

Public-health impact of accelerated measles control in the WHO African Region 2000–03

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Summary

Background In 2000, the WHO African Region adopted a plan to accelerate efforts to lower measles mortality with the goal of decreasing the number of measles deaths to near zero. By June, 2003, 19 African countries had completed measles supplemental immunisation activities (SIA) in children aged 9 months to 14 years as part of a comprehensive measles-control strategy. We assessed the public-health impact of these control measures by use of available surveillance data.

Methods We calculated percentage decline in reported measles cases during 1–2 years after SIA, compared with 6 years before SIA. On the basis of data from 13 of the 19 countries, we assumed that the percentage decline in measles deaths equalled that in measles cases. We also examined data on routine and SIA measles vaccine coverage, measles case-based surveillance, and suspected measles outbreaks.

Findings Between 2000 and June, 2003, 82·1 million children were targeted for vaccination during initial SIA in 12 countries and follow-up SIA in seven countries. The average decline in the number of reported measles cases was 91%. In 17 of the 19 countries, measles case-based surveillance confirmed that transmission of measles virus, and therefore measles deaths, had been reduced to low or very low rates. The total estimated number of deaths averted in the year 2003 was 90 043. Between 2000 and 2003 in the African Region as a whole, we estimated that the percentage decline in annual measles deaths was around 20% (90 043 of 454 000).

Interpretation The burden of measles in sub-Saharan Africa can be reduced to very low levels by means of appropriate strategies, resources, and personnel.

Introduction

Measles is an important cause of child mortality in sub-Saharan Africa. Estimates of the annual number of measles deaths in the WHO African Region (which now includes all countries south of the Sahara except Somalia and Djibouti; Algeria is included, but Sudan is not) made by different methods have been in the same range: 445 000 in 1998,¹ 482 000 in 1999,² and 452 000 in 2000.³ The WHO reported that in 2000 sub-Saharan Africa had 58% of worldwide measles deaths.³

In 1996, seven countries in southern Africa (Botswana, Lesotho, Malawi, Namibia, South Africa, Swaziland, and Zimbabwe) began a measles-elimination initiative based on the successful strategy used in the Americas.^{4,5} In 1998, the WHO African Region Office drafted a plan of action to decrease the number of measles deaths to near zero in response to the measles mortality burden in the rest of the African countries. This plan emphasised four components: improved routine immunisation, a second opportunity for measles vaccination during supplemental immunisation activities (SIA), measles case management, and measles surveillance. Owing to shortage of funding and potential adverse effects on the polio-eradication programme, supplemental immunisations in a limited age-group (children aged 9 months to 4 years) were given in seven countries for 3 years from December, 1998, to 2001.¹ Because surveillance data indicated that targeting of this age-group did not have the desired effect on the burden of disease from

measles,¹ in December, 2001, SIA began to target children aged 9 months to 14 years in eastern and western African countries. In 2001, a joint WHO and UNICEF global plan for measles mortality was formulated,⁶ with one of the four strategies being provision of a second opportunity for measles immunisation for all children through SIA or routine immunisation systems. The target for the overall measles-mortality reduction plan was a 50% decrease in the number of measles deaths by 2005 compared with 1999.

A new partnership supporting measles-mortality reduction in Africa, the Measles Initiative, started in 2001. Initial partners were the American Red Cross, the WHO, the US Centers for Disease Control and Prevention, the United Nations Foundation, and UNICEF. Subsequently, the Canadian International Development Agency, the Bill and Melinda Gates Foundation, the Church of Latterday Saints, and the Global Alliance for Vaccines and Children (GAVI) have joined the partnership. Partnership funds permitted the financing of SIA in the extended age-group. With funding primarily from the Measles Initiative, 12 African countries undertook SIA in children aged 9 months to 14 years from December, 2001, to June, 2003. In addition, seven southern African countries carried out their first round of follow-up SIA in children aged 9 months to 4 years from 2000 to 2003 mainly using national funds.

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Starting in 1999, routine immunisation services began to improve in several African countries, owing to better resources, more staff, and attention to immunisation because of the polio-eradication and measles programmes, and a focus on improving routine immunisation by the new GAVI.

We report on the estimated effect of these accelerated control activities on the numbers of measles cases and deaths, and thus monitor progress towards the goal of lowering measles mortality. We used three sources of epidemiological data to assess the effect of accelerated control efforts on the burden of measles: aggregate routine surveillance data, case-based surveillance data, and information from outbreak investigations.

