Health System Reform in Mexico 6

Improvement of child survival in Mexico: the diagonal approach

Jaime Sepúlveda, Flavia Bustreo, Roberto Tapia, Juan Rivera, Rafael Lozano, Gustavo Oláiz, Virgilio Partida, Lourdes García-García, José Luis Valdespino

Public health interventions aimed at children in Mexico have placed the country among the seven countries on track to achieve the goal of child mortality reduction by 2015. We analysed census data, mortality registries, the nominal registry of children, national nutrition surveys, and explored temporal association and biological plausibility to explain the reduction of child, infant, and neonatal mortality rates. During the past 25 years, child mortality rates declined from 64 to 23 per 1000 livebirths. A dramatic decline in diarrhoea mortality rates was recorded. Polio, diphtheria, and measles were eliminated. Nutritional status of children improved significantly for wasting, stunting, and underweight. A selection of highly cost-effective interventions bridging clinics and homes, what we called the diagonal approach, were central to this progress. Although a causal link to the reduction of child mortality was not possible to establish, we saw evidence of temporal association and biological plausibility to the high level of coverage of public health interventions, as well as significant association to the investments in women education, social protection, water, and sanitation. Leadership and continuity of public health policies, along with investments on institutions and human resources strengthening, were also among the reasons for these achievements.

Lancet 2006; 368: 2017–27

Published Online October 25, 2006 DOI:10.1016/S0140-6736(06)69569-X

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This is the sixth in a Series of six papers about health system reform in Mexico

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Introduction

Despite substantial reductions in child mortality in low-income and middle-income countries in the late 20th century, more than 10 million children younger than 5 years still die every year, most of them from preventable causes, such as diarrhoea, pneumonia, measles, malaria, HIV/AIDS, undernutrition, and the cluster of other causes leading to neonatal deaths.[1,2] The 2005 Report on the fourth Millennium Development Goal (MDG-4) is sobering, because it shows that the progress in reducing child mortality is slowing down worldwide. Between 1960 and 1990, the rates of decline in worldwide child mortality averaged 2·5% per year. By contrast, from 1990 to 2001 the rates of decline averaged 1·1% per year. Although this deceleration might be expected in areas that had already achieved low rates of mortality, such slowing has also happened in high-rate regions.[1]

Efficacious interventions have been identified that can avert childhood deaths in settings where mortality is high and health systems are weak. In the 42 countries with 90% of childhood deaths worldwide in 2000, 63% of these deaths could have been prevented through full implementation of a few known and effective interventions.[3]

Recent analysis by Jennifer Bryce and colleagues[4] confirms that in 2005, only seven of the 60 countries that account for more than 94% of child deaths in the world were on track to reach MDG-4. Additionally, coverage for the 16 key interventions identified in previous research remained seriously low, although some countries made giant leaps in coverage, increasing the proportion of mothers and children with access to life-saving interventions by as much as ten percentage points in 2 years.[4]

Mexico is one of the seven countries where a sustained decline in under-5 mortality has been recorded, and hence Mexico is estimated to be on track to achieve MDG-4—ie, to reduce the child mortality rate for these children from 44·9 deaths per 1000 livebirths in 1990 to 15·0 deaths per 1000 livebirths in 2015. This paper is the last of the *Lancet* series on health sector reform in Mexico and focuses on a specific health outcome. We hope that by sharing this experience, we can contribute to the acceleration of investment and actions for achieving MDG-4 in other countries.

Data sources

Information for this study has been drawn from different sources that include census data, mortality datasets registered by the Secretary of Health and the National Institute of Statistics Geography and Informatics, the nominal registry of children gathered by the Universal Vaccination Programme, and national nutrition surveys. The specific methodologies, including reliability and limitations, are included in each section.

Information about cause-of-death was derived from death certificates completed mostly by physicians. Physician completion of death certificates rose from 87% in 1980 to 98% in 2005. Causes were coded according to the 9th and 10th International Classification of Diseases. The information is registered by the Secretary of Health and the National Institute of Statistics Geography and Informatics, and undergoes periodic quality assurance. The census and mortality data refer to the entire Mexican population in the country's territory between 1980 and 2006. In some cases, definitions and methods have changed during the study (eg, for the International Classification of Diseases coding). However, Mexico was

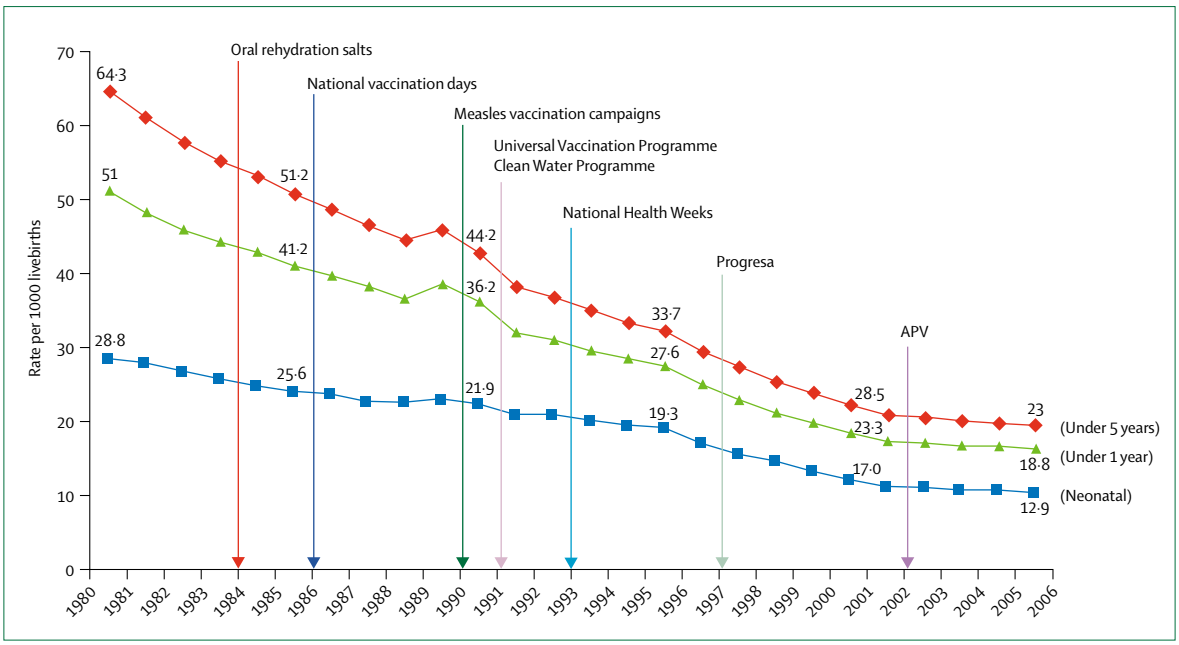

Figure 1: **Mortality in children under 5 years, under 1 year, and neonates, Mexico 1980–2005**
Rate per 1000 livebirths. Source: Ministry of Health Mexico/SEED and CONAPO.

recently ranked in the top 20 countries for high-quality system records for mortality.[5]

To correct the under-reporting of deaths of children in poor rural settings, standard demographic methods were used. The infant and child mortality rates were obtained in three steps.[6] First, national rates were derived directly from pregnancy records from the National Fertility Surveys for 1980–2005. Second, initial rates at state level were estimated by applying indirect methods (Brass method[7]), with death rates for all children ever born based on the 1990, 2000, and 2005 Mexican population censuses. Third, values were corrected according to birth distribution by state.

