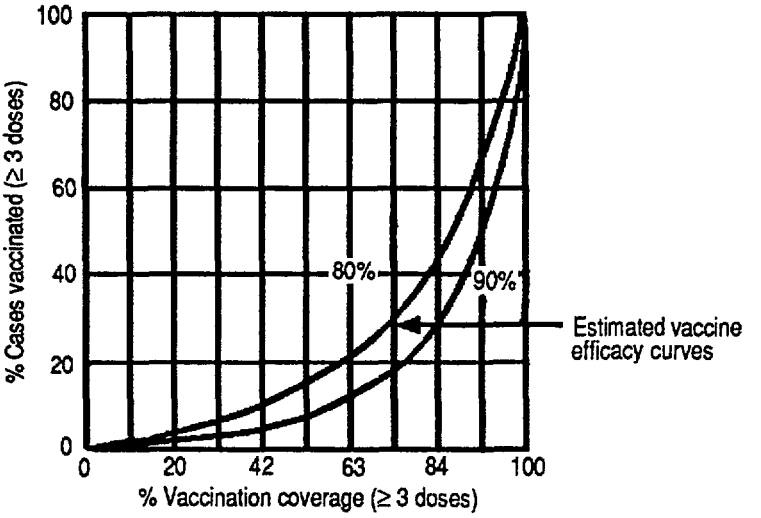
In the case-control study, the mothers or guardians of the 18 children with cases who could be located and of 63 control subjects were interviewed. Comparison of the two childhood groups' socioeconomic levels, schooling, home sanitation, and home attitudes and beliefs showed great similarity. Indeed, the only truly important difference was found in their vaccination histories. That is, in both the crude and paired analyses (Tables 5 and 6) the likelihood of not having received three or more doses of vaccine was over five times greater for the cases than for the controls (in the crude analysis the odds ratio = 0.19, C.I.$_{.05}$ = 0.05–0.67, $p < 0.01$; in the paired analysis the odds ratio = 0.18, C.I.$_{.05}$ = 0.05–0.56, $p < 0.0005$).

There was some tendency for the presence of "newcomers" (people with less than seven years' residence in the locality or children under seven who were not born there) and also for low socioeconomic status to be associated with the occurrence of polio. However, stratification showed this same occurrence of

TABLE 4. A comparison of adequate polio vaccination (receipt of ≥ 3 doses) among the 678 coverage survey children 7-11 months old and 1-4 years old. (Children under the minimum age were excluded from this analysis.) The comparison shows a significantly higher rate of adequate vaccination among the older children (odds ratio = 2.8, C.I.$_{.05}$ = 1.7-4.8, $p < 0.0001$).

Vaccinated with ≥3 doses	Age (months)		Total
	7–11	12–59	
No	39	179	218
Yes	33	427	460
Total	72	606	678

FIGURE 5. Estimated efficacy of the Sabin vaccine administered in the Sinaloa municipalities of Culiacán, Elota, and Guasave, based on coverage (≥ 3 doses) and the proportion of polio cases vaccinated with ≥ 3 doses in 1984–1986.



Source: Adapted from the World Health Organization *Weekly Epidemiological Record (4).*

TABLE 5. Crude comparison of study cases and controls grouped according to whether they had received three or more doses of polio vaccine. Sinaloa, Mexico, 1984–1986.[a,b]

Vaccination status (≥ 3 doses)	Cases	Controls	Total
Vaccination completed	5	42	47
Unvaccinated or vaccination incomplete	13	21	34
Total	18	63	81

[a]Vaccine efficacy indicated by Smith's alternative method *(4)* = $\frac{13/21 - 5/42}{13/21}$ = 80.8%.

[b]Odds ratio = 0.19 (C.I.$_{05}$ = 0.05–0.67; $p < 0.01$).

