Child development in developing countries 1

Developmental potential in the first 5 years for children in developing countries

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This is the first in a Series of three articles about child development in developing countries

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Many children younger than 5 years in developing countries are exposed to multiple risks, including poverty, malnutrition, poor health, and unstimulating home environments, which detrimentally affect their cognitive, motor, and social-emotional development. There are few national statistics on the development of young children in developing countries. We therefore identified two factors with available worldwide data—the prevalence of early childhood stunting and the number of people living in absolute poverty—to use as indicators of poor development. We show that both indicators are closely associated with poor cognitive and educational performance in children and use them to estimate that over 200 million children under 5 years are not fulfilling their developmental potential. Most of these children live in south Asia and sub-Saharan Africa. These disadvantaged children are likely to do poorly in school and subsequently have low incomes, high fertility, and provide poor care for their children, thus contributing to the intergenerational transmission of poverty.

Introduction

A previous *Lancet* series[1] focused attention on the more than 6 million preventable child deaths every year in developing countries. Unfortunately, death is the tip of the iceberg. We have made a conservative estimate that more than 200 million children under 5 years fail to reach their potential in cognitive development because of poverty, poor health and nutrition, and deficient care. Children's development consists of several interdependent domains, including sensory-motor, cognitive, and social-emotional, all of which are likely to be affected. However, we focus on cognitive development because of the paucity of data from developing countries on other domains of young children's development. The discrepancy between their current developmental levels and what they would have achieved in a more nurturing environment with adequate stimulation and nutrition indicates the degree of loss of potential. In later childhood these children will subsequently have poor levels of cognition and education, both of which are linked to later earnings. Furthermore, improved parental education, particularly of mothers, is related to reduced fertility,[2,3] and improved child survival, health, nutrition, cognition, and education.[3–7] Thus the failure of children to fulfil their developmental potential and achieve satisfactory educational levels plays an important part in the intergenerational transmission of poverty. In countries with a large proportion of such children, national development is likely to be affected.

The first UN Millennium Development Goal is to eradicate extreme poverty and hunger, and the second is to ensure that all children complete primary schooling.[8] Improving early child development is clearly an important step to reaching these goals. Although policymakers recognise that poverty and malnutrition are related to poor health and increased mortality,[5,9] there is less recognition of their effect on children's development or of the value of early intervention. This paper is the first of a three part series reviewing the problem of loss of developmental potential in young children in developing countries. The first paper describes the size of the issue, the second paper discusses the proximal causes of the loss, and the final paper reviews existing interventions. Here, we first examine why early child development is important and then develop a method to estimate the numbers of children who fail to fulfil their developmental potential. We then estimate the loss of income attributed to poor child development.

Search strategy and selection criteria

The following databases were searched for studies in developing countries reported in English from 1985, to February, 2006: BIOSIS via ISI web of science, PubMed, ERIC, PsychInfo, LILACS, EMBASE, SIGLE, and Cochrane Review, along with published documents from the World Bank, UNICEF, and UNESCO's International Bureau of Education. References in retrieved papers were examined and further information sought from experts in the field. Keywords used for search 1 were: "developing countries" or "developing nations" or "third world" and "child development" or "cognitive development" or "language development" or "cognition" or "education" or "school enrolment", "school dropout", "grade retention", "grade attained", "educational achievement". For search 2 we also used stunting or malnutrition or undernutrition, and for search 3 we used search 1 keywords and poverty or income or economic status.

Why early child development is important

Children's development is affected by psychosocial and biological factors[10] and by genetic inheritance. Poverty and its attendant problems are major risk factors.[11–15] The first few years of life are particularly important because vital development occurs in all domains.[16] The brain develops rapidly through neurogenesis, axonal and dendritic growth, synaptogenesis, cell death, synaptic pruning, myelination, and gliogenesis. These ontogenetic events happen at different times (figure 1)[17] and build on each other, such

