MEASLES ELIMINATION — IS IT ACHIEVABLE? LESSONS FROM AN IMMUNISATION COVERAGE SURVEY

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Objectives. To determine routine measles coverage at district level and to explore reasons for immunisation failure in Mpumalanga Province, South Africa.

Design. An adaptation of the World Health Organisation (WHO) Expanded Programme on Immunisation (EPI) cluster sampling method was used to make a random selection of 30 clusters in each of 21 health districts, 630 clusters in total. Seven individuals from the age group 12 - 23 months were randomly selected from each cluster and immunisation status and source were transcribed from their child health records. Where no immunisations were administered, reasons provided by parents or guardians were recorded.

Setting. Mpumalanga Province, South Africa.

Results. The weighted valid population coverage with measles vaccine for children aged 12 - 23 months in Mpumalanga Province was 71.1% (95% confidence interval 64.9 - 78.5%); this was the lowest of all EPI antigens. There was marked heterogeneity in measles coverage across the province, with a coefficient of variation of 22.2%. Districts with the lowest coverage shared borders with neighbouring provinces. District measles coverage was highly positively correlated with diphtheria, pertussis and tetanus (DPT3) coverage ($r = 0.960$, $P = 0.000$). There was a strong negative correlation between ranked measles campaign coverage and routine measles immunisation coverage. Obstacles to immunisation accounted for nearly half (49%) of all reasons for immunisation failure, while lack of information and lack of motivation accounted for 30% and 22%, respectively.

Conclusions. Survey results highlight the need for supplementary immunisation, including non-selective campaigns, if Mpumalanga is to achieve the South African goal of measles elimination by 2002. The value of determining district resolution coverage in order to identify areas with low measles coverage requiring supplementary intervention was also demonstrated. A strong negative correlation between routine and campaign coverage deserves further study in other settings.

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The eradication of smallpox during the late 1970s has been hailed as one of the greatest public health achievements of all time.[1] This success provided the impetus for the current global poliomyelitis eradication effort. In addition, it has fuelled speculation that regional progress towards measles elimination might prove the forerunner of global measles eradication.

This same optimistic buoyancy resulted in a South African Measles Elimination Meeting hosted in Pretoria, South Africa from 2 to 4 December 1997, and subsequent to this, the publication of a draft measles elimination plan for South Africa.[2] Although the goal of measles elimination enjoys broad support in South Africa, a key elimination strategy, namely mass immunisation campaigns, has galvanised controversy within the public health fraternity. This culminated in a tempestuous reception for the national measles catch-up campaigns conducted during 1996 and 1997.[3-5] The potential for mass campaigns to divert resources away from routine services was cited as the principal argument against this strategy, with critics arguing that a targeted approach focused on areas of low coverage and attendant epidemic risk would be a more appropriate strategy for South Africa.

Mpumalanga is a predominantly rural agricultural area in the north-east of the country flanked by Mozambique in the east and Swaziland in the south. The population of approximately 3.5 million inhabitants is largely concentrated in a number of urban areas and two former 'homeland' areas, Kangwane in the east and Kwandebele in the west. Measles immunisation is offered to all children at 9 and 18 months of age through the public health system, which consists of 227 fixed clinics, 21 mobile services and 22 hospitals. Reliable data required for defining vulnerable areas of low immunisation coverage are not routinely available.[6] An immunisation coverage survey was therefore conducted during November 1997 in order to determine measles coverage at district level and to investigate reasons for immunisation failure.

METHODS

Communicable Disease Control Programme Co-ordinators (CDCCs) from the 21 health districts were trained on locally adapted World Health Organisation (WHO) coverage survey material.[7] This well-established survey method makes use of a simplified cluster sampling methodology to allow estimation of vaccination status within 10% confidence limits.[8] The CDCCs determined their total district populations using projections from the 1991 national census, validated and adjusted where necessary by other credible sources of demographic information, including tribal or elected municipal authorities, and agricultural unions. The comprehensive community listing with defined population sizes was then used to select 30 clusters in each district with probability proportional to estimated size, resulting in a total of 630 clusters.