Methods

Aggregate routine surveillance data

All African countries include notification of measles cases in their routine surveillance or health-information systems. The national aggregate number of cases is reported each year to WHO, which maintains a global database with this information, with data starting in 1980.⁷

For 19 African countries that undertook measles SIA between 2000 and June, 2003 (table 1), we compared the average annual number of reported measles cases in the 6 years before the start of SIA with the average annual number of reported measles cases after the SIA. For the

12 countries that undertook SIA from December, 2001, to June, 2003 (Benin, Burkina Faso, Burundi, Cameroon, Ghana, Kenya, Mali, Rwanda, Senegal, Tanzania, Togo, Zambia), we used 1996–2001 as the pre-SIA years. Data were missing for 4 (2%) of 175 country-years. We imputed the number of cases for the missing years by using the average of the previous 6 years. In seven of the 12 countries (Benin, Burundi, Cameroon, Ghana, Kenya, Senegal, Tanzania), we used 2003 as the post-SIA comparison year. For Burkina Faso, Togo, and Mali (the only countries with 2 complete years after nationwide catch-up SIA), we averaged nationwide data for 2002 and 2003. For Rwanda (SIA in February, 2003), we used data from March, 2003, to February, 2004, and for Zambia (SIA in June, 2003), we used data from July, 2003, to June, 2004. For the seven southern African countries (table 1), we used 1990–95 as the pre-SIA comparison period and all available data for the years after the initial SIA until 2003 (ie, 6 years of data for Namibia and South Africa; 5 years for Malawi, Botswana, and Zimbabwe; 4 years for Swaziland; and 3 years for Lesotho) as the post-SIA comparison period.

To estimate the number of measles deaths averted in 2003 in each of the 19 countries, we assumed that SIA resulted in the same percentage reduction in measles deaths as was observed for measles cases. This assumption was based on the following experience in 13 of the 19 countries. After the initial SIA in the seven

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Country	Dates of SIA	Children 9 months to 14 years covered (%)	Target number of children (millions)	SIA coverage (%) [*]	Routine immunisation coverage, 2000
Countries with initial SIA in children aged 9 months to 14 years					
Benin	December, 2001	35	0.9	98 (A)	85
	December, 2002	65	2.0	105 (A)	..
Burkina Faso	December, 2001	Nationwide	5.2	97 (S)	59
Burundi	June, 2002	Nationwide	3.2	90 (A)	57
Cameroon	December, 2001	34	2.8	93 (A)	49
	December, 2002	66	5.1	90 (A)	..
Ghana	December, 2001	9	0.8	98 (S)	84
	December, 2002	91	7.7	102 (A)	..
Kenya	June, 2002	Nationwide	13.6	94 (S)	46
Mali	December, 2001	Nationwide	5.1	99 (S)	57
Rwanda†	February, 2003	Nationwide	3.1	96 (S)	57
Senegal	January, 2003	Nationwide	5.0	98 (A)	48
Tanzania	September, 2001	33	3.7	104 (A)	78
	September, 2002‡	67	7.0	97 (A)	..
Togo	December, 2001	Nationwide	2.4	95 (S)	43
Zambia	October, 2002	11	0.7	110 (A)	70
	June, 2003	89	5.0	108 (A)	..
Southern African countries undertaking follow-up campaigns in children aged 9 months to 4 years					
Botswana	May–June, 2001	Nationwide	0.3	85 (A)	79
Lesotho	April–July, 2003	Nationwide	0.2	87 (A)	63
Malawi	August, 2002	Nationwide	1.5	95 (A)	81
Namibia	June, 2000	Nationwide	0.3	89 (A)	69
	June, 2003	Nationwide	0.3	89 (A)	..
South Africa	May–June, 2000	Nationwide	4.5	91 (A)	95
Swaziland	June, 2002	Nationwide	0.2	86 (A)	80
Zimbabwe	July, 2002	Nationwide	1.8	85 (A)	70

^{*}S=survey, A=adminstrative; administrative coverage is the reported number of children immunised divided by the estimated number targeted. †SIA done in children aged 9 months to 14 years in 16 districts and aged 6–14 years in 23 districts. ‡SIA done in children aged 7–14 years.

Table 1: Dates, target population, and measles vaccination coverage of SIA, 2000 to June, 2003

southern African countries, the number of reported measles cases declined by 99.8% and the number of reported measles deaths by 100%.⁵ After similar SIA in Mali, Burkina Faso, and Togo, the number of reported measles cases declined by 91.0% and the number of reported deaths by 84.0%.⁸ After SIA in Benin and Cameroon, the number of reported measles cases declined by 97.0% and the number of measles deaths by 96.0% (unpublished data, WHO African Regional Office). In Zambia, the number of reported cases declined by 87% and the number of deaths by 99%.⁹

Because there are few vital-event systems registering a high proportion of deaths in Africa, we used previously published estimates of the number of measles deaths before the SIA (1998 baseline year).¹ We chose 1998 as the baseline year because it was the last year before measles SIA began in non-southern African countries.