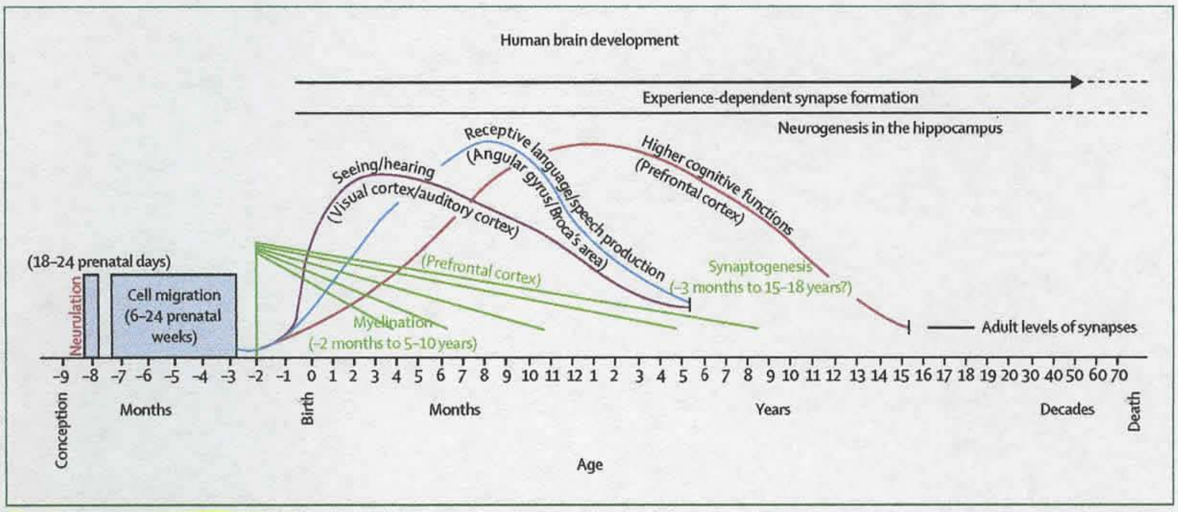

***Figure 1:* Human brain development**
Reproduced with permission of authors and American Psychological Association[37] (Thompson RA, Nelson CA. Developmental science and the media: early brain development. *Am Psychol* 2001; **56:** 5–15).

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that small perturbations in these processes can have long-term effects on the brain's structural and functional capacity.

Brain development is modified by the quality of the environment. Animal research shows that early under-nutrition, iron-deficiency, environmental toxins, stress, and poor stimulation and social interaction can affect brain structure and function, and have lasting cognitive and emotional effects.[18–24]

In humans and animals, variations in the quality of maternal care can produce lasting changes in stress reactivity,[25] anxiety, and memory function in the offspring.

Despite the vulnerability of the brain to early insults, remarkable recovery is often possible with interventions,[18,26,27] and generally the earlier the interventions the greater the benefit.[28]

Early cognitive development predicts schooling

Early cognitive and social-emotional development are strong determinants of school progress in developed countries.[29–31] A search of databases for longitudinal studies in developing countries that linked early child development and later educational progress identified two studies. In Guatemala, preschool cognitive ability predicted children's enrolment in secondary school[32] and achievement scores in adolescence.[33] In South Africa, cognitive ability and achievement at the end of grade one predicted later school progress.[34] Three further studies had appropriate data that we analysed (from the Philippines[35,36] and Jamaica[37]) or requested the investigators to analyse (from Brazil[38,39]). In each case, multiple regression of educational outcome (or logistic regression for dichotomous variables), controlling for a wealth index,[40] maternal education, and child's sex and age, showed that early cognitive development predicted later school outcomes. Table 1 shows that each SD increase in early intelligence or developmental quotient was associated with substantially improved school outcomes. Further evidence of the importance of early childhood is that interventions at this age[37,41] can have sustained cognitive and school achievement benefits (table 1[35–39]).

Problem of poor development

National statistics on young children's cognitive or social-emotional development are not available for most developing countries, and this gap contributes to the invisibility of the problem of poor development. Failure to complete primary education (Millennium Development Goal 2) gives some indication of the extent of the issue,

	N	Independent variable	Outcome variable	Measure of effect	Estimate	95% CI
Jamaica†	165	IQ on the Stanford Binet test (42) at 7 years	Dropped out before grade 11	Odds ratio	0·53‡	0·32–0·87
			Reading and arithmetic score at age 17	Mean difference in SD	0·65§	0·53–0·78
Philippines	1134	Cognitive Score at 8 years	Ever repeat a grade by age 14 years	Odds ratio	0·60¶	0·49–0·75
Brazil‖	152	DQ on Griffiths test (43) at 4.5 years	Grades attained by age 18 years	Mean difference in grades achieved	0·71**	0·34–1·07

*Adjusted for sex, age, mother's education, and wealth quintile. †Sample consisted of stunted (<–2 SD) children participating in an intervention trial and a non-stunted (>–1 SD) comparison group. Intervention and stunting status were also adjusted for. ‡p=0·0117; Hosmer-Lemeshow goodness-of-fit test p=0·5704. §p<0·0001; R^2=54·4%. ¶p<0·0001; Hosmer-Lemeshow goodness-of-fit test p=0·5375. ‖Boys only. **p=0·0002; R^2=51·9%.

Table 1:* Change in later school outcomes per SD increase in intelligence quotient (IQ) or developmental quotient (DQ) in early life

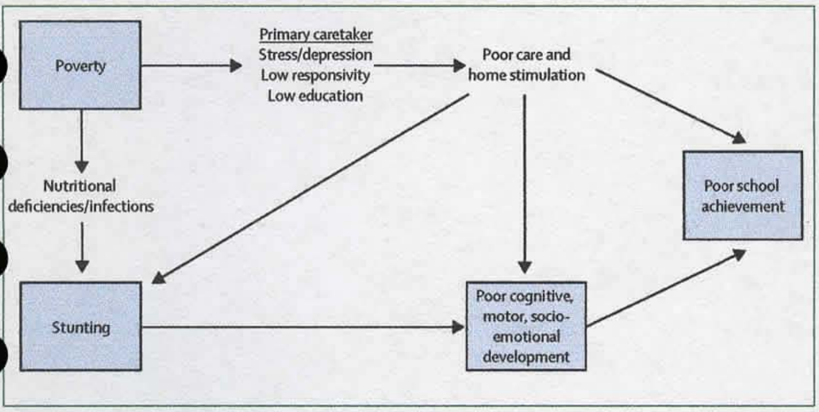

Figure 2: Hypothesised relations between poverty, stunting, child development, and school achievement