Before 1990, information on vaccination coverage was based on unreliable administrative data. Since the initiation of the Universal Vaccination Programme, every child has an individual computerised record and a personal record for vaccines received. Periodically, probabilistic sero-epidemiological surveys are done to monitor effective coverage. Data for population size, household conditions, and women's education came from the population census of 1980, 1990, 2000, and 2005.

Information about the nutritional status of the population during the study comes from three probabilistic, multi-staged, stratified, cluster household surveys done by the Mexican Secretariat of Health and the National Public Health Institute, representative of the civilian, non-institutionalised Mexican population in 1988, 1998–99, and 2005–06. All three surveys had national coverage and were representative of the population of Mexico at the national level and for four regions in 1988 and 1998–99, and for the 32 states in 2005–06. The sampling methods and response rates are described in detail elsewhere.[8,9] As with almost all household surveys, some segments of the population (eg, homeless people) could not be sampled because of their living arrangements, and therefore are not included in the results. Anthropometric indicators of nutritional status were used, including underweight (weight-for-age less than 2 SD from the World Health Organization/National Centre of Health Statistics [WHO/NCHS] reference), wasting (weight-for-height less than 2 SD from the WHO/NCHS reference) and stunting (height-for-age less than 2 SD from the WHO/NCHS reference).[10]

National probabilistic surveys on household income and expenses have been done since the 1980s on a regular basis, using standardised methods, by the autonomous National Institute of Statistics, Geography and Informatics. All of the surveys are representative at the national level.

	Percentage of 5 year period reduction		
	Neonates	Children under 1 year	Children under 5 years
1980–85	11·2%	19·3%	20·4%
1985–90	14·3%	12·1%	13·7%
1990–95	12·1%	23·8%	23·6%
1995–2000	10·9%	15·3%	15·4%
2000–05	24·1%	19·4%	19·5%

Source: CONAPO. *Rate per 1000 registered livebirths.

Table 1: **Percentage of reduction in mortality rates by all causes in neonates, children under 1 year, and under 5 years, Mexico 1980–2005***

	1980	Rate	1985	Rate	1990	Rate	1995	Rate	2000	Rate	2005	Rate
1	Diarrhoeal disease	15·2	Diarrhoeal disease	11·5	Birth asphyxia and birth trauma	7·7	Birth asphyxia and birth trauma	7·6	Birth asphyxia and birth trauma	7·4	Birth asphyxia and birth trauma	5·8
2	Lower respiratory infections	12·5	Lower respiratory infections	8·9	Diarrhoeal disease	7·2	Lower respiratory infections	4·7	Lower respiratory infections	2·5	Congenital heart anomalies	1·9
3	Birth asphyxia and birth trauma	6·9	Birth asphyxia and birth trauma	7·1	Lower respiratory infections	6·3	Diarrhoeal disease	2·8	Congenital heart anomalies	1·9	Lower respiratory infections	1·8
4	Chronic bronchitis	1·8	Low birth weight	1·1	Measles	2·3	Congenital heart anomalies	1·6	Diarrhoeal disease	1·6	Diarrhoeal disease	1·1
5	Low birthweight	1·5	Protein-energy malnutrition	1·1	Protein-energy malnutrition	2·0	Protein-energy malnutrition	1·2	Low birthweight	0·8	Low birthweight	0·8
Total		64·3		51·2		44·2		33·7		28·5		23·0

Source: Data Ministry of Health, Mexico. *Rate per 1000 livebirths.

Table 2: **Five leading causes of death in children under 5 years and total child mortality rates, Mexico 1980–2005***

Data analysis

Ordinary least-squares regression models with the maximum likelihood stepwise procedure were used to identify the best model for predicting child mortality rates. The study of the relation between child mortality and the socioeconomic context took into account both proximal and contextual determinants.[11] The proximal determinants are basic mechanisms common to all diseases of interest, and through which all socioeconomic determinants must operate.[12] We selected those for which we had information across all states in Mexico. We selected as proximal determinants stunting and underweight, and as contextual variables education of women (proportion of fertile women with fewer than 9 years of schooling), measles vaccination coverage of children younger than 5 years, and household conditions (the proportion of homes without access to sewage systems, and the proportion with a dirt floor).

Child mortality reduction

Mortality rates of children younger than 5 years dropped from 64 to 23 per 1000 livebirths in the past 25 years (figure 1). The decline has been steady with the exception of a sudden increase in mortality rate in 1989–90 as a result of a measles outbreak. The average rate of decline during the entire 25 years was 1·6% per year. As in other countries, slightly faster rates of decline were seen in children younger than 5 years (64·2%) than in infants (63·1%) and neonates (55·2%; figure 1, table 1).

Table 2 shows the distribution of causes of deaths in children younger than 5 years. In 1980, five leading causes accounted for about 60% of deaths in such children: diarrhoeal diseases, lower respiratory infections, birth asphyxia and trauma, chronic bronchitis, and low birthweight. Measles was the fourth most common cause of child mortality in the country in 1990, and even became the first or second cause of child mortality in several poor