TABLE 6. Paired comparison of polio exposure based on vaccination status of the 18 study cases and the 63 control subjects. Sinaloa, Mexico, 1984–1986.[a]

Case status	Control status: Exposed (< 3 vaccine doses)	Control status: Not exposed (≥ 3 vaccine doses)	Total
Exposed (< 3 vaccine doses)	16	27	43
Not exposed (≥ 3 vaccine doses)	5	15	19
Total	21	42	63

[a]Odds ratio = 0.18 (C.I.$_{05}$ = 0.05–0.56; $p < 0.0005$).

polio to be due to insufficient vaccination. Analysis with the hierarchical log-linear model did not warrant a conclusion as to the presence or absence of interaction between socioeconomic status and the occurrence of polio in the communities involved.

Once it had been established that the vaccine being administered had reasonable clinical efficacy and that the factor generating the greatest risk of developing poliomyelitis under current conditions in Sinaloa was incomplete vaccination or nonvaccination, the factors influencing immunization were examined. To arrive at an unbiased assessment, the 18 study cases were excluded from the analysis, and the variables tested were crossed with the controls' vaccination status in the ongoing (regular) campaign. (All those who had received less than three doses of vaccine were considered unvaccinated.)

Unvaccinated status was found to be associated with the following indicators of low socioeconomic status, among others: incomplete primary schooling (33% of the vaccinated subjects versus 68% of the unvaccinated subjects), lack of a home refrigerator (33% and 65%, respectively), only one bedroom (34% and 75%), no indoor piped water supply (37% and 75%), and overcrowding (4.1 versus 6.0 people per bedroom). As Table 7 shows, certain parental attitudes and beliefs indicative of little health education were also correlated with unvaccinated status. In addition, there was a remarkably close correlation ($p < 0.07$) between unvaccinated status before a case occurred within a neighboring family and unvaccinated status at the time of the interview, indicating that the nearby occurrence of cases had not prompted changes in the control subjects' vaccination status.

TABLE 7. A comparison of risk factors potentially influencing vaccination status in vaccinated versus unvaccinated control subjects. (Vaccinated subjects had received at least three doses of vaccine; all others were placed in the unvaccinated category.)

Risk factor	No. + or − for indicated risk factor among control subjects who were:				Odds ratio (C.I.$_{.05}$)	Value of p
	Unvaccinated		Vaccinated			
	+	−	+	−		
Parental education ≤ 6th grade	13	6	13	26	4.3 (1.2 − 16.7)	<0.05
No home refrigerator	13	7	13	27	3.9 (1.1 − 14.1)	<0.05
One-bedroom home	15	5	14	27	5.8 (1.5 − 23.2)	<0.01
Home lacking piped water	15	5	15	26	5.2 (1.3 − 20.7)	<0.01
Interview subject believed vaccinations harmful	4	15	0	39	Not calculable	<0.01
Interview subject believed that disease is God's punishment	6	13	1	38	17.5 (1.7 − 134.7)	<0.01
Subject had never received vaccine during any of the National Vaccination Days	4	16	1	38	9.5 (0.9 − 112.9)	<0.07

DISCUSSION

The most important factor responsible for persistence of polio in the study areas is lack of vaccination (low coverage) rather than any vaccine shortcoming (such as low potency attributable to defects in the cold chain). Indeed, the present data suggest that such lack of vaccination could account for the persistent polio problem in certain areas (referred to by Mexican epidemiologists since the 1960s as "poliomyelitogenic") where the disease has been hyperendemic.

It is striking that even with relatively "good" vaccination coverages, such as around 70% through the regular campaign, the virus is able to circulate within the coverage gaps and cause outbreaks such as that of 1986 in Guasave. However, it may be inferred from the occurrence of cases in only certain specific localities that the coverages in those localities are quite low or almost nil.

Certain factors connected with the availability of services and community perception of vaccination programs appear to account for the fact that the proportions of unvaccinated children among the very poorest socioeconomic sectors are relatively high. In these sectors the vaccination program may be said to have achieved little penetration. This, in turn, could partly account for the correlation between areas receiving low coverage through the regular vaccination program and areas receiving low coverage through the National Vaccination Days.