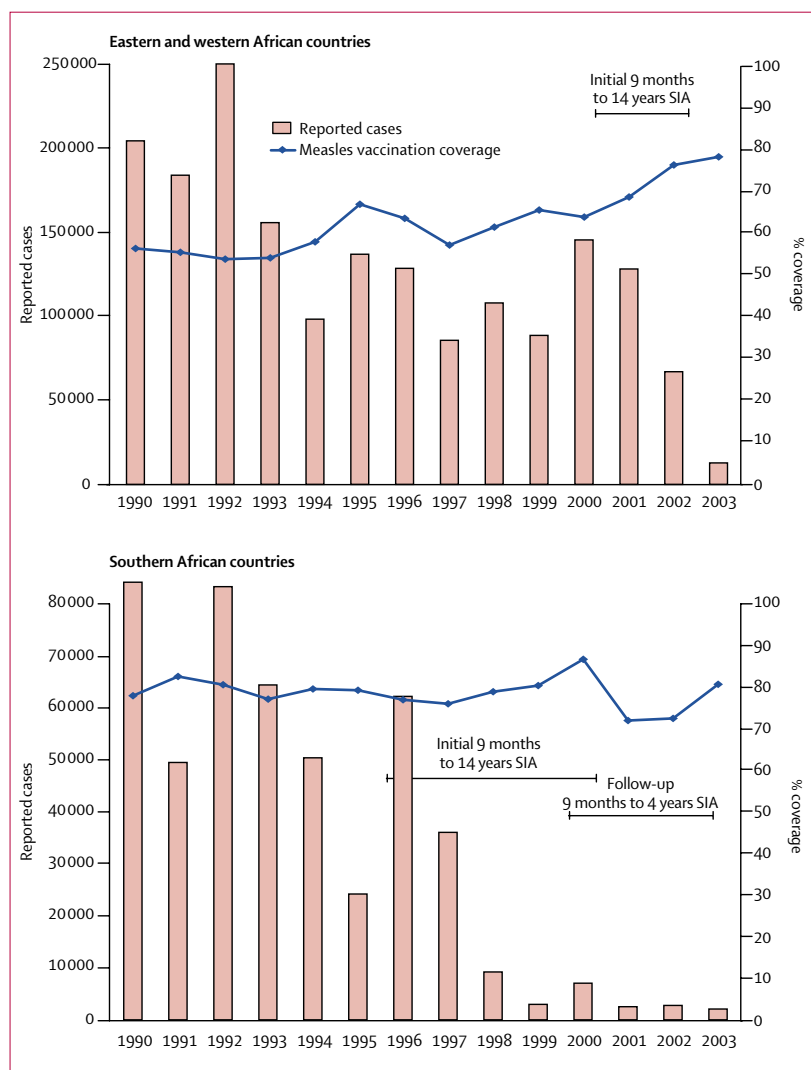


Figure: Numbers of reported measles cases and weighted average of routine measles vaccination coverage by year for two groups of countries

Note that the vertical scales for reported cases differ between the two plots.

These estimates were based on: the estimated number of surviving infants in 1998 in each country; a vaccine efficacy of 85%; the 1998 national routine measles coverage percentage as reported to WHO; the assumption that all susceptible children would be infected with measles; and an estimated measles case-fatality rate of 6.0% in west and central Africa, 2.0–3.0% in east African countries, and 0.5–3.0% in southern African countries.¹

Case-based surveillance

After completing nationwide measles SIA, all countries started case-based reporting of suspected measles cases with laboratory confirmation. A case of suspected measles was defined as an illness characterised by rash, fever, and cough, coryza, or conjunctivitis, or any illness that a clinician suspected to be measles. Surveillance was classified as case-based if individual data, such as date of onset of rash, district of residence, age, and vaccination status, were collected on a case form or line list and sent to the national level. The serum sample was sent to the national measles laboratory to be tested for measles IgM antibody by Enzygnost (Dade-Behring, Marburg, Germany) diagnostic kits. The national measles laboratories are part of a WHO measles laboratory network that requires successful completion of a proficiency panel of serum samples each year. Measles case-based data are reported electronically to the WHO African Regional Office monthly. This office monitors surveillance reporting and publishes measles surveillance results and quality indicators in both bloc bulletins¹⁰ and regional feedback bulletins.^{11–13} After the SIA, most countries continued aggregate measles reporting in parallel with measles case-based reporting.

We used data from case-based surveillance to assign each country to one of three categories of measles transmission: very low; low intermittent; or moderate continuing. These categories were based on the proportion of suspected cases of measles with laboratory samples that were positive for measles IgM: less than 10% was classified as very low; 10–49% as low; and 50% or greater as moderate. This epidemiological profiling was based on nearly a decade of experience with surveillance after SIA in more than 40 countries in the Americas^{4,14} and Africa.⁵

Measles outbreaks after SIA

After completing nationwide SIA, countries began to carry out measles outbreak investigations on a nationwide basis. The WHO African Regional Office has distributed guidelines to all African countries detailing recommended procedures for investigation of measles outbreaks, including village-level searches for additional suspected cases, laboratory confirmation, reporting, and analyses. In the African Region, a measles outbreak is defined as at least three laboratory-confirmed or five suspected measles cases in a district in any month that

occurred more than 60 days after the SIA. All suspected and laboratory-confirmed cases are routinely mapped by district and examined for place and time clustering. Where outbreaks were detected, we examined the case-based information and attempted to define the extent and cause of each outbreak.