although school and family characteristics also play a part. In developing countries, an estimated 99 million children of primary-school age are not enrolled, and of those enrolled, only 78% complete primary school.[44] Most children who fail to complete are from sub-Saharan Africa and south Asia. Only around half of the children enrol in secondary schools. Furthermore, children in some developing countries have much lower achievement levels than children in developed countries in the same grade.[45] In 12 African countries, surveys of grade 6 (end of primary school) children showed that on average 57% had not achieved minimum reading levels (webtable).[46–57]

See Online for webtable

Indicators of poor development

In the following section we estimate the numbers of children who fail to reach their developmental potential. We first identify early childhood growth retardation (length-for-age less than –2 SD according to the National Center for Health Statistics growth reference[58] [moderate or severe stunting]) and absolute poverty as possible indicators for poor development. We then show that they are good predictors of poor school achievement and cognition. Finally, we use these indicators to estimate the number of children involved. We identified stunting and poverty for indicators because they represent multiple biological and psychosocial risks, respectively, stunting and to a lesser extent poverty are consistently defined across countries, both are relevant to most developing countries, and worldwide data are available. We omit other risk factors that could affect children's development because they fail to fit all the above criteria and there is marked overlap between them and with stunting and poverty. However, by using only two risk factors we recognise that our estimate is conservative.

Assessment of stunting, poverty, and child development

Growth potential in preschool children is similar across countries,[59,60] and stunting in early childhood is caused by poor nutrition and infection rather than by genetic differences. Patterns of growth retardation are also similar across countries.[61] Faltering begins in utero or soon after birth, is pronounced in the first 12–18 months,[62] and could continue to around 40 months, after which it levels off. Some catch-up might take place,[63] but most stunted children remain stunted through to adulthood.

There are multiple approaches to measuring poverty.[64] One assessment used measures of deprivation of basic needs, availability of services, and infrastructure,[65] and surveys in 45 developing countries reported that 37 % of children lived in absolute poverty, more so in rural areas. We use the percentage of people having an income of less than US$1 per day, adjusted for purchasing power parity by country[66] because this information is available for the largest number of countries. This indicator is considered the best available despite excluding important components of poverty,[67] and is more conservative than measures based on deprivation[65] since it identifies only the very poorest families.

Poverty is associated with inadequate food, and poor sanitation and hygiene that lead to increased infections and stunting in children. Poverty is also associated with poor maternal education, increased maternal stress and depression,[12,68,69] and inadequate stimulation in the home.[70] All these factors detrimentally affect child development (figure 2).[12,70] Poor development on enrolment leads to poor school achievement, which is further exacerbated by inadequate schools and poor family support (due to economic stress, and little knowledge and appreciation of the benefits of education).

Risk factors related to poverty frequently occur together, and the developmental deficit increases with the number of risk factors.[15,33,71] Deficits in development are often seen in infancy[31,72] and increase with age.[71,73,74] For example, a cross sectional study in Ecuador reported that the language deficit in poor children increased from 36 to 72 months of age compared with wealthier children (figure 3).[70]

As a first step to examining the use of poverty and stunting as indicators, we did regression analyses of the relation between the percentage of children completing primary school[44] and poverty and stunting, with data from

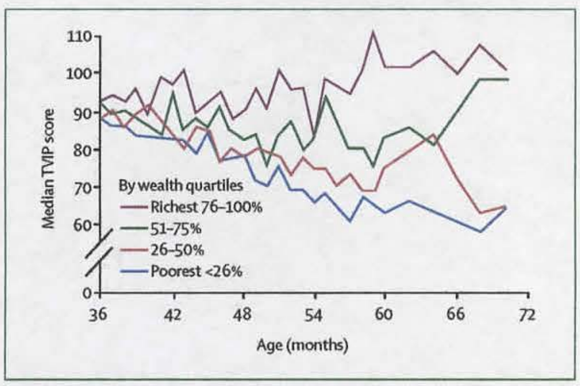

Figure 3: Vocabulary scores of Ecuadorian children aged 36 to 72 months by wealth quartiles

TVIP=Test de Vacabulario en Imagenes Peabody. Reproduced with permission from the authors.[70]

developing countries (defined as the non-industrialised countries in UNICEF classification).[75] Stunting prevalence was based on the WHO Global Database on Child Growth and Malnutrition,[76] and absolute poverty prevalence came from UNICEF.[75] In 79 countries with information on stunting and education, the average prevalence of stunting was 26·0%. For every 10% increase in stunting (less than –2 SD), the proportion of children reaching the final grade of primary school dropped by 7·9% (b=–0·79, 95% CI –1·03 to –0·55, R^2=36·2%, p<0·0001). In 64 countries with information on absolute poverty, the average prevalence was 20%; for every 10% increase in the prevalence of poverty there was a decrease of 6·4% (b=–0·64, 95% CI=–0·81 to –0·46, R^2=46·3%, p<0·0001) of children entering the final grade of primary school.