After simple maps were prepared for each cluster, a starting household was randomly selected using standard approaches specific for urban and rural clusters. Seven children in the age group 12 - 23 months were then selected, beginning at the starting household and continuing to the next nearest household, but all children in the appropriate age range living in the last household were included. The survey was completed within 6 weeks. On average 214 children were included per district, with a maximum of 224 in Tonga district. The number of households visited per district ranged from 375 to 3 480, with an average of 1 160 households or 39 per cluster.

Antigen administered (Bacillus Calmette Guérin (BCG), diphtheria, pertussis and tetanus (DPT), hepatitis B (HepB), trivalent oral polio vaccine (OPV), measles), date of administration, dose of antigen where appropriate (DPT, OPV, HepB), and source of immunisation (clinic, mobile clinic, hospital, private practitioner) were all recorded. Where a child health card was not available, the mother or guardian's recollection of immunisation history was recorded and clearly marked 'by history' for separate analysis. Sampled children present were examined for a BCG scar.

If one or more immunisations had not been administered, then a second standardised form was completed during the visit. The mother was asked to provide the most important reason why the child had failed to receive all immunisations. The interviewer catergorised reasons according to the most relevant of 20 predetermined 'reasons for failure', the major categories being lack of information, lack of motivation, or obstacles to immunisation.[7] Immunisations were only considered valid during analysis if they were administered in accordance with the provincial Expanded Programme on Immunisation (EPI) schedule, i.e. BCG — as soon as possible after birth; OPV, DPT, HepB — the first dose at 6 weeks of age with second and third doses at least 4 weeks apart; and measles — a dose after 9 months of age and recorded on the child health card.

Data were processed and entered into a customised Excel for Windows 97 spreadsheet. Statistical analysis was performed using the SSPS for Windows 95 software package. Weighted provincial coverage was calculated by summation of each district's coverage weighted by the proportion of the province's population resident in that district. The Pearson correlation coefficient was used to calculate the strength of linear association between measles coverage at district level and other variables of interest, while Spearman's correlation coefficient was used to assess linear association between district ranks for routine measles coverage (1997) and ranks for campaign coverage (1996). Multiple regression, the forward stepwise method with probability of F to enter = 0.50 and probability of F to remove = 0.10, was used to explore the independent contribution of different factors to district measles coverage, e.g. coverage of other antigens and sources of vaccination.

RESULTS

The valid weighted population coverage with measles vaccine for children aged 12 - 23 months in Mpumalanga was 71.1% (95% confidence interval (CI) 64.9% - 78.5%). Coverage by card plus history was considerably higher at 83.4% (95% CI 77.8 - 89.1%). The difference between coverage by card alone and by card plus history was greatest for measles (13% compared with 6 - 9% for the remaining antigens), due at least in part to a practice of ticking the dose of measles administered on the immunisation card without recording the date. Measles coverage was the lowest of all the antigens (Table I).

There was, however, marked variation in measles coverage across the province. The z-score varied from -2.7 (Lydenburg) to 1 (Eerstehoek, Highveld Ridge and Kabokweni) (Fig. 1). The coefficient of variation for district measles coverage was 22.2%. Similarly, district measles 'drop-out' rates showed conspicuous variation ranging from 0% in Standerton to 27% in Lydenburg (Fig. 2). Of note was the geographical distribution of low-coverage districts, with the lowest coverage districts generally sharing borders with neighbouring provinces, namely Northern Province in the north and KwaZulu-Natal in the south.

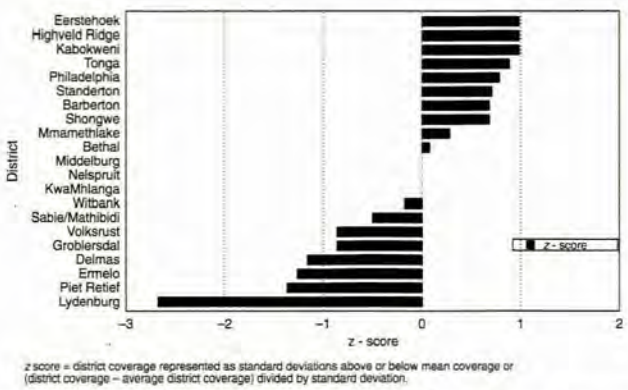

Fig. 1. Variation in district measles coverage, Mpumalanga Province, 1997.