Routine measles-vaccination coverage

For the years 1990 to 2003, a weighted average of coverage with one dose of measles vaccine was calculated for the two groups of countries (southern Africa and eastern and western Africa) by use of the annual measles-vaccination coverage information that is officially reported to WHO.⁷ The weighted average was calculated from the 1995 population estimate for each country from the United Nations Population Division.¹⁵

Role of the funding source

No funding source had any role in the study design; collection, analysis, or interpretation of data; or the writing of the report. The corresponding author had full access to all the data in the study and had final responsibility for the decision to submit the paper for publication.

Results

Between January, 2000, and June, 2003, 19 African countries carried out SIA and had at least 12 months

of post-SIA measles-surveillance data (table 1). 12 countries in western and eastern African undertook SIA in children aged 9 months to 14 years (total children targeted 73·0 million), and seven southern African countries carried out follow-up SIA in children aged 9 months to 4 year (total children targeted 9·1 million). Five countries completed the SIA nationwide over 2 years (Benin, Cameroon, Ghana, Zambia, and Tanzania). Thus, the total number of children targeted in these SIA was 82·1 million. The reported measles vaccination coverage was 85% or higher for all SIA. The average SIA measles vaccination coverage for the six countries that did surveys was 97% (table 1).

In the 12 western and eastern African countries, the number of reported measles cases declined from 85 000–250 000 during 1990–2001 to 12 073 in 2003 (figure). In the seven southern African countries, the number of reported measles cases fell from 24 000–140 000 during 1990–97 to 2081–7057 per year from 1999 to 2003 (figure). The average proportional decrease in reported measles cases was 89% for the 12 eastern and western African countries and 91% for all 19 countries (table 2). Three countries had an average decline of less than 70%. The low percentage decreases for Burkina Faso (67%) and Namibia (65%) were probably due to measles outbreaks. The low percentage decrease for Botswana (64%) was probably due to misreporting of rubella cases as measles cases in 2000; of

Country	Estimated nationwide number of deaths before SIA*	Average number of reported cases per year before SIA†	Number of reported cases per year after SIA‡	Percentage decrease in number of cases§	Number of deaths averted per year¶
Countries with initial SIA in children aged 9 months to 14 years, December, 2001, to June, 2003					
Benin	2990	4051	217	95	2830
Burkina Faso‡	15626	7147	2345	67	10499
Burundi	4472	8022	224	97	4347
Cameroon	9398	13260	899	93	8761
Ghana	12899	24583	1939	92	11882
Kenya	9669	9529	65	99	9603
Mali‡	11014	5568	475	91	10075
Rwanda	2448	2425	52	98	2396
Senegal	6855	9275	1638	82	5644
Tanzania	13955	10078	1673	83	11638
Togo‡	5475	2082	329	84	4610
Zambia	3781	17609	2963	83	3145
Subtotal	98582	113629	12819	89	85430
Southern African countries with follow-up campaigns in children aged 9 months to 4 years, 2000–03					
Botswana	62	1767	636	64	40
Lesotho	126	1246	73	94	119
Malawi	2686	9581	173	98	2637
Namibia	96	2515	879	65	62
South Africa	1034	11118	112	99	1024
Swaziland	55	2151	112	95	52
Zimbabwe	704	22592	817	96	679
Subtotal	4763	50967	2800	95	4613
Grand total	103345	164596	15619	91	90043

*Based on data from 1998. †Average for 1996–2001 in the 12 eastern and western African countries, and for 1990–95 in the southern African countries. ‡2003; Mali, Togo, and Burkina Faso had 2 years of post-SIA data (2002, 2003), which were averaged. §Average number before SIA minus number after SIA, divided by pre-SIA average, ×100. ¶Pre-SIA deaths multiplied by percentage decrease in cases. ||Rwanda post-SIA data were from March, 2003, to February, 2004; Zambia data were from July, 2003, to June, 2004.

Table 2: Estimated annual measles deaths averted by SIA completed between 2000 and June, 2003

210 blood samples tested during that year, 170 (81%) were positive for rubella IgM and none for measles IgM.¹⁶

The total estimated number of annual deaths averted in 2003 was 90 043: 85 430 for the 12 eastern and western African countries and 4613 for the southern African countries. The pre-SIA baseline estimate of the annual number of measles deaths for all countries in the African Region in 1998 was 454 000. Therefore, for the African Region as a whole, the estimated proportional decrease in annual measles deaths was 20% (90 043 divided by 454 000) resulting from control activities in these 19 countries from 2000 to June, 2003.