To establish whether stunting and absolute poverty were useful predictors of poor child development in individual studies, we searched the published papers and identified all observational studies that related stunting and poverty in early childhood to concurrent or later child development or educational outcomes. We also identified all studies that related stunting at school age to cognition or education, based on the assumption that stunting developed in early childhood. We selectively reviewed studies of older children that linked economic status to school achievement or cognition, choosing examples with international or nationally representative samples. We assessed whether measurements of the risk factors and developmental outcome were clearly reported, and the relation between them (adjusted or unadjusted) was examined. We did not assess causality.

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Stunting and poor development

Cross-sectional studies

Many cross-sectional studies of high-risk children have noted associations between concurrent stunting and poor school progress or cognitive ability. Stunted children, compared with non-stunted children, were less likely to be enrolled in school (Tanzania[77]), more likely to enrol late (eg, Nepal,[78] and Ghana and Tanzania[79]), to attain lower achievement levels or grades for their age (Nepal,[78] China,[80] Jamaica,[81,82] India,[83] Philippines,[84–86] Malaysia,[87] Vietnam,[88] Brazil,[89] Turkey,[90] Guatemala [only in boys][91]), and have poorer cognitive ability or achievement scores (Kenya,[92] Guatemala,[93] Indonesia,[94] Ethiopia, Peru, India, and Vietnam,[95] and Chile[96]). Only three studies[97–99] reported no significant relation between stunting and poor school progress. In the Philippines, associations were recorded with weight-for-height,[99] and in Ghana[98] stunted children enrolled in school late but taller children left school early to earn money or help with family farming.

There are fewer studies with younger children. In Guatemala,[100] Jamaica,[101] Chile,[102] and Kenya,[103] associations between height and child development measures were reported. Age of walking was related to height-for-age in Zanzibarian[104] and Nepalese children,[105] but height was not related to motor development in Kenyans at 6 months of age.[106] Weight-for-age, which indicates a combination of weight-for-height and height-for-age, has often been used instead of stunting to measure nutrition in young children. Weight-for-age was associated with child development in India,[107] Ethiopia,[108] and Bangladesh.[109,110]

Longitudinal studies

In Pakistan[111] and Guatemala,[112] growth retardation in infancy predicted age of walking. Excluding studies of children hospitalised for severe malnutrition, four published longitudinal studies showed that early stunting predicted later cognition, school progress, or both. Stunting at 24 months was related to cognition at 9 years in Peru[113] and, in the Philippines to intelligent quotient (IQ) at 8 and 11 years, age at enrolment in school, grade repetition, and dropout from school.[35,36] In Jamaica, stunting before 24 months was related to cognition and school achievement at 17–18 years and dropout from school.[37] In Guatemala, height at 36 months was related to cognition, literacy, numeracy, and general knowledge in late adolescence,[114] and stunting at 72 months was related to cognition between 25–42 years.[115] In Indonesia,[116] weight-for-age at 1 year of age did not predict scores on a cognitive test at 7 years, whereas growth in weight between 1 and 7 years did.

To assess the size of the deficit in later function associated with a loss of 1 SD in height in early childhood, we reanalysed the data from Philippines,[36] Jamaica,[37] Peru,[113] and Indonesia[116] (Guatemala had too few well-nourished children to be included). We added two other longitudinal studies, from Brazil[38] and South Africa,[117] that had not previously analysed the effect of stunting (table 2). In these studies, stunting between 12 and 36 months was

	Philippines	South Africa	Indonesia	Brazil*	Peru	Jamaica†	
	Cognitive score (8 years, n=2489)	Ravens Matrices[120] (7 years, n=603) ‡	Reasoning and arithmetic (9 years, n=368)	Attained grades (18 years, n=2041)	WISC IQ[119] (9 years, n=72)	WAIS IQ‡[118] (17–18 years, n=165)	Reading and arithmetic‡ (17–18 years)
Not stunted	56·4	0·17	11·2	8·1	92·3	0·38	0·40
Mildly stunted	53·8 (–0·21)	0·05 (–0·12)	10·3 (–0·26)	7·2 (–0·4)	89·8 (–0·20)		
Moderately or severely stunted	49·6 (–0·54)	–0·23 (–0·40)	9·7 (–0·43)	6·5 (–0·7)	79·2 (–1·05)	–0·55 (–0·93)	–0·60 (–1·00)

Data are mean (effect size as unadjusted difference from non-stunted children in z scores). *Males only. †The sample comprised stunted (<–2 SD) children participating in an intervention trial and a non-stunted (>–1 SD) comparison group. ‡SD scores. WISC=Wechsler Intelligence Scale for Children. WAIS=Wechsler Adult Intelligence Scale.