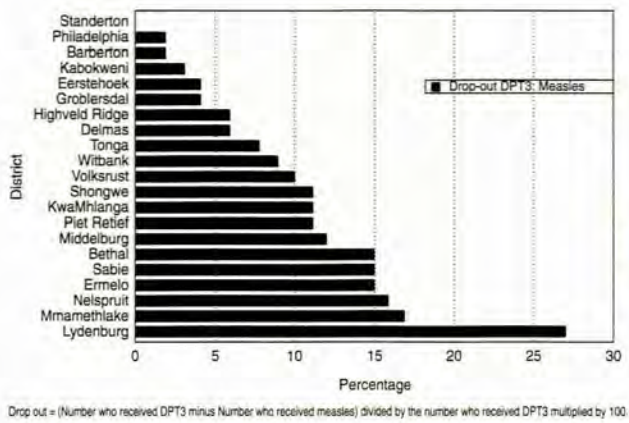

Fig. 2. Measles drop-out rate, Mpumalanga Province, 1997.

Table I. Immunisation coverage (%)* with EPI antigens in children aged 12 - 23 months, Mpumalanga Province, 1997

District	BCG	DPT1	DPT2	DPT3	HepB1	HepB2	HepB3	OPV1	OPV2	OPV3	Measles
Barberton	86 (100)	83 (100)	83 (100)	83 (100)	83 (100)	83 (100)	83 (100)	83 (100)	83 (100)	83 (100)	82 (97)
Bethal	91 (99)	87 (99)	86 (96)	86 (95)	86 (96)	86 (95)	84 (93)	86 (97)	86 (95)	86 (94)	73 (91)
Delmas	63 (100)	57 (96)	57 (95)	56 (93)	57 (95)	57 (94)	56 (93)	58 (95)	57 (94)	56 (93)	52 (87)
Eerstehoek	91 (100)	94 (100)	93 (100)	92 (99)	94 (100)	93 (99)	91 (98)	94 (100)	94 (100)	92 (99)	88 (94)
Ermelo	81 (94)	74 (85)	67 (77)	60 (69)	73 (83)	67 (77)	59 (69)	74 (85)	67 (77)	60 (69)	51 (60)
Groblersdal	79 (96)	66 (94)	64 (92)	60 (90)	56 (86)	54 (83)	50 (79)	67 (94)	65 (92)	58 (87)	57 (80)
Highveld Ridge	96 (98)	96 (98)	95 (97)	92 (94)	95 (97)	93 (95)	90 (92)	96 (98)	95 (97)	92 (94)	87 (98)
Kabokweni	96 (100)	95 (100)	95 (100)	90 (97)	95 (100)	95 (100)	90 (100)	95 (100)	95 (100)	90 (97)	87 (91)
KwaMhlanga	81 (100)	81 (99)	80 (98)	80 (97)	77 (89)	69 (81)	62 (71)	81 (99)	80 (98)	80 (97)	72 (90)
Lydenburg	51 (77)	56 (76)	48 (64)	40 (52)	48 (62)	43 (55)	33 (43)	56 (74)	48 (64)	39 (51)	29 (40)
Middelburg	84 (95)	83 (96)	82 (95)	82 (94)	83 (95)	82 (94)	82 (94)	82 (95)	82 (94)	82 (93)	73 (86)
Mmamethlake	99 (99)	98 (99)	96 (97)	91 (91)	79 (80)	63 (64)	51 (51)	97 (97)	93 (94)	88 (89)	76 (76)
Nelspruit	94 (100)	87 (99)	86 (97)	86 (96)	87 (99)	86 (97)	86 (96)	87 (99)	86 (97)	86 (96)	72 (83)
Philadelphia	96 (96)	96 (97)	90 (90)	86 (83)	90 (90)	86 (86)	86 (86)	90 (90)	90 (90)	83 (84)	84 (87)
Piet Retief	65 (91)	65 (91)	59 (83)	56 (73)	65 (91)	59 (83)	56 (73)	65 (91)	59 (83)	56 (73)	50 (65)
Sabie	78 (99)	77 (95)	76 (94)	74 (93)	76 (94)	75 (94)	73 (92)	76 (95)	76 (94)	74 (93)	63 (81)
Shongwe	94 (99)	93 (98)	93 (98)	93 (97)	93 (98)	93 (97)	93 (97)	93 (97)	93 (97)	93 (97)	82 (85)
Standerton	96 (100)	87 (100)	83 (98)	82 (100)	86 (100)	83 (98)	82 (99)	87 (100)	84 (98)	82 (100)	84 (93)
Tonga	100 (100)	97 (97)	97 (97)	94 (94)	97 (97)	97 (97)	94 (94)	98 (98)	97 (97)	95 (95)	87 (87)
Volksrust	71 (99)	71 (99)	67 (93)	63 (87)	67 (93)	59 (84)	54 (77)	71 (99)	67 (93)	63 (87)	57 (79)
Witbank	75 (97)	75 (100)	75 (99)	75 (99)	75 (99)	75 (99)	75 (99)	75 (99)	75 (99)	75 (99)	68 (91)
Province	85 (97)	83 (96)	81 (94)	78 (91)	81 (93)	77 (90)	74 (86)	83 (96)	81 (94)	78 (90)	72 (83)