In 2002–03, the proportion of suspected measles cases that were confirmed to be positive for measles IgM ranged from 2% in Zambia to 74% in Burkina Faso (table 3). Among the 11 western and eastern African countries other than Burkina Faso, 10% (588 of 5929) of samples tested were positive for measles IgM antibody. Among the 12 western and eastern African countries, six countries had very low measles transmission (less than 10% of the laboratory samples positive for measles IgM), five had low measles transmission profiles, and one country (Burkina Faso) had moderate transmission. Among the seven southern African countries, five had very low transmission, one had low transmission, and one (Namibia) had moderate transmission (table 3). In southern Africa, 643 (10%) of 6619 samples tested were positive for measles IgM.

In 2002–03, 16 measles outbreaks occurred 60 days or longer after an SIA (table 4). In 11 outbreaks there were more than ten cases. Five of the 11 outbreaks were in areas bordering countries that had not undertaken SIA (southern Mali bordering Guinea, Cameroon bordering Nigeria [three outbreaks], and Mpumalanga Province, South Africa, bordering Mozambique). One outbreak occurred mainly among individuals aged 15 years and older among nomads in northern Mali. Two outbreaks occurred in island populations that had very low coverage during the catch-up campaign (Pemba island, Tanzania, and Bonassama district, Cameroon).

In Burkina Faso, the number of reported cases was only partly reduced after SIA (1744 in 2002 and 2946 in 2003). Burkina Faso was the only country of 19 countries that had measles transmission during the entire period after the initial SIA as shown by case-based and aggregate surveillance data. An outbreak investigation showed that the continuing transmission was related to a large number of unvaccinated children returning from Côte d'Ivoire during a time of political turmoil.¹⁷

In Namibia, after 4 years of no measles circulation, an outbreak (1218 cases and 13 reported measles deaths) continued for 18 months during 2002–03. In Zimbabwe, an outbreak with 80 cases and 20 reported deaths occurred 4 years after the initial SIA and after the first follow-up SIA. The Zimbabwe outbreak was restricted and occurred near the border with Mozambique, which

Country	Year	Number of reported measles cases*	Number of cases with laboratory samples taken and results available	Positive for measles IgM	Epidemiological profile of measles transmission
Countries with initial SIA in children aged 9 months to 14 years, December, 2001, to June, 2003					
Benin	2002	76	70 (92%)	22 (31%)	Low
	2003	215	211 (98%)	58 (27%)	Low
Burkina Faso	2002	1337	1029 (77%)	709 (69%)	Moderate
	2003	6315	2682 (42%)	1997 (74%)	Moderate
Burundi	2003	89	79 (89%)	3 (4%)	Very low
Cameroon	2002	33	33 (100%)	5 (15%)	Low
	2003	878	878 (100%)	215 (24%)	Low
Ghana†	2002	147	85 (58%)	6 (7%)	Very low
	2003	1487	1148 (77%)	46 (4%)	Very low
Kenya	2003	1791	1736 (97%)	59 (3%)	Very low
Mali	2002	533	63 (12%)	22 (35%)	Low
	2003	226	130 (58%)	61 (47%)	Low
Rwanda	2003	48	47 (98%)	7 (15%)	Low
Senegal	2003	348	109 (31%)	23 (21%)	Low
Tanzania	2003	665	240 (36%)	17 (7%)	Very low
Togo	2002	333	250 (75%)	23 (9%)	Very low
	2003	275	250 (91%)	11 (4%)	Very low
Zambia	2003	2315	600 (26%)	10 (2%)	Very low
Seven southern African elimination countries					
Five countries‡	2002	1159	1015 (88%)	30 (3%)	Very low
	2003	4780	4535 (95%)	233 (5%)	Very low
Zimbabwe	2003	489	489 (100%)	59 (12%)	Low
Namibia	2002	646	422 (65%)	300 (71%)	Moderate
	2003	163	158 (97%)	21 (13%)	Low

*Cases reported within 60 days of the end of the SIA are excluded. †Central province of Ghana only. ‡Botswana, Lesotho, Malawi, South Africa, and Swaziland.