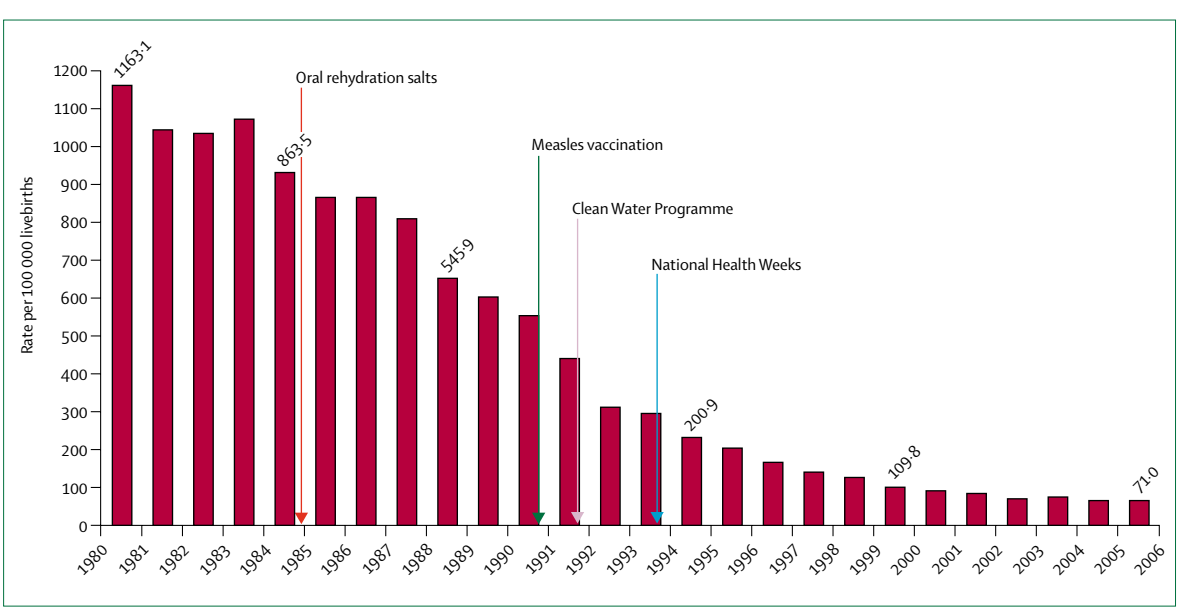

Figure 2: **Diarrhoea mortality in children under 1 year old, Mexico 1980–2005**
Rate per 100 000 livebirths (estimated). Source: CONAPO and Preliminary data SEED.

	Percentage of 5 year period reduction	
	Children under 1 year*	Children under 5 years*
1980–85	25·8%	24·3%
1985–90	36·8%	37·4%
1990–95	63·2%	61·1%
1995–2000	45·3%	42·9%
2000–05	35·3%	37·5%

Source: CONAPO. *Rate per 1000 registered livebirths.

Table 3: **Reduction in diarrhoea mortality rates in children under 1 year and under 5 years, Mexico 1980–2005**

states, such as Chiapas and Oaxaca. During the past 25 years, the contribution of diarrhoea and lower respiratory infections to child mortality decreased substantially. The specific mortality rates in children under 5 years for these diseases decreased 93% and 86%, respectively. The drastic decline in diarrhoea mortality rates in children younger than 1 year during this time deserves special analysis (figure 2). After a sudden increase in diarrhoea mortality rates in 1983, a hospital-based oral-rehydration programme was introduced. From then on, the decline of diarrhoea mortality began to accelerate, with the largest drop between 1990 and 2000 (table 3). These changes in causes of deaths were temporally associated with the introduction of three major public health interventions: the Universal Vaccination Programme, the Clean Water Programme, and the National Health Weeks (figure 2).

	Percentage of 5 year period change	
	Lower respiratory infections	Birth asphyxia and birth trauma
1980–85	–29·20%	+3·1%
1985–90	–28·5%	+8·8%
1990–95	–25·6%	–1·8%
1995–2000	–47·1%	–2·6%
2000–05	–27·7%	–22·1%

Source: CONAPO. *Rate per 1000 registered livebirths.

Table 4: **Changes in lower respiratory infections, and birth asphyxia and birth trauma rates in children under 5 years, Mexico 1980–2005***

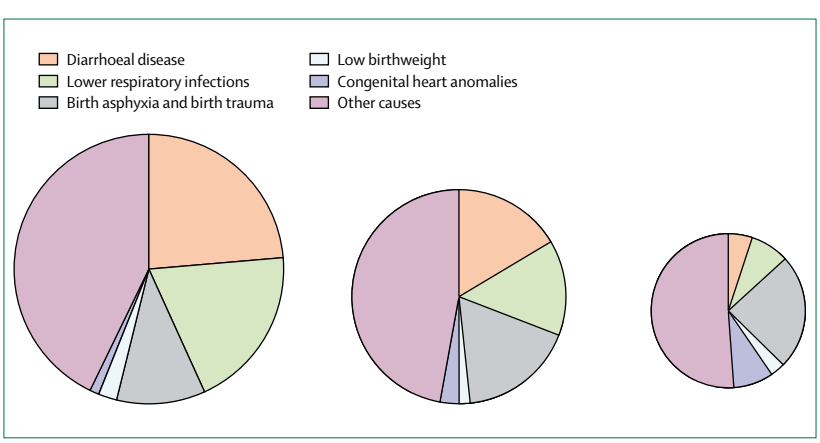

Figure 3: **Proportion of total child mortality rate for five selected causes of death, children under 5 years, Mexico 1980, 1990, 2005**

During the same period, the proportion of neonatal deaths among all causes of deaths in children younger than 1 year increased from 56% in 1980 to 69% in 2005. The proportion of some other main causes of death in children under 5 years, such as lower respiratory infections, low birthweight, and birth asphyxia and birth trauma, have also changed (table 4, figure 3). Lower respiratory infections have continued to rank second or third as cause of death in this age-group. Deaths from lower respiratory infections and low birthweight have decreased by 86% and 47%, respectively, during the past 25 years. Mortality rate due to birth asphyxia and birth trauma, on the other hand, has decreased by only 16%, mainly during the past 10 years. These data indicate the transition in causes of death for children under 5 years that resulted from public-health campaigns and primary health-care interventions, which have had positive effects mainly on diarrhoea, lower respiratory infections, low birthweight, and vaccine-preventable diseases. The effect of other primary health-care interventions, such as improvement of perinatal care over birth asphyxia and birth trauma, has been lower and more recent than for other causes of death.

Undernutrition is a contributing factor to over half of all childhood deaths worldwide.[13] In Mexico, an important decline took place in every form of undernutrition from 1988 to 2006 (figure 4). Wasting dropped to less than a third of its original prevalence between 1988 and 2006, with most of the reduction happening between 1988 and 1999. Stunting dropped about half, from nearly 23% to less than 13%, and underweight declined about two-thirds, from 14% to 5%, during the same period.

Anaemia and micronutrient deficiencies are highly prevalent in Mexico. In the National Nutrition Survey of 1999, more than one in every four children between the ages of 1 and 4 years (28%) were anaemic. This prevalence dropped to 23·7% (a 15·3% drop) by 2006. In 1999, the prevalence of iron, zinc, and vitamin A deficiencies was 52%, 33%, and 27%, respectively.[14]

Public health interventions

During the past 25 years, several public health interventions were implemented that could explain the rapid declines in child mortality, particularly from diarrhoeal diseases in infants (figures 1 and 2). These interventions started as vertical programmes (panel 1), and were scaled-up as experience and some success in health indicators were gained. We called this strategy the diagonal approach—that is, the proactive, supply-driven provision of a set of highly cost-effective interventions on a large scale bridging health clinics and homes. This experience in incremental implem-

Panel 1: Diagonal approach

The medical published work has long debated which approach to delivering health interventions is more effective: vertical programmes or horizontal programmes. Vertical programmes refer to focused, proactive, disease-specific interventions on a massive scale, whereas horizontal programmes refer to more integrated, demand-driven, resource-sharing health services. This situation is a false dilemma, because both interventions need to coexist in what could be called a diagonal approach, that is, the proactive, supply-driven provision of a set of highly cost-effective interventions that bridge health clinics and homes.[15]

entation of multiple public-health interventions could be thought of as the equivalent of a public health polypill.[15]

The provision of oral rehydration salts is one of the most cost-effective interventions for reducing the mortality of children with diarrhoea.[16] Such provision was introduced in hospital settings in Mexico in 1984, when the mortality rate due to diarrhoea was quite high. The introduction of oral rehydration salts in clinical practice was associated with a substantial decline in mortality due to diarrhoea, with a roughly 60% reduction over the next 5 years (figure 2).