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To establish whether stunting and absolute poverty were useful predictors of poor child development in individual studies, we searched the published papers and identified all observational studies that related stunting and poverty in early childhood to concurrent or later child development or educational outcomes. We also identified all studies that related stunting at school age to cognition or education, based on the assumption that stunting developed in early childhood. We selectively reviewed studies of older children that linked economic status to school achievement or cognition, choosing examples with international or nationally representative samples. We assessed whether measurements of the risk factors and developmental outcome were clearly reported, and the relation between them (adjusted or unadjusted) was examined. We did not assess causality.

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Moderately or severely stunted	49·6 (–0·54)	–0·23 (–0·40)	9·7 (–0·43)	6·5 (–0·7)	79·2 (–1·05)	–0·55 (–0·93)	–0·60 (–1·00)

Data are mean (effect size as unadjusted difference from non-stunted children in z scores). *Males only. †The sample comprised stunted (<–2 SD) children participating in an intervention trial and a non-stunted (>–1 SD) comparison group. ‡SD scores. WISC=Wechsler Intelligence Scale for Children. WAIS=Wechsler Adult Intelligence Scale.

Table 2: **Descriptive summary of follow-up studies showing associations between stunting in early childhood and later scores on cognitive tests and school outcomes**

	Philippines	Indonesia	South Africa	Brazil	Guatemala*	
	Cognitive score (8 years of age at assessment, n=2485)	Reasoning and arithmetic (9 years of age at assessment, n=371)	Ravens progressive matrices†[120] (7 years of age at assessment, n=1143)	Attained grades (18 years of age at assessment, n=2222)	**Reading and vocabulary (26–41 years of age at assessment)**	
					Boys (n=683)	Girls (n=786)
Fifth quintile (wealthiest)	56·9	12·1	0·47	9·3	50·9	44·8
Fourth quintile	52·5 (–0·35)	11·0 (–0·31)	0·13 (–0·34)	8·2 (–0·48)		
Third quintile	51·6 (–0·42)	11·0 (–0·31)	–0·16 (–0·63)	7·4 (–0·84)	43·3 (–0·45)	43·6 (–0·01)
Second quintile	49·4 (–0·60)	9·5 (–0·74)	–0·20 (–0·67)	6·8 (–1·11)		
First quintile (poorest)	46·4 (–0·84)	8·4 (–1·06)	–0·23 (–0·70)	6·5 (–1·24)	41·0 (–0·53)	37·6 (–0·45)

Data are mean (effect size as unadjusted difference from the richest quintile in z scores). *Tertiles. †SD scores.

Table 3: **Descriptive summary of follow-up studies showing association between wealth quintiles in early childhood, and later cognitive and school outcomes**

related to later measures of cognition[117] or grade attainment.[38] Being moderately or severely stunted compared with not stunted (height-for-age greater than –1 SD) was associated with scores for cognition in every study, and the effect size varied from 0·4 to 1·05 SD. Stunting was also associated with attained grades. The consistent relation between early childhood stunting and poor child development, with moderate to large effects, justifies its use as an indicator of poor development.

Poverty and poor development

Cross-sectional studies

Nationally representative studies from many countries have seen relations between household wealth and school enrolment, early dropout, grades attained, and achievement.[46–57,95,121–123] Gaps in mean attained grades between the richest and poorest children were particularly large in western and central Africa and south Asia, reaching as high as ten grades in India.[123] In Zambia, poor children were four times more likely to start school late than the richest children, and in Uganda the difference was ten times. Representative surveys in 16 Latin American countries[124] also reported that family income predicted the probability of completing secondary schooling. Rural children were worse off in most studies.[123]

There are fewer studies on wealth and development in preschool children. In 3668 Indian children under 6 years, paternal occupation was associated with developmental milestones.[107] In Ecuador, wealth was related to vocabulary scores of children from 3 to 6 years of age.[70] In Jamaica, 71·4% of 3887 children from more affluent families entering fee-paying preparatory schools had mastery of all four school-readiness subjects tested, compared with 42·7% of 22 241 children entering free government primary schools.[125] An association between poverty and child development was recorded at as early as 6 months of age in Egypt,[126] 12 months in Brazil,[127] 10 months in India,[128] and 18 months in Bangladesh.[68] In another Brazilian study, preschool children's language scores were associated with maternal working but not income.[129]

Longitudinal studies

Several longitudinal studies have assessed the association between wealth at birth and later educational and cognitive attainment. Socioeconomic status in infancy was associated with children's cognition at 5 years of age in Kenya.[130] In Brazil, parental income at birth was associated with poor performance on a developmental screening test at 12 months in 1400 infants, and with school grades attained at 18 years in 2222 men on army enlistment.[38] In Guatemala,[131] socioeconomic status at birth was associated with school attainment and cognition in 1469 adults. We analysed data from three other longitudinal studies (table 3). Wealth quintiles at birth were related to IQ at 8 years in the Philippines,[36] and to cognitive scores at 7 years in South Africa[117] and 9 years in Indonesia.[116] The effect size in all these studies was substantial, ranging from 0·70 to 1·24 SD scores between the top and bottom quintiles in children from varied socioeconomic backgrounds, and from 0·45 to 0·53 SD scores in Guatemala where all study children were poor. We had to use wealth quintiles rather than the cutoff of US$1 per day because of limitations in the data. Poor children consistently had considerable developmental deficits compared with more affluent children. Thus poverty can be used as an indicator of poor development.