Table 3: Results of case-based measles surveillance with laboratory confirmation in areas after SIA, 2002–03

Country	Location	Year	Number of cases	Duration of outbreak, months	Comment
Benin	Tchaourou district	2002	10	2	
	D'Dali district	2002	5	2	
Burkina Faso	Many districts	2002 and 2003	1744 and 6315	>24	Widespread transmission after SIA, many cases just returning from Côte d'Ivoire
Cameroon	Bonassama district	2002	38	2	Low SIA coverage, island
	Mogode district	2002	5	2	Cases mainly from Nigeria
	Garoua rural district	2002	10	2	Cases mainly from Nigeria
	Toubo district	2002	6	2	Cases mainly from Nigeria
Mali	Tombouctou	2002	39	1	Mostly nomads, >15 years old
	Southern	2002	36	1	
	Sikasso district	2003	35	3	
	Goa district	2003	38	2	
Namibia	Most of country	2002–03	1218	18	Long-lasting transmission (>12 months)
South Africa	Gauteng province,	2003	102	4	Limited outbreak, 1 death in child with HIV and tuberculosis
	Region A, B Nkomazi subdistrict, Mpumalanga Province	2003	35	5	Thought to be imported from Mozambique
Tanzania	Pemba island	2003	131	1	Very low SIA coverage (68%)
Zimbabwe	Manicaland Province	2003	80	3	20 deaths, religious refusers, near Mozambique border

Table 4: Measles outbreaks detected at least 60 days after SIA in children aged 9 months to 14 years, 2001 to June, 2003

is the only country in southern Africa that has not undertaken measles SIA.

In 2000, nine of the 12 countries that undertook initial SIA in 2001–03 reported routine measles vaccination coverage of less than 80% (table 1). In 2003, reported measles vaccination coverage had increased by 10% or more in all of these nine countries. In the 12 eastern and western African countries, the weighted average of routine measles vaccination coverage increased from 64% in 2000 to 78% in 2003 (figure). In the seven southern African countries, the weighted average of routine measles vaccination coverage was stable at 78–83% before the SIA (1990–95) then increased to 87% in 2000 during the period of initial SIA. In 2001 and 2002, routine coverage decreased to 72% and 73%, respectively, largely owing to lower reported coverage in Namibia, Swaziland, and Zimbabwe. In 2003, reported coverage was 81%.

Discussion

In 19 of 46 countries in the African Region, analyses of three types of surveillance data indicate a substantial reduction in the number of measles cases after SIA. On the basis of aggregate surveillance data from these 19 countries, there was a 91% reduction in the number of reported measles cases after SIA targeting of a wide age range. Furthermore, the low proportion of suspected measles cases confirmed as true cases and the infrequent occurrence of outbreaks are consistent with a striking reduction in measles transmission immediately after the SIA. Extrapolating these findings to the effect on measles deaths, we estimated a 20% reduction in the annual number of measles deaths in the African Region as a whole in 2003. This estimated decline represents

substantial progress towards the Regional goal of near-zero measles deaths and the worldwide goal of 50% reduction in measles deaths by 2005.

To allow assessment of progress toward these mortality reduction goals, we made a crucial assumption that the proportional reduction in measles deaths was equal to the proportional reduction in measles cases. We believe that this assumption was realistic for the following reasons. First, after initial SIA in 13 of the 19 countries, the decline in reported measles deaths closely matched the decline in reported measles cases. Second, case-based surveillance after the SIA confirmed that measles transmission was low or very low in 17 of the 19 countries and outbreaks that did occur were small (five to 130 cases). At high SIA coverage and with such low rates of transmission, to conceive of a plausible scenario in which the death reduction would not approximate the case reduction is difficult. Third, the proportional decline in routinely reported measles cases could underestimate the true reduction in mortality after SIA, because only 10% of reported measles cases were confirmed as measles after SIA.

We used available surveillance data to measure the effect of the programme. Common criticisms of surveillance data include under-reporting and variable quality in some areas. Nevertheless, we found striking decreases in aggregate reported measles cases in all 19 countries immediately after implementation of wide-age-range SIA. The quality of measles case-based surveillance is monitored by the WHO African Regional Office with two indicators: the rate of suspected measles cases with blood samples collected (target at least 1·0 per 100 000 total population) and the proportion of districts with at least one suspected measles case with a blood

sample (target at least 80%). All countries reached the minimum rate of suspected measles cases with blood samples collected in both 2003¹¹ and 2004 (unpublished WHO African Regional Office bulletin). The proportion of districts with at least one suspected measles case with a blood sample reached at least 50% in 17 of 19 countries in 2003 and in 16 of 19 countries in 2004.

The evidence of substantial declines in measles burden is lent further support from all three overlapping surveillance components pointing to the same conclusion. Routine surveillance showed a decline of more than 80% in reported measles cases in 16 of 19 countries. Case-based measles surveillance showed that only 10% of more than 12 000 blood samples tested were positive for measles IgM (with Burkina Faso excluded). Outbreak surveillance showed no continuing transmission except in Namibia and Burkina Faso.