* Numbers in parentheses are percentage coverage according to child health card and history.
BCG = Bacillus Calmette Guerin; DPT = diphtheria, pertussis, tetanus; HepB = hepatitis B; OPV = trivalent oral polio vaccine; 1, 2, 3 = number of dose.

The most important sources of measles vaccine were fixed and mobile clinics, which accounted for 71.6% and 26.4% of doses recorded, respectively. Hospitals and private practitioners were the source of only 1.4% and 1.1% of measles immunisations recorded, respectively. The immunisation source pattern was heterogeneous (Fig. 3). Although the median hospital contribution was 0%, Philadelphia Hospital provided 19% of immunisations in that district. In five predominantly rural districts fixed clinics were the source of more than 90% of measles immunisations, and in 15 districts less than 1% of children received immunisations from private practitioners.

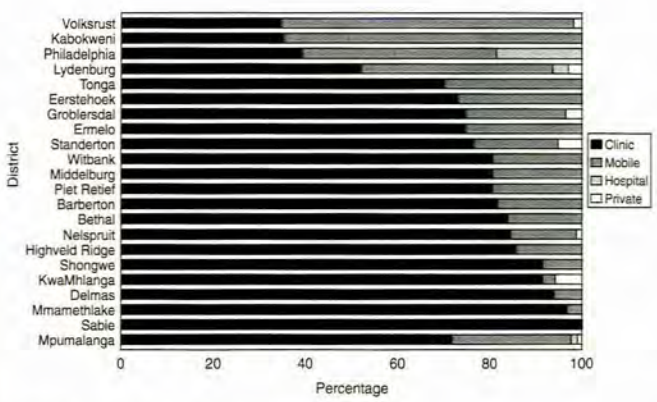

Fig. 3. Source of measles immunisation.

'Obstacles to immunisation' accounted for nearly half (49%) of all reasons provided for immunisation failure, while 'lack of information' and 'lack of motivation' accounted for 30% and 21%, respectively. The most important obstacles mentioned were the non-availability of vaccine (9%), place of immunisation being too far (7%) or illness in the child (6%). Important reasons provided in the 'lack of information' category were a lack of awareness of the need for immunisation (8%) and timing of immunisation (9%). Under 'lack of motivation' the most common reason provided was that immunisation was postponed until a more convenient time (18%).