Estimate of number of children who are stunted or living in poverty

We estimated the prevalence of children under 5 years who are stunted or living in absolute poverty in developing countries. Data for the number of children in 2004 and percent living in poverty were obtained from UNICEF[75] and data for stunting obtained from WHO.[76] Of the 156 countries analysed, 126 have a known stunting prevalence and 88 have a known proportion living in absolute poverty (table 4). We replaced missing country values of stunting and poverty with the average prevalence of the region for the purpose of estimating the proportion and number of disadvantaged children. Sensitivity analysis based on imputing stunting by poverty and imputing poverty by stunting through regression analysis gave similar results to using the regional average

	Population younger than 5 years *	Percentage living in poverty*†‡	Number living in poverty	Percentage stunted†‡§	Number stunted	Percentage stunted, living in poverty or both¶	Number stunted, living in poverty or both¶
Sub-Saharan Africa	117·0	46%	54·3	37%	43·7	61%	70·9
Middle east and north Africa	44·1	4%	1·6	21%	9·1	22%	9·9
South Asia	169·3	27%	46·3	39%	65·6	52%	88·8
East Asia and Pacific	145·7	11%	16·6	17%	25·2	23%	33·6
Latin America and the Caribbean	56·5	10%	5·9	14%	7·9	19%	10·8
Central and eastern Europe	26·4	4%	1·0	16%	4·2	18%	4·7
Developing countries	559·1	22%	125·6	28%	155·7	39%	218·7

*Population and poverty source data from UNICEF State of the World's Children, 2006.[75] †Where data missing, regional averages were used for percentage living in poverty and percentage stunted. ‡We extrapolated poverty figures to 2004 based on findings from Chen and Ravallion[132] that, in the 1990s and early 2000s, decline in absolute poverty (less than US$1 per day) was stagnant in all developing regions except east Asia and south Asia. In east Asia, the decline was levelling off and could be captured accurately by a non-linear regression equation (R^2=93%); in south Asia the decline could be accurately captured by a linear equation (R^2=99%). We used their equations[132] to estimate the expected poverty figures for east Asia and Pacific and south Asia for each country in these regions in the latest years with available poverty data, and then calculated the difference between the expected and observed figures for each country. We added this country-level difference to the regional figure in 2004 projected by Chen and Ravallion's equations to obtain the projected poverty level in 2004 for each country. We used the observed poverty figures as the 2004 estimates for other developing countries. We projected stunting figures for every country except those in the central and eastern Europe region to 2004 based on sub-regional linear trends estimated by de Onis, et al.[133] de Onis, et al, did not include the central and eastern Europe region in their analysis. Poverty reduction was stagnant in the 1990s and early 2000s[132] in central and eastern Europe. We therefore assume that for countries in this region there has been no change in stunting prevalence in the period concerned.[3] §Stunting source data taken from WHO Global Database on Child Growth and Malnutrition.[76] ¶Based on estimate that prevalence of stunting among children in poverty is 50%.

Table 4: **Prevalence and number (in millions) of disadvantaged children under 5 years by region in 2004**

(webappendix). The most recent poverty data we obtained was up to year 2003, with median 2000 and inter-quartile range of 4 years. The most recent stunting data were up to year 2004, with median 2000 and inter-quartile range of 3 years. We extrapolated all the stunting and poverty data to the year 2004 (table 4).[75,76,132,133]

There are 559 million children under 5 years in developing countries, 156 million of whom are stunted and 126 million are living in absolute poverty (table 4). To avoid the double-counting of children who are both stunted and living in poverty, we estimated the prevalence of stunting among children in poverty in countries with both indicators available, and calculated the numbers of stunted children plus the number of non-stunted children living in poverty. We refer to these children as disadvantaged.

The relation between prevalence of stunting and poverty at the country level is non-linear and can be captured by a regression line of percentage stunted=$7\cdot8+4\cdot2\times\sqrt{\%\text{poverty}}$ (using the 82 countries with available data; R^2=40·9%). Extrapolation of this regression line gives an estimate of the prevalence of stunting in people living in poverty to be 50%. Hence, the number of children stunted or living in poverty is the sum of the total number of stunted children (156 million) plus 50% of children living in poverty (63 million) making a total of 219 million disadvantaged children, or 39% of all children under 5 in developing countries.

An alternative estimate of the prevalence of stunting in children in poverty was obtained by analysis of micro-level data from 13 Multiple Indicator Cluster Surveys[134] in developing countries with data for both stunting and a wealth index. A meta-analysis of the datasets showed that 43% of children below the poverty line were stunted. Based on this estimate, the total number of disadvantaged children is 227 million. Although the estimate of 219 million is inevitably crude, it is more conservative than the alternative estimate of 227 million; we use the lower estimate in the rest of the paper.