In the Americas⁴ and southern Africa,⁵ high-quality SIA have resulted in interruption of endemic measles transmission for 3 years or longer depending on the pre-existing routine vaccination coverage. If we assume that the effect of SIA lasted 4 years when routine measles coverage was 80% or higher and 3 years if routine measles coverage was less than 80%, the total projected number of deaths that would be averted over the next 3–4 years is 304 212: 285 783 in the 12 eastern and western African countries and 18 429 in the seven southern African countries. These projections provide a rough estimate of the public-health impact of accelerated measles control efforts in the African Region over the medium term.

The advantage of estimating mortality reduction on the basis of measured declines in reported disease (over a model based on vaccination coverage) is shown by the examples of Burkina Faso and Namibia. These two countries had episodes of continuous measles transmission lasting longer than 12 months despite reported measles SIA coverage similar to other countries in the region; in Burkina Faso, post-SIA coverage was verified by a standard cluster survey (table 1). Yet measles surveillance detected unexpected increases in measles cases, which led to investigations and responses. The unexpected increase in measles cases came immediately after SIA in Burkina Faso and after the first follow-up SIA in Namibia. The discrepancy between a coverage-only model approach and a disease-measurement approach might become magnified once more countries in Africa are undertaking follow-up campaigns and large countries with low routine vaccination coverage such as Ethiopia and the Democratic Republic of Congo complete their initial catch-up SIA.

The mostly likely explanation for the observed sudden reduction in the number of cases after SIA is the ability of these activities to increase population immunity rapidly and thereby prevent measles transmission. Routine measles vaccination coverage increased 14% over a 3-year period in the 12 eastern and western African

countries but remained unchanged in the seven southern African countries. A gradual increase in routine immunisation measles coverage will decrease accumulation of susceptible children and might allow countries to increase the time between follow-up SIA from 3 years to 4–5 years.

Our study had several limitations. Because measles deaths are not routinely reported to WHO, we relied on available WHO estimates for the number of deaths before the SIA. For most non-southern African countries, we had surveillance data for only 1 year after SIA. However, data from southern African countries showed an effect that has lasted 4–8 years, as long as regular follow-up SIA are undertaken. In addition, we did not have information on changes in case management (eg, use of vitamin A) or changes in age distribution of patients with reported measles, and we could not assess changes in surveillance quality of the routine (aggregate) surveillance system. A substantial decline in measles transmission might result in a shift in the age distribution of measles to older individuals, in whom the case-fatality rate is lower, thereby resulting in an underestimate of the reduction in measles burden.

There is active debate about the positive and negative effects of mass vaccination campaigns on routine primary-health-care services.^{18,19} On the positive side, mass campaigns, if well planned and executed, achieve equity by reaching children who are missed by routine services and result in protection of children who are vulnerable (eg, owing to HIV infection) or unvaccinated by reducing transmission to very low rates. Benefits of campaigns can be increased by addition of interventions such as oral poliovirus vaccine, vitamin A, insecticide-treated bednets, and anthelmintics and through new equipment (eg, for the cold chain) and training (eg, for injection safety) put in place for the campaign. On the negative side, mass campaigns divert staff and resources such as vehicles that were intended for other primary-care services. Furthermore, if training and logistics are inadequate, they can lead to unsafe injection practices, difficulties with waste disposal, and adverse events due to human error. Measles SIA are done only once every 3–4 years and, despite their disruption of routine health services, they can be highly cost-effective disease-control activities in settings where country infrastructure is weak. Although more data are needed, the available evidence suggests that countries can both complete high-quality SIA and increase routine coverage.

SIA in children aged 9 months to 14 years have been superior to those in children aged 9 months to 4 years during the past 5 years in most African settings.¹ The number of deaths averted is three times higher with SIA in children aged 9 months to 14 years than with those in the narrower age range. In countries with moderate to high routine coverage, SIA in children aged 9 months to 4 years lowered the number of measles cases by half for

1–2 years;¹ SIA in children aged 9 months to 14 years lower the number of measles deaths to near zero for nearly twice as long (3–4 years). We hypothesise that reduction of transmission to near zero is the reason for the better effect of the wider-age-range SIA. With no measles transmission, all measles vaccinations (even those given at ages 1–4 years) are given before infection, no measles cases occur before the time of vaccination at 9 months, older children do not act as reservoirs to infect younger non-immune children, and children who are missed by the routine vaccination programme or who have experienced vaccine failure are not infected.

The total donor costs for the SIA in the 19 countries were US\$68.1 million (Measles Initiative and WHO African Regional Office, unpublished data). From the donor's perspective, the cost per child targeted was US\$0.83 and cost per death averted was US\$224. More detailed economic studies are needed for assessment of the costs and benefits of accelerated measles-control strategies in the African setting, for example from societal and government perspectives.