The inclusion of oral rehydration salts as part of the set of interventions included in the National Health Weeks, bridging clinics and homes, along with the Universal Vaccination Programme and the Clean Water Programme, further accelerated the decline of diarrhoea mortality in the next decade by delivering millions of free rehydration salts to households. The Clean Water Programme focused on appropriate water chlorination and regulations that banned the use of sewage for crop irrigation. Of the many activities that were reinforced in anticipation of a cholera outbreak, the most important was provision of potable water through appropriate purification both outside the household through chlorination of supplies and within the household through boiling and chlorination. Other important steps were adequate disposal of waste, sewage-treatment plants, and monitoring the maintenance of drainage systems. In addition to legal amendments to ban sewage water from use for irrigation, local communities placed a special emphasis on construction of latrines, and food vendors were monitored to ensure compliance with basic sanitation laws. Water and sanitation are important risk factors for the endemic patterns of diarrhoea.[17,18] As a consequence, cholera cases decreased notably and diarrhoeal diseases from other causes also substantially diminished during this period.[19]

Immunisations have been foremost in the set of cost-effective, non-personal, public-health interventions. Before 1985, vaccines were given only to children in Mexico at public-health clinics at a mother's request, and included the six immunogens recommended at the time by WHO. Vertical immunisation strategies evolved from single poliomyelitis vaccination days in 1985, to vaccination weeks in 1988, and finally to the introduction in 1993 of a basic package of health services, described here as National Health Weeks.

Figure 5 shows the effect of increasing measles vaccination coverage. In 1989–90, a huge measles epidemic hit Mexico, causing more than 70 000 cases and 6000 deaths, mostly malnourished rural children under 5 years. The outbreak triggered the creation of the Universal Vaccination Programme. Before 1990, information on vaccination coverage was based on unreliable administrative data, and effective coverage was estimated from the national sero-epidemiological survey done in 1985. In 1990, a national probabilistic survey in a quarter of a million households showed that only 42% of children were fully immunised with the expanded programme of immunisation schedule. Within 3 years, immunisation coverage exceeded 92%, and this rate was sustained for the remaining years (figure 6). A computerised system of individual records for almost 12 million children allowed quality control of coverage data. Additionally, serological sampling in household probabilistic surveys was done before and after the Universal Vaccination Programme. The effect of universal vaccination in preschool children was immediate: the last notification of a polio case in Mexico was in 1990, of diphtheria in 1991, and of autochthonous measles in 1996. In 2006, Mexican children and adolescents are benefiting from one of the most comprehensive immunisation schedules in the world, including: hepatitis B; diphtheria, tetanus, and pertussis; *Haemophilus influenzae* type b; inactivated polio vaccine; measles, mumps, and rubella; pneumococcal; influenza; rotavirus; and Bacillus Calmette-Guerin vaccine. The cost of these vaccines per person is around US$200.

With the experience gained from the national polio immunisation days, in 1993 the strategy was expanded to a whole week, twice a year, dedicated to children's health

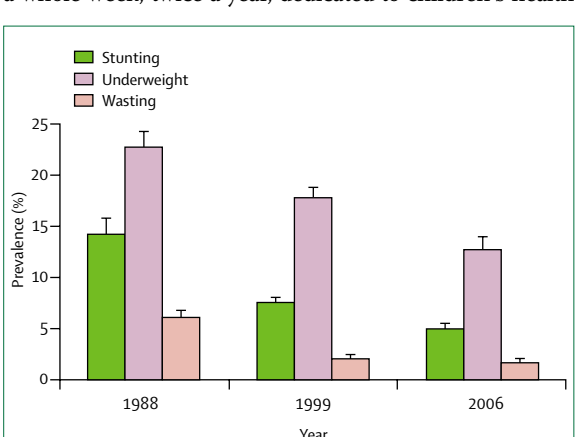

***Figure 4*: Trends in stunting, underweight, and wasting prevalence, Mexico 1988, 1999, and 2005**
WHO/HCHS/CDC reference pattern. Source: National Nutrition Surveys.

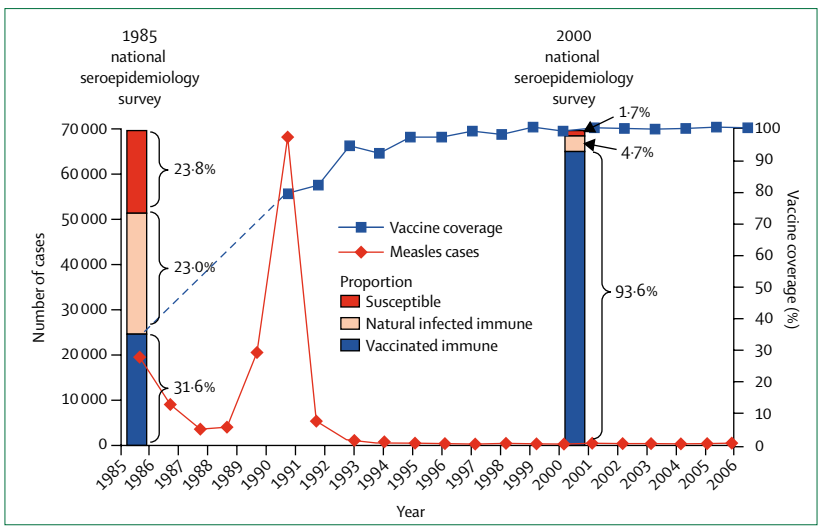

Figure 5: **Measles morbidity and vaccine coverage in children aged 1–4 years, Mexico 1985–2005**

at their homes, schools, and clinics. In addition to all vaccines in the WHO expanded programme of immunisation, a package of highly cost-effective interventions was also included: the active promotion of oral rehydration salts, the distribution of mega-doses of oral vitamin A, and mass anthelmintic therapy (albendazole). This strategy proved to be effective, efficient, and socially accepted.