See Online for webappendix

Figure 4 shows the numbers of disadvantaged children in millions by region. Most disadvantaged children (89 million) are in south Asia. The top ten countries with the largest number of disadvantaged children (in millions) are: India 65, Nigeria 16, China 15, Bangladesh 10, Ethiopia 8, Indonesia 8, Pakistan 8, Democratic Republic of the Congo 6, Uganda 5, and Tanzania 4. These ten countries account for 145 (66%) of the 219 million disadvantaged children in the developing world.

Figure 5 shows the prevalence by country. Sub-Saharan Africa has the highest prevalence of disadvantaged children under 5 years, 61% (table 4), followed by south Asia with 52%.

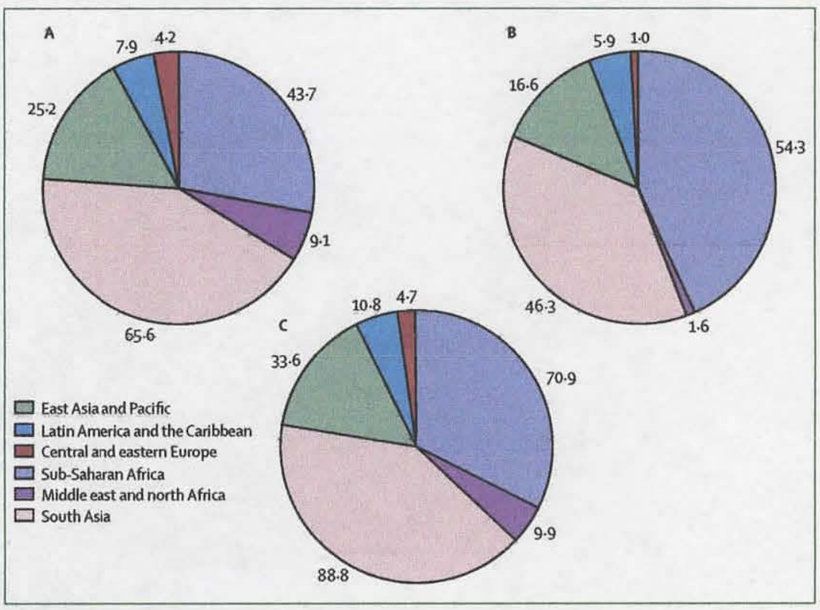

Figure 4: **Regional distribution of the number of children under 5 years in millions**
(A) stunted, (B) living in poverty, and (C) disadvantaged (either stunted, living in poverty, or both) in year 2004.

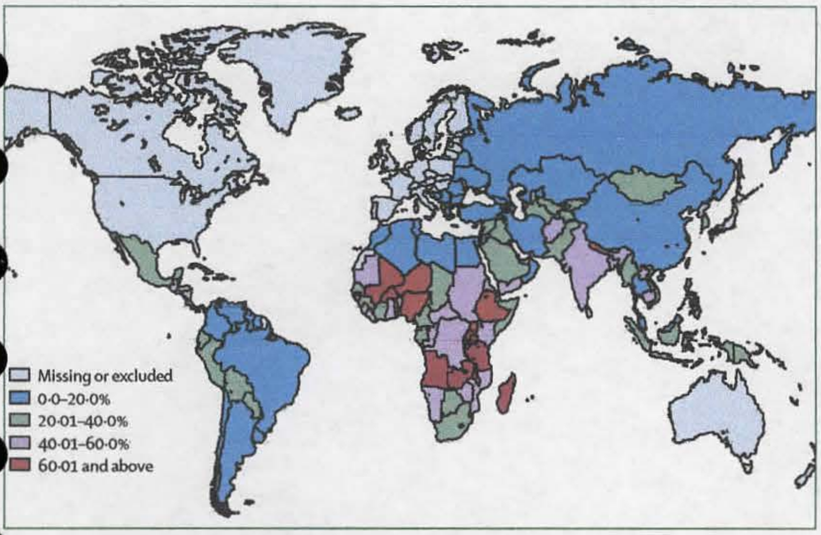

Figure 5: Percentage of disadvantaged children under 5 years by country in year 2004

Limitations of the estimate of numbers of disadvantaged children

More than 200 million disadvantaged children is an exceedingly large amount. However, limitations in the data suggest that the estimate is conservative. We assumed that the percentage of people in absolute poverty was equal to the percentage of children in absolute poverty. This assumption probably underestimates the number of children because poverty is associated with higher fertility levels and larger household size. Furthermore, less than US$1 per day is an extreme measure of poverty, and children in slightly better off households are probably also at risk. Also, we did not take into account many other risk factors for poor development, such as maternal illiteracy, unstimulating homes, and micronutrient deficiencies.

WHO recently produced new growth standards,[135] and the –2 SD curves for length and height-for-age are slightly higher than the –2SD curves of the previous standards in certain age ranges under 60 months. Therefore, if we used the new growth standards our estimate of prevalence of stunting and disadvantaged children would be slightly higher.