District measles coverage was found to be highly positively correlated with DPT3 coverage ($r = 0.960$, $P = 0.000$). The adjusted coefficient of determination (R^2) was 0.917, and only DPT3 coverage remained in the forward stepwise regression model constructed from all variables associated with district measles coverage.

Fig. 4 depicts notified measles cases in Mpumalanga from 1980 to 1997, inclusive. If an epidemic threshold of 220 measles notifications in a single quarter is used, then there were four epidemics in Mpumalanga before 1996, viz. in the fourth quarter of 1980 and the third quarters of 1983, 1987 and 1992,

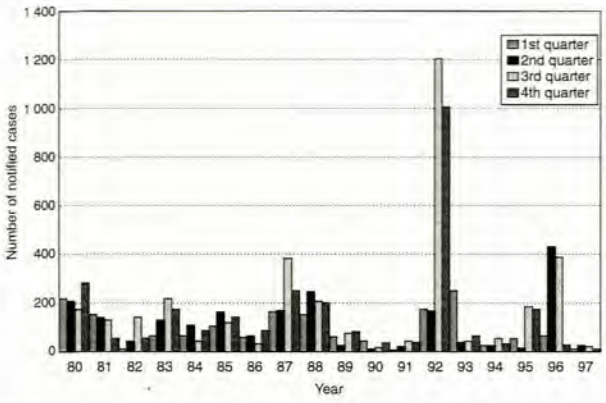

Fig. 4. Notified measles cases by quarter, 1980 - 1997, Mpumalanga Province.

the latter three after an increase in cases during the second quarter. In 1996 there was a marked increase in measles notifications during the second quarter before the provincial mass immunisation campaign.

District measles coverage figures from the present survey were compared with district coverage achieved during the 1996 mass measles campaigns. A strong negative correlation was found between ranked district routine measles coverage and ranked campaign coverage (Spearman's rho = –0.695, $P = 0.000$).

Discussion

Immunisation against measles demonstrates some of the greatest strengths and weaknesses of public health programmes. The discrepancy between the availability of an efficacious and cost-effective measure and the relatively poor record in routinely realising its full potential is highlighted by the findings of this survey. Nearly 30% of children surveyed in Mpumalanga did not have a record of measles immunisation and were therefore potentially at risk for the complications associated with measles infection in developing settings.[9,10] Nevertheless, these results represent a marked improvement on previous coverage surveys conducted in this area. Measles coverage recorded by card was found to be 59% in 1991 and 69.5% in 1994.[11,12] The latter included 20.7% of measles doses administered before 9 months of age, doses considered invalid in the present analysis. This increase is due, at least in part, to the restructuring of health services in the province, with a commitment to delivering immunisation on each clinic day and extension of clinic services to previously under-served areas.

It is important that Mpumalanga should continue to optimise routine delivery of measles vaccine.[13] However, when present coverage is considered in the light of measles epidemiology it becomes evident that Mpumalanga will not achieve measles eradication by means of routine immunisation alone.[14] Measles is a remarkably contagious disease with a basic reproductive rate of 15 - 17 in developing settings such as sub-Saharan Africa.[3,15-17] As a result, the critical level of population vaccination immunity necessary for interrupting transmission is 92 - 95%.

Although a number of antagonists remain sceptical that measles can be eradicated, there is a burgeoning belief that the goal is feasible, cost-effective and worth pursuing.[18-20] Factors favouring measles eradication include the successful eradication of smallpox, the anticipated success of polio eradication and the success of measles elimination in the Americas, Finland and elsewhere.[21-23] It is notable that much of the success achieved in South America has been accredited to well-organised single-dose mass campaigns.[24]