Mega-doses of vitamin A (100 000 IU given to children aged 6–12 months and 200 000 IU to children 12–36 months) was included in areas with high levels of vitamin A deficiency. A study of children living in slums in a northern state of Mexico revealed that massive vitamin A distribution might have had an important improvement on retinol serum levels in children. Baseline values showed that 6·3% of the children had severe vitamin A deficiency, which disappeared after supplementation.[20] Also, the assessment of the mass anthelmintic therapy to children aged 2–14 years living in high-risk municipalities produced a satisfactory cure rate, defined as the proportion of children who did not have a single helminth egg after treatment of those who had at least one egg before treatment. In addition to the health benefits, this intervention most likely contributed to improving the nutritional status of children.[21]

In 1997, the Mexican Federal Government implemented a conditional cash transfer programme (Oportunidades) targeted to about 300 000 low-income households in rural areas. By 2005, Oportunidades covered about 5 million low-income households (about 25% of total households) in both rural and urban areas. Cash transfers are provided to women as financial incentives for preventive health and nutrition behaviours, and as incentive for retaining children in school. Families do not receive cash benefits unless they regularly attend health clinics where they receive health and nutrition services. The programme also distributes food supplements to all children 6–23 months of age and to underweight children aged 2–4 years in target households. The supplement is a dry mix of whole dry milk, sugar, maltodextrin, vitamins, and minerals in different flavours, which after the addition of water produces a supplement with the consistency of a purée. The families of eligible children are provided with amounts of supplement that provide a daily dose containing the following nutrients (expressed in percentage of US recommended dietary allowances for children 1–3 years): 15% of energy, 36% of protein, and 100% of iron, zinc, folic acid, and vitamins A, E, C, and B12. The average cost of each daily dose is around US$0·09.

An independent and rigorous programme assessment showed positive effects on the nutritional status of children. A randomised effectiveness study was done of 347 communities assigned either to immediate incorporation to the programme in 1998 (intervention group; n=205) or to incorporation in 1999 (crossover intervention group; n=142). 650 children aged 12 months or younger (n=373 intervention group; n=277 crossover intervention group) were randomly selected for both study groups, and surveyed at baseline and at 1 and 2 years after. The programme was associated with better gain (1·1 cm; p=0·046) in height in the poorest (half low-income households) and younger infants (younger than 6 months at enrolment) after 2 years. Also, after a year of programme enrolment, the age-adjusted rate of anaemia (haemoglobin level <110 g/L) was 19% higher in the crossover intervention group than in the intervention group (54·9% *vs* 44·3%; p=0·03).[22]

In 2001, the Mexican Ministry of Health launched the national programme *Arranque Parejo en la Vida* (APV; "An Equal Start in Life").[23] The main objective was to reduce maternal and perinatal mortality rates by improving the traditional mother-child health care. Innovations included: promotion of social and community participation; strengthening the maternal and perinatal health care model through reorganisation of primary-level and emergency care in the most affected and marginalised areas; key prevention interventions such as neonatal screening and folic acid supplementation for women; training for traditional midwives and alternative qualified personnel; and community and institutional articulated services. APV is a strategy involving joint efforts and resources from local communities, civil society, and different government levels.

Since APV started, the percentage of births with skilled birth attendants present increased from 69% in 2000 to 91% in 2005.[24] Antenatal care coverage increased from 82% in 2000 to 88% in 2005 at the national level, with important growth in coverage in the southern and most impoverished states: Chiapas (36%, from 64% to 87%), Oaxaca (35%, from 66% to 90%), and Veracruz (22%, from 69% to 85%). 265 clinics and hospitals were

supported with medical equipment; APV opened 50 shelters (Posadas AME), where women from distant communities who need health care can stay before and after delivery; several communities improved transportation from and to local hospitals with the use of radio communication supported by local stakeholders and coordinated with governmental institutions. An assessment of the effect of APV is being done at the population level.

Inequalities in income distribution and health

Mexico is characterised by great inequities in its distribution of wealth. The Gini index[25] was used as a measure of social inequality, ranging between 0·5 and 0·6 in Mexico during the study. The lowest Gini value (0·51) corresponded to the first years of the period for which Gini information was available (1984), when the highest income decile accumulated about 40%, whereas the lowest decile accumulated only about 1% of the wealth. The highest (most inequitable) Gini value was in 1992 (0·6), when about 53% of the wealth was in the hands of the wealthiest 10%, whereas the poorest 10% had less than 1% of the wealth. Other experts prefer to describe income concentration in Mexico by the ratio of the shares of the richest 10% to the poorest 10% (D10/D1).[25]

Income inequality is often thought inevitably to lead to health inequality.[26] In Mexico, there is evidence that despite the large income inequalities, health can be improved substantially even in the poorer strata of the population. Figure 6 shows the secular decline both in overall child mortality levels and a variance reduction in the 32 federal states of Mexico. This decline took place despite income concentration increasing until 1998. Similarly, while structural economic reform took place, disparities in life expectancy within regions slowly but steadily decreased.[27]

A clear example is shown by the progress in preventable childhood diseases through universal vaccination. The rates of coverage obtained in indigenous rural areas were similar to those in urban industrialised regions; children from poor families were equally protected, as were those coming from more privileged strata, resulting in what was known as immunological equity (Jesus Kumate, personal communication). Figure 5 shows the relation between immunological protection to measles, drawn from sero-epidemiological surveys, and vaccine coverage rates. Immunological equity led to elimination of autochthonous measles and to control of other vaccine-preventable diseases across all socioeconomic groups in the population.

Determinants of reduction of child mortality

In an attempt to disentangle the contribution of several child health determinants to the reduction in child mortality, we did an analysis of the variation across the federal states and measured the strength of the association between those determinants and the under-5 mortality reduction. Because income data are not representative at the state level, we did not include income measures in the regression analysis.

All contextual and proximal determinants selected were associated with reduction in under-5 mortality (correlation coefficients ≥0·66; table 5). The best ordinary least-squares regression model for predicting under-5 mortality (table 6) included, as independent variables, the prevalence of underweight, the percentage

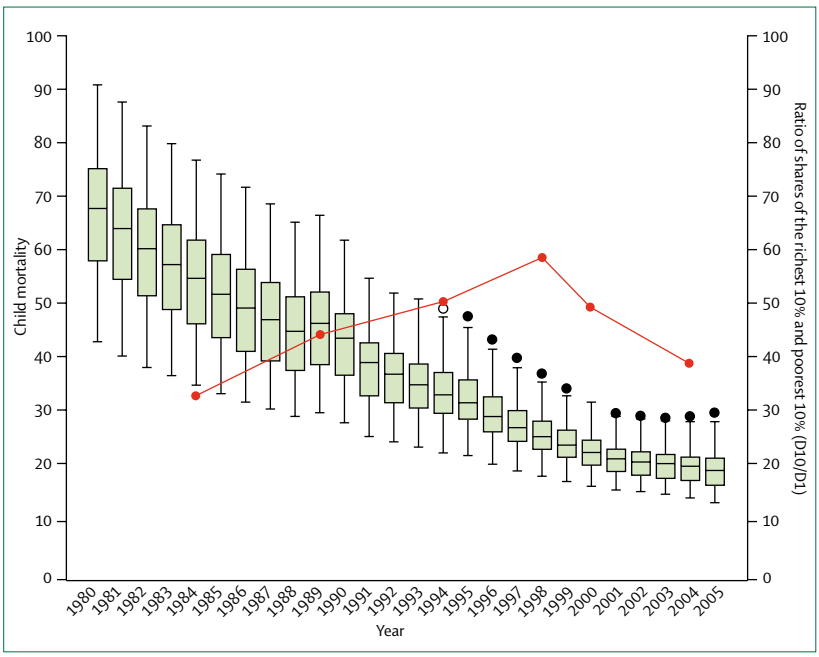

Figure 6: **Box-plot of levels, variance, and trends of child mortality in Mexico, and income concentration, 1980–2005**

Source: Analysis by authors from data taken from ENIGH 1984–2004 (National Survey on Household Income and Expenditure).