Infancy (being less than one year old) is another factor associated with nonvaccination (< 3 doses received). Belief that the vaccine should not be administered during episodes of acute

respiratory and diarrheal infections—episodes very frequent among infants—could partly account for this low infant coverage. In any case, the fact that the probability of being properly vaccinated (receiving three or more doses) rises as a child grows older could help to explain the greater concentration of cases among children under three years of age as well as the undeniable fact that many children in the areas involved acquire immunity very young at the high price of natural infection.

The method proposed by WHO—using attributable risk to evaluate vaccine efficacy from coverage data and the proportion of cases occurring among vaccinated subjects—yields an estimate similar to the one obtained with the method proposed by Smith et al. *(4)* for evaluating the protective efficacy of vaccines against common diseases in analytical epidemiologic studies. Though it has been said that such evaluation is hampered by the frequency of asymptomatic cases, the results of the present study support the use of the WHO model for field evaluation of polio vaccine under the conditions prevailing in national programs seeking to eliminate the disease by 1990. It should be noted, in addition, that a number of vaccine potency studies done between 1983 and 1986 by Mexico's General Epidemiologic Directorate indicate that the cold chain has adequately conserved the potency of biologicals *(7)*.

The study of risk factors failed to find any direct association between the subjects' socioeconomic and health status on the one hand and the occurrence of polio on the other. However, the data do point to at least an indirect association that varies with the probability of being vaccinated. Also, it is clear that the ability of this study to detect such an association is rather low, the potential being only about 30% for a relative risk of 2.[7] In addition, it should be noted that we would be barely 90% sure of finding a relative risk of 8 or more with a sample such as the one examined in this study. It is likewise apparent that the relative risk (odds ratio) and attributable risk data yield estimates with large confidence intervals resulting from the small size of the study samples—a size consonant with polio's wane in recent years and with the relative scarcity of paralytic cases.

Conclusions

We conclude from these data that the persistence of wild poliovirus transmission in the state of Sinaloa has resulted from the vaccination program's failure to provide complete coverage.

Although the new National Vaccination Day strategy paves the way for a major increase in coverage associated with broader community support, difficulties encountered by the ongoing program have also been encountered by the new strategy. While these difficulties need to be more clearly defined, they appear linked to indicators of low socioeconomic status and poor health education.

All in all, it appears advisable to stratify the country for risk factors on the basis of surveillance and sociodemographic data so that priority can be assigned to high-risk areas, vaccination

[7] The relative risk being defined as the ratio of the attack rate among those at risk to the attack rate among those not at risk.

coverages can be extended, and the goal of eradication can be attained. It may also be necessary to evaluate the vaccine's efficacy for every new polio case that occurs and to increase the sensitivity of our epidemiologic surveillance system.

Acknowledgments

We wish to thank Ms. Noemí Ales Gatti of the Universidad de Occidente for her collaboration in devising an attitude measurement instrument and Drs. José Luis Bobadilla of the Public Health Research Center of Mexico and Silvia Hartman of the PAHO Country Office in Mexico City for their valuable comments on the manuscript.

Summary

A case-control study was conducted to determine preventable risk factors for development of poliomyelitis in Sinaloa, a northwestern state of Mexico that has consistently had a high incidence of reported cases. All reported 1984–1986 cases in selected high-risk areas of this state were matched by age with neighborhood controls. The cases were found significantly less likely than the controls to have received three or more doses of oral poliovirus vaccine.

The efficacy of the vaccine received was estimated at 80–90% based on vaccination histories of the cases and on data obtained from a vaccine coverage survey conducted in the same area. An analysis of control children showed that unvaccinated status (receipt of < 3 doses) was strongly associated with low income ($p < 0.001$), low educational level ($p < 0.05$), poor housing ($p < 0.05$), and parental attitudes that might lead to refusal of vaccination. Another important finding was that communities with low coverage rates in the routine vaccination program tended to have low coverage rates in intensive campaigns. Overall, this study supports the view that continuing transmission of polio in Mexico is not due to failings of the vaccine provided but rather to gaps in coverage. Accordingly, it appears advisable to stratify the country for risk factors on the basis of surveillance and sociodemographic data so that priority can be assigned to high-risk areas, vaccination coverages can be extended, and the goal of eradication can be attained.

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