Concerns have been expressed that campaigns may be unsustainable and that they will divert critical resources away from routine health services. However, if Mpumalanga is to achieve the South African goal of measles elimination by 2002, supplementary immunisation will be required, including non-selective campaigns in which all children below a certain age are immunised regardless of prior immunisation status.[4,25,26] The initial experience with mass measles campaigns in the province was positive, with unprecedented political, community and health worker support. The expected epidemic in 1990/1991 did not materialise because of national accelerated immunisation campaigns, and the measles campaign in Mpumalanga during the third quarter of 1996 averted a large-scale epidemic predicted by mathematical modelling.[27] Coverage was 104.3% in the latter campaign, with more children immunised than initially targeted in the 9 months - 14-year age group because of flows across provincial and international borders, in particular from the Northern Province of South Africa and Swaziland.[6]

The need for repeated campaigns to avert post-honeymoon measles epidemics resulting from the accumulation of susceptible individuals and waning immunity has been appreciated both in South Africa and in countries where interruption of indigenous measles transmission has been accomplished.[28-31]

We found profound variation in district measles coverage, a finding also documented previously in South Africa at local level and explained largely by fragmentation of health service delivery and vast socio-economic differentials in the population.[32,33]

Of considerable interest was the strong negative association between measles campaign coverage (1996) and routine coverage (12 - 23 months) found at district level. Although numerous factors may have contributed to this finding, it provides support for a blend of routine fixed and outreach services supplemented by mass immunisation activities in low-

coverage areas, as this strategy appears to be effective in reaching children who missed their routine immunisations.[26,34,35] In addition to rapidly increasing immunisation coverage, campaigns have been accredited with effectively mobilising additional political, human and financial resources and improving logistical systems for vaccine delivery.[36,37]

The experience of one district, Philadelphia, where the large district hospital has conducted a sustained campaign to minimise opportunities for childhood immunisation, contrasts with the proportional contribution of hospitals in other districts. Attempts to address missed health service opportunities in South African hospitals have previously had little impact, with one study in the Western Cape recording missed opportunities at a hospital exceeding 50% despite a previous study that made careful recommendations.[38] However, this should not deter Mpumalanga facilities from making every attempt to minimise missed opportunities for immunisation through a 'supermarket' approach.[39-41]

When investigating reasons for immunisation failure, many of the factors emphasised by previous studies were in evidence, viz. the proximity of health facilities, district of residence, mother's awareness of disease and importance of immunisation, and false beliefs of mothers regarding contraindications to immunisation, in particular fever.[42-46] Many of these are difficult to address, but the finding of non-availability of vaccine at health facilities cannot be condoned.

False contraindications to measles immunisation, particularly among health professionals, are recognised as being an important barrier to routine measles coverage.[47] During a survey conducted immediately before the WHO EPI Review in South Africa during 1997 to explore vaccinator's knowledge, attitudes and practices at 20 randomly selected clinics in Mpumalanga, vaccinators were presented with a number of vignettes and asked to give their usual response.[48] Only 55% of vaccinators interviewed indicated that they would provide measles immunisation to a 9-month-old child with a mild fever (38°C) despite this being a false contraindication.[49-52]

The EPI coverage survey technique has been maligned by purists because of its susceptibility to non-homogeneous clustering, but field-based public health practitioners have noted the direct and indirect benefits of properly conducted EPI surveys coupled with appropriate feedback.[53] These include an increase in the provision of outreach services, targeting of socially marginalised communities, appointment of additional community health workers, improvement in supervision and marked increases in immunisation coverage.[54-56] In this regard the experience of Eerstehoek District in Mpumalanga should be mentioned. Three immunisation coverage surveys, making use of the standard EPI technique, have been conducted in recent years in this district. Measles coverage by card in the 12 - 23-month age group increased from 48.0% in 1992, to 86.6% in 1994, to 88.1% in the present survey.

Conclusions

The goal of measles elimination in South Africa and the southern African region has altruistic and economic appeal, if it is indeed achievable. Although there is documented improvement in routine coverage with measles immunisation in Mpumalanga over time, and the present survey demonstrates scope for further enhancing routine immunisation services, current coverage makes elimination highly improbable by this route alone. The strong negative correlation between routine and campaign coverage at district level provides support for the complementary approach of combining routine and supplementary immunisation for measles elimination in areas similar to Mpumalanga Province.

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