Variable	Coefficient
Proximate determinants	
Underweight prevalence (children <5 years)	0·71
Stunting prevalence (children <5 years)	0·87
Context determinants	
Percentage of women age 15–49 years with fewer than 9 years of schooling	0·94
Percentage of population without access to sewage systems	0·79
Percentage population living in households with dirt floor	0·66
Percentage of children aged 0–4 years vaccinated against measles	–0·81

Sources: Estimates from CONAPO of child mortality rate; National Nutrition Surveys 1988, 1999, and 2006; Population Censuses 1990, 2000, and 2005; CONAVA.

Table 5: **Linear correlation coefficients between child mortality rates in Mexico (1988 and 1999 at regional level and in 2005 at state level) with proximate and context determinants**

	Coefficient
Percentage of children aged 0–4 with low weight-for-age	0·37*
Percentage of women aged 15–49 with fewer than 9 years of schooling	0·36†
Percentage of children aged 0–4 vaccinated against measles	–0·51†
Constant	54·05†
Coefficient of determination (R2)	0·95

Sources: Estimates from CONAPO of child mortality rate; National Nutrition Surveys 1988, 1999, and 2006; Population Censuses 1990, 2000, and 2005; CONAVA. *p=0·05. †p=0·01.

Table 6: **Ordinary least squares regression coefficients of some determinants of child mortality rate Mexico (1988 and 1999 at regional level, and in 2005 at State level)**

of women with low schooling, and the coverage of measles vaccination, which were all significant ($p<0·05$). The model accounted for almost 95% of the state variance of child mortality ($R^2=0·95$). The regression coefficients indicated that for every 10% increase in measles coverage there was a reduction of 5·1 deaths per 1000 livebirths. Similarly, for every 10% decrease in underweight and in low schooling, there was a decrease of 3·7 and 3·6 deaths per 1000, respectively. The association between reduction in mortality rates and schooling is further confirmed by the increase in formal education in women during the study. The percentage of women (15–49 years of age) with no schooling went from 13·7% in 1980 to 4·7% in 2005, while the percentage of women in the same age-group who completed high-school or higher education went from 5·8% in 1980 to 29·1% in 2005.

Discussion

In this study we show that during the past 25 years in Mexico, child mortality rates declined from 64 to 23 per 1000 livebirths. A dramatic decline of diarrhoea mortality rates was recorded, and polio, diphtheria, and measles were eliminated. Nutritional status of children improved significantly for wasting, stunting, and underweight. Although we are not able to precisely attribute the relative contribution by each of the interventions described in the paper, one conclusion seems clear: public health interventions, when applied to vulnerable populations and with sustained coverage, can have a positive effect on child mortality rates, even in the presence of an adverse economic situation. Hence, for countries attempting to reach MDG-4, not only is investment in measures to improve economic growth important, but also urgent improvement of the coverage of key interventions.

Our paper has several limitations. A causal relation between an intervention and child health outcome cannot be conclusively shown without a control group and a prospective design that accounts for several determinants of mortality reduction. As well as being retrospective, the study uses datasets that were obtained for different purposes and in some cases definitions and methods have changed during the 25 years (eg, for the International Classification of Diseases). However, the temporal association, the national coverage of census and mortality data, and the national representativeness of nutritional surveys, along with the biological plausibility and the cumulated global health experience, allows one to infer a highly likely causal pathway.

As described in other papers in this series,[29,30] an artificial divide between the vertical approach, focusing on specific disease priorities, and the horizontal approach, aimed at strengthening the overall structure and functions of the health system, has been bridged in the public health experience in the country. To go beyond this false dichotomy, and extending the geometry metaphor to what we call the diagonal, Mexican health authorities defined a strategy in which explicitly defined intervention priorities were used to drive the needed improvements into the health system. In the attempt to reduce child mortality, the health authorities initially focused on a set of cost-effective interventions, such as immunisation, vitamin A supplementation, oral rehydration salts, and de-worming, and reached and sustained high population coverage. Substantial evidence exists of positive effects of these interventions on child mortality in other countries.[16,31] As evidence of cost-effectiveness emerged for other interventions, and the epidemiological transition in causes of child deaths took place, Mexico created a more comprehensive package addressing maternal, neonatal, and child health. Recent assessment confirms that effective coverage for this package is higher than for interventions covering other adult health problems.[24] The provision of these interventions has remained a key issue in the health sector reform, and through the *Seguro Popular*, Mexico legislated access to maternal and child health services as citizens' entitlements.[30,32] Their documented effect allowed for the creation of a separate fund for community and public health interventions aimed at the whole population, irrespective of their health insurance status.

Even though the causes for reductions in child mortality and for malnutrition have much in common, the reduction in both acute and chronic under-nutrition in Mexico probably had a role in the reduction of child mortality rates during the study. The relation between infection and malnutrition is synergistic. Infection adversely affects nutritional status through reductions in dietary intake, intestinal absorption, increased energy expenditure during fever, catabolism, and sequestration of nutrients needed for tissue growth. Conversely, malnutrition can predispose to infection because of its negative effect on the barrier protection afforded by the skin and mucous membranes and by inducing alterations in host immune function.[33–35] Moreover, even

mild to moderate malnutrition, which was reduced substantially in Mexico during the study period, increases the risk of death.[36] Therefore, interventions aimed at reducing the incidence of infections, such as immunisations and water purification and sanitation, or at reducing their duration and severity, such as oral rehydration salts, have had a direct positive effect on survival while contributing to improved nutritional status. At the same time, interventions aimed at improving nutritional status, including micronutrient status, have had an effect on the reduction of mortality, since anaemia and micronutrient deficiencies are highly prevalent in Mexico.

Worldwide, iron deficiency anaemia is estimated to be an underlying factor in 841 000 deaths per year resulting from maternal and perinatal causes, and it directly causes the deaths of 134 000 young children per year. Improving iron status not only reduces anaemia but also can prevent deaths.[13] In addition to contributing to child stunting, zinc deficiency is estimated to be responsible for about 800 000 deaths every year from diarrhoea, pneumonia, and malaria in children under 5 years worldwide. Improving zinc status prevents and palliates diarrhoea and pneumonia.[13] Although anthelmintic therapy does not have a direct effect on mortality, it contributes to reducing other risk factors such as impaired growth and anaemia. Further, the ingredients of the successful strategy for reducing child mortality were leadership in health, building system institutional capacity both in the public and private sector, strengthening the human resources base, and the continuity of policies over two decades (panel 2).