The goal of the African Regional measles plan of action is to sustain measles mortality at near zero. The southern African countries showed sustainable measles control, having maintained the striking reduction in measles cases for 5 years or longer (figure). The challenges for the future are to increase routine measles immunisation coverage to more than 80% in every district so that follow-up SIA targeting children aged 9 months to 4 years would be required only every 4 years, to identify resources to undertake regular follow-up SIA to sustain the number of measles deaths near zero, and to maintain continuous monitoring and feedback through surveillance. The cost of follow-up SIA every 3–4 years for all countries of the African Region (until 2010) is estimated at US\$30–40 million per year (annual WHO African Regional Office measles plan of work, 2003, unpublished).

During the past 5 years, a partnership has been formed between ministries of health, non-governmental organisations, and civil society that has been able to ensure high equitable coverage with live-saving vaccines through SIA while increasing coverage of routine services. The immunisation programme has also established an information system to measure coverage and impact continuously at the district level. The potential exists to use similar partnerships, programme infrastructure, and information systems to reach nationwide high coverage for other child survival interventions (eg, insecticide-treated bednets²⁰).

Contributors

M Otten, R Kezaala, A Fall, B Masresha, R Martin, R Eggers, R Biellik, M Grabowsky, J-M Okwo-Bele, and D Nshimirimana helped with designing and implementing data-collection systems and the measles control programme. P Strebel and L Cairns helped write the report. All the authors critically contributed to the final preparation of the report. The views expressed are solely those of the authors and are not those of the WHO.

Conflict of interest statement

We declare that we have no conflict of interest.

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References

- Otten MW Jr, Okwo-Bele JM, Kezaala R, Biellik R, Eggers R, Nshimirimana D. Impact of alternative approaches to accelerated measles control: experience in the African region, 1996–2002. *J Infect Dis* 2003; **187** (suppl 1): S36–43.
- WHO. Progress in reducing global measles deaths: 1999–2002. *Wkly Epidemiol Rec* 2004; **79**: 20–21.
- WHO. World health report 2001 statistical annex. Available at: <http://www.who.int/whr/2001/annex/en/>. Annex Table 2: Deaths by cause, sex and mortality stratum in WHO Regions, estimates for 2000. Annex2_en.pdf, p 145 (accessed March 9, 2005).
- de Quadros CA, Hersh BS, Nogueira AC, Carrasco PA, da Silveira CM. Measles eradication: experience in the Americas. *Bull World Health Organ* 1998; **76** (suppl 2): 47–52.
- Biellik R, Madema S, Taole A, et al. First 5 years of measles elimination in southern Africa: 1996–2000. *Lancet* 2002; **359**: 1564–68.
- WHO, United Nations Children's Fund. Joint statement on strategies to reduce measles mortality. WHO/V&B/01.40, UNICEF/PD/Measles/01. 2001.
- WHO Africa Regional Office. <http://www.who.int/vaccines-surveillance/StatsAndGraphs.htm> (accessed Aug 1, 2004).
- Centers for Disease Control and Prevention. Measles mortality reduction, West Africa, 1996–2002. *MMWR Morb Mortal Wkly Rep* 2004; **53**: 28–30.
- Centers for Disease Control and Prevention. Progress in measles control, Zambia, 1999–2004. *MMWR Morb Mortal Wkly Rep* 2005; **54**: 581–84.
- WHO Africa Regional Office. <http://www.afro.who.int/csr/ids/bulletins/index.html> (accessed March 9, 2005).
- WHO Africa Regional Office. <http://www.afro.who.int/measles/feedback-tables/> (accessed March 9, 2005).
- WHO Africa Regional Office. <http://www.afro.who.int/ddc/vpd/bulletins/2004/index.html> (accessed March 9, 2005).
- WHO Africa Regional Office. <http://www.afro.who.int/csr/ids/bulletins/index.html> (accessed March 9, 2005).
- Hersh BS, Tambini G, Nogueira AC, Carrasco P, de Quadros CA. Review of regional measles surveillance data in the Americas, 1996–99. *Lancet* 2000; **355**: 1943–48.
- <http://esa.un.org/unpp/p2k0data.asp> (accessed Feb 23, 2005).
- <http://www.afro.who.int/csr/ids/bulletins/2000.html>, Southern Bloc bulletin dec2000.pdf (accessed Aug 30, 2004).
- Yaméogo RK, Perry RT, Yaméogo A, et al. Risk factors for measles after a mass vaccination campaign, Burkina Faso, 2002. *Int J Epidemiol* 2005; **34**: 556–64.
- Dietz V, Cutts F. The use of mass campaigns in the expanded program on immunization: a review of reported advantages and disadvantages. *Int J Health Serv* 1997; **27**: 767–90.
- Loevinsohn B, Aylward B, Steinglass R, Ogden E, Goodman T, Melgaard B. Impact of targeted programs on health systems: a case study of the Polio Eradication Initiative. *Am J Public Health* 2002; **92**: 19–23.
- <http://www.ifrc.org/docs/news/pr04/8504.asp> (accessed March 8, 2005).