Our analyses also show that the pathway to reduction of child mortality is multifaceted and includes several sectors. The divide between health sector and intersectoral policies and investments is another artificial dichotomy that the Mexico experience has bridged. In many countries, mother's education has been seen to increase child survival and to decrease child malnutrition, even when other determinants are held constant. The link between maternal education and child health is one of the other key explanations for why poorer children die earlier and are less well nourished.[37] In Mexico, education of women has been a key determinant of the progress in child mortality reduction, as many other studies have shown. We tested this hypothesis with regression analyses of determinants, which showed that maternal education is correlated with child mortality rates, despite the fact that non-hierarchical data analyses underestimate the role of distal determinants when the regression model also includes intervening variables, such as measles vaccine coverage and anthropometric status of the child. Furthermore, the experience with conditional cash transfers shows the link with social protection, and probably explains some of the reduction in health inequalities, despite the persistence of income inequalities.

Panel 2: Leadership, institutional building, and human resources strengthening

Mexico has had strong leadership and continuity of policies in health during the past 25 years. All the Secretaries of Health since 1982 had strong managerial experience, technical health knowledge, and a clear sense of public-health needs. They all finished their 6-year terms (with one exception), preserved population-based health policies from preceding administrations when they were shown to be effective, and maintained a focus on protecting health and welfare of children and other vulnerable populations.[27]

Staffing in the Ministry of Health took into consideration technical expertise and managerial experience, and a results-oriented culture permeated from the top-down. Senior scientists, modern administrators, and recent graduates of USA schools of public health, were recruited to create the strong teams that conceived the programmes and implemented the results described in the previous sections. New recruits came from programmes such as the Field Epidemiology Training Programme, started in 1982 in association with the Centers for Disease Control and Prevention of the USA, and the National Institute of Public Health (INSP). This public institution was created in 1987 with the mission to become a think tank for health policy and a source of human capital. INSP was involved in several of the evaluations described and contributed to the development of evidence for policies in child health during the past 20 years.

Human-resources strengthening has been fundamental to the development of a strong public health system in Mexico. Most senior staff members at the Mexican Ministry of Health hold postgraduate degrees and are now members of the civil service. As described by Gakidou and colleagues,[24] from 2001 to 2005 the number of doctors and nurses per 1000 population increased from 0·83 to 0·94. Also the ratio of doctors and nurses per 1000 population of the state with the highest number to the state with the lowest number has decreased from 4·27 to 4·03.

Hence, the skills and capacity developed over 25 years were essential to the formulation of appropriate policies and programmes for child health in Mexico, and are likely to have contributed to child mortality reduction, as a recent cross-country analysis suggests.[46]

Improved drinking water sources, in terms of quality, but especially quantity, and adequate sanitation typically lead to better child health outcomes.[38–40] Provision of potable water in Mexico is by law a responsibility of municipal authorities. Unfortunately, before the re-emergence of cholera, this activity was not a priority for many municipal officers. Paradoxically, the last cholera pandemic, which arrived in Mexico in June, 1991, was a blessing in disguise. The outbreak forced the implementation of an ambitious sanitation programme aimed at preventing disease outbreaks caused by contaminated water and food.[19] In a previous communication, we have documented the beneficial consequences of the cholera re-emergence.[19] Special mention should be given to the importance of inter-sectorial coordination. Provision of potable water was the responsibility of the National Water Commission at the federal level, of the State Water Commissions at the state level and of municipal authorities at the local level. The National Water Commission was the federal body authorised to administer water, protect bodies of water, and enforce legislation on water discharges and treatment, and was linked to several Secretariats such as Agriculture and Environment and Natural Resources. These levels coordinated with other public and private sectors to

promote the appropriate purification of water both outside the household through chlorination of water supplies and within the household through boiling and household chlorination.

Finally, the remaining challenge for Mexico is the further reduction of neonatal mortality. In 2005, several researchers and organisations focused world attention on newborn survival, on the slow progress in reducing deaths in this period of life,[1,41–43] and showed that effective interventions are available.[41] The 2005 World Health Report emphasised the need for integration of maternal, neonatal, and child health. A continuum of care that will address maternal and child mortality has emerged as a new framework. There are two dimensions to this continuum: time—from pre-pregnancy, through pregnancy, childbirth, and the crucial early days and years of life; and place—between homes and health system, including linkages between various levels of health facilities.[44,45] The Mexican diagonal approach and the APV already contain in their design some of the necessary ingredients for successful reduction of overall child mortality. We must maintain the investments and commitments over the years to come, and continue to rigorously assess progress and effective coverage.

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J Sepúlveda coordinated the group and each step of the process. J Sepúlveda, F Bustreo, R Tapia, J Rivera, R Lozano, G Oláiz, V Partida, L García-García, and J L Valdespino participated in the conceptual framework, collection and analysis of data, and wrote and reviewed the report.

Conflict of interest statement

We declare that we have no conflict of interest.

Acknowledgments

We thank Secretary of Health Julio Frenk Mora, who saw the opportunity to write this paper, and the other authors of the *Lancet* Mexico Series for their valuable comments and suggestions. We acknowledge the support and cooperation of Cuauhtémoc Ruiz Matus, Francisco Becerra, and Florencia Zulberti; and Jesús Kumate, who was the driving force behind most of the child health programmes described here when he was Under-Secretary of Health (1985–1988) and Secretary of Health (1988–1994). We also appreciate the useful comments of the peer reviewers.

References

1 Black RE, Morris SS, Bryce J. Where and why are 10 million children dying every year? *Lancet* 2003; **361:** 2226–34.
2 Lawn JE, Cousens S, Bhutta ZA, et al. Why are 4 million newborn babies dying each year? *Lancet* 2004; **364:** 399–401.
3 Jones G, Steketee RW, Black RE, Bhutta ZA, Morris SS. How many child deaths can we prevent this year? *Lancet* 2003; **362:** 65–71.
4 Bryce J, Terreri N, Victora C, et al. Countdown to 2015: tracking intervention coverage for child survival. *Lancet* 2006; **368:** 1067–76.
5 Mathers CD, Fat DM, Inoue M, Rao C, Lopez AD. Counting the dead and what they died from: an assessment of the global status of cause of death data. *Bull World Health Organ* 2005; **83:** 171–77.
6 CONAPO. Estimaciones y proyecciones del Consejo Nacional de Población, 2002: Consejo Nacional de Población, 2006.
7 Brass W. Methods for estimating fertility and mortality from limited and defective data (1975). Occasional publication of the Laboratory for Population Statistics, University of North Carolina, Chapel Hill, NC, USA.
8 Resano-Perez E, Mendez-Ramirez I, Shamah-Levy T, Rivera JA, Sepúlveda-Amor J. Methods of the National Nutrition Survey 1999. *Salud Publica Mex* 2003; **45** (suppl 4)**:** S558–64.
9 Sepúlveda-Amor J, Lezana-Hernandez M, Tapia-Conyer R, Valdespino J, Madrigal H, Kumate J. [Nutritional status of pre-school children and women in Mexico: results of a probabilistic national survey]. *Gac Med Mex* 1990; **126:** 207–24.
10 WHO. Measurement of nutritional impact. World Health Organization: Geneva, 1979.
11 Partida-Bush V. La mortalidad en los primeros años de vida. Mexico, ante los desafíos de desarrollo del milenio. Mexico: Consejo Nacional de Poblacion, 2005: 193–214.
12 Mosley WH, Chen LC. An analytical framework for the study of child survival in developing countries. 1984. *Bull World Health Organ* 2003; **81:** 140–45.
13 Caulfield L, Richard S, Rivera J, Musgrove P, Black R. Stunting, Wasting, and Micronutrient Deficiency Disorders. Disease Control Priorities in Developing Countries. 2nd edn. Washington, DC: The World Bank and Oxford University Press, 2006: 551–67.
14 Rivera JA, Sepúlveda Amor J. Conclusions from the Mexican National Nutrition Survey 1999: translating results into nutrition policy. *Salud Publica Mex* 2003; **45** (suppl 4)**:** S565–75.
15 Sepúlveda J. Foreword. In: Jamison D, Breman J, Measham A, et al., eds. Disease Control Priorities in Developing Countries. 2nd edn. Washington, DC: The World Bank and Oxford University Press, 2006.
16 Victora CG, Bryce J, Fontaine O, Monasch R. Reducing deaths from diarrhoea through oral rehydration therapy. *Bull World Health Organ* 2000; **78:** 1246–55.
17 Cifuentes E, Hernandez JE, Venczel L, Hurtado M. Panorama of acute diarrhoeal diseases in Mexico. *Health Place* 1999; **5:** 247–55.
18 Cifuentes E, Mazari-Hiriart M, Carneiro F, Bianchi F, Gonzalez D. The risk of enteric diseases in young children and environmental indicators in sentinel areas of Mexico City. *Int J Environ Health Res* 2002; **12:** 53–62.
19 Sepúlveda J, Valdespino JL, García-García L. Cholera in Mexico: the paradoxical benefits of the last pandemic. *Int J Infect Dis* 2006; **10:** 4–13.
20 Robles-Sardin AE, Astiazaran-Garcia H, Davalos-Navarro R, Quihui-Cota L, Cabrera-Pacheco RM, Valencia ME. [Effect of supplementation with a massive dose of vitamin A in children 6 to 36 months of age]. *Salud Publica Mex* 1998; **40:** 309–15.
21 Valdespino JL. WHO Schistosomiasis and Intestinal Parasites Unit, Division of Control of Tropical Diseases. Report of the WHO informal consultation on the use of chemotherapy for the control of morbidity due to soil-transmitted nematodes in humans Geneva 29 April to 1 May 1996. WHO/CTD/SIP/96.2. Geneva: World Health Organization, 1996.
22 Rivera JA, Sotres-Alvarez D, Habicht JP, Shamah T, Villalpando S. Impact of the Mexican program for education, health, and nutrition (Progresa) on rates of growth and anemia in infants and young children: a randomized effectiveness study. *JAMA* 2004; **291:** 2563–70.
23 Secretaria de Salud. Programa de Accion: "Arranque Parejo en la Vida". Mexico DF: Secretaria de Salud, 2002.
24 Lozano R, Soliz P, Gakidou E, et al. Benchmarking of performance of Mexican states with effective coverage. *Lancet* 2006; published online Oct 25. DOI:10.1016/S0140-6736(06)69566-4.
25 Dorfman R. Formula for the Gini coefficient. *Rev Econ Stat* 1979; **61:** 146–49.
26 Hernandez-Laos E, Velazquez-Roa J. Globalización, desigualdad y pobreza. Lecciones de la experiencia mexicana. México, DF: Plaza y Valdés Editores, 2003.
27 Wagstaff A. Socioeconomic inequalities in child mortality: comparisons across nine developing countries. *Bull World Health Organ* 2000; **78:** 19–29.
28 Frenk J, Sepúlveda J, Gomez-Dantés O, Knaul F. Evidence-based health policy: three generations of reform in Mexico. *Lancet* 2003; **362:** 1667–71.
29 Frenk J. Bridging the divide: global lessons from evidence-based health policy in Mexico. *Lancet* 2006; **368:** 954–61.
30 Frenk J, González-Pier E, Gomez-Dantes O, Lezana MA, Knaul F. Comprehensive reform to improve health system performance in Mexico. *Lancet* 2006; published online Oct 25. DOI:10.1016/S0140-6736(06)69564-0.

31 Victora CG, Olinto MT, Barros FC, Nobre LC. Falling diarrhoea mortality in Northeastern Brazil: did ORT play a role? *Health Policy Plan* 1996; **11:** 132–41.

32 González-Pier E, Gutiérrez-Delgado C, Stephens G, et al. Priority-setting for health interventions in Mexico's system of Social Protection in Health. *Lancet*; **368:** published online Oct 25; DOI:10.1016/S0140-6736(06)69567-6.

33 Brown KH. Diarrhea and malnutrition. *J Nutr* 2003; **133:** 328S–32S.

34 Scrimshaw NS, Taylor CE, Gordon AJE. Interactions of Nutrition and Infection. WHO monograph series no 57. Geneva: World Health Organization, 1968.

35 Sepúlveda J, Willett W, Munoz A. Malnutrition and diarrhea. A longitudinal study among urban Mexican children. *Am J Epidemiol* 1988; **127:** 365–76.

36 Pelletier DL, Frongillo EA Jr, Schroeder DG, Habicht JP. The effects of malnutrition on child mortality in developing countries. *Bull World Health Organ* 1995; **73:** 443–48.

37 Wagstaff A, Bustreo F, Bryce J, Claeson M. Child health: reaching the poor. *Am J Public Health* 2004; **94:** 726–36.

38 Jalan J, Ravallion M, eds. Does Piped Water Reduce Diarrhea for Children in Rural India? Washington DC: World Bank, 2001.

39 Lee L, Rosenzweig M, Pitt M. The effects of improved nutrition, sanitation, and water quality on child health in high-mortality populations. *J Econometrics* 1997; **77:** 209–35.

40 Merrick TW. The effect of piped water on early childhood mortality in urban Brazil, 1970 to 1976. *Demography* 1985; **22:** 1–24.

41 Darmstadt GL, Bhutta ZA, Cousens S, Adam T, Walker N, de Bernis L. Evidence-based, cost-effective interventions: how many newborn babies can we save? *Lancet* 2005; **365:** 977–88.

42 Knippenberg R, Lawn JE, Darmstadt GL, et al. Systematic scaling up of neonatal care in countries. *Lancet* 2005; **365:** 1087–98.

43 Martines J, Paul VK, Bhutta ZA, et al. Neonatal survival: a call for action. *Lancet* 2005; **365:** 1189–97.

44 Tinker A, ten Hoope-Bender P, Azfar S, Bustreo F, Bell R. A continuum of care to save newborn lives. *Lancet* 2005; **365:** 822–25.

45 WHO. World Health Report 2005. Make every mother and child count. Geneva: World Health Organization, 2005.

46 Anand S, Barnighausen T. Human resources and health outcomes: cross-country econometric study. *Lancet* 2004; **364:** 1603–09.