	Income quintile				
	Poorest 20%	2nd quintile	3rd quintile	4th quintile	Wealthiest 20%
HAZ ≥ -1	6·96 (2·11)	7·10 (2·17)	7·69 (2·05)	8·43 (1·89)	9·40 (1·83)
n	141	213	274	325	336
HAZ -1 to -2	6·67 (2·05)	6·44 (2·08)	7·06 (1·92)	7·74 (1·91)	9·27 (2·03)
n	116	123	127	111	59
HAZ < -2	5·54 (2·17)	6·56 (1·98)	7·03 (2·05)	6·65 (2·42)	8·69 (2·29)
n	71	77	38	17	13

Data are mean (SD) unless otherwise stated. HAZ=height-for-age z score. *Data provided by the Pelotas Birth Cohort Study, Brazil.[38]

Table 5: Attained grades in 18-year-old Brazilian men, by income level, and stunting status in early childhood*

The precision of the estimate of disadvantaged children would be improved with internationally comparable data for maternal education and stimulation in the home. We also need data to establish which cutoff for income and poverty is best for identifying children at high risk. Internationally comparable and feasible measures of child development would produce the best estimate of disadvantaged children, and there is an urgent need to develop such measures both to more accurately assess the problem and to assess interventions.

Some of the disadvantaged children would have IQs of less than –2 SD, the level used to diagnose mild mental retardation (IQ 50–69).[136] However, a deficit in adaptive behaviour is usually needed to make the diagnosis and these data are not available, although most would have learning problems in school and restricted employment opportunities. We are concerned in this series about the loss of potential across the whole range of cognitive ability.

Economic implications of poor child development

Disadvantaged children in developing countries who do not reach their developmental potential are less likely to be productive adults. Two pathways reduce their productivity: fewer years of schooling, and less learning per year in school. What is the economic cost of one less year of schooling? Studies from 51 countries show that, on average, each year of schooling increases wages by 9·7%.[137] Although some of the studies had methodological weaknesses, this average matches another more rigorous study,[138] which reported that each year of schooling in Indonesia increased wages by 7–11%.

Both stunting and poverty are associated with reduced years of schooling. Table 5 presents data for school grades attained in 18-year-old Brazilian men,[38] by income quintile at birth and stunting status in the first 2 years. We estimate from these data that the deficit attributed to being stunted (height-for-age less than –2 z scores compared with non-stunted greater than –1 z scores), stratified for income quintiles was 0·91 grades, and the deficit from living in poverty (first *vs* third quintile of income) stratified for stunting status was 0·71 grades. Furthermore, the deficit from being both stunted and in poverty (first income quintile) compared with being non-stunted and in the third income quintile was 2·15 grades.

Stunted children also learn less per year in school. Data from the Philippines has shown that, controlling for years of schooling and income, the combined reading and math test score of stunted children was 0·72 SD below that of non-stunted children. This reduction was equivalent to 2·0 fewer years of schooling.[86] Regression analysis with Jamaican data[37] corroborate this finding; controlling for wealth and grade level, stunted children's combined math and reading test score was 0·78 SD below those of non-stunted children. Controlling for stunting, poor children almost certainly learn less per year in school, but we know of no studies that convincingly estimate the deficit.

	Deficit in school grades attained	Deficit in learning ability per grade in grade equivalents	Total deficit in grade equivalents	Percentage loss of adult yearly income per grade*	Total percentage loss† of adult yearly income (compounded)	Number (%) of children younger than 5 years in developing countries	Average percentage loss of adult yearly income per disadvantaged child
Stunted only	0·91‡	2·0	2·91	8·3%	22·2%	92·9 (16·6%)	19·8%
Poor only	0·71§	≥0¶	0·71¶	8·3%	5·9%	62·8 (11·2%)	
Stunted and poor	2·15‖	≥2·0¶	4·15¶	8·3%	30·1%	62·8 (11·2%)	
Evidence	Brazil[38]	Philippines[86] and Jamaica[37]	Sum of columns 1 and 2	51 countries[137] plus Indonesian study[138]	Combining columns 3 and 4	See table 4	Weighted average from columns 5 and 6

*An increase of one grade of schooling is assumed to increase income by 9%.[137,138] Implies that a reduction of 1 year of schooling will reduce income by 8·3% (1/1·09–1 = 0·083); that is, a person with an income of 91·7 due to a loss of 1 year of schooling would have had an income of 100 (91·7×1·09) had that person not lost that year of schooling. †($1/1·09^{2·91}$)–1=–0·222; ($1/1·09^{0·71}$)–1=–0·059; ($1/1·09^{4·15}$)–1=–0·301. ‡Deficit associated with stunting, controlling for wealth quintiles. (The estimate is a weighted average of the differences between stunted [<–2 z] vs non-stunted [>–1 z] children in the five wealth quintiles, with the weights inversely proportional to the square of the SE of the quintile-specific difference). §Deficit associated with poverty, controlling for stunting (similar method to [‡]). ¶Indicates that the figure is lower bound and under-estimates true figure because the effect of poverty on learning per year of schooling is unknown. ‖Difference between non-stunted and third quintile vs stunted and first quintile in Brazil (table 5).

Table 6: **Deficit associated with stunting, poverty (first vs third quintile of wealth), and both, in schooling and percentage loss in yearly income in developing countries**

Assuming that every year of schooling increases adult yearly income by 9%,[137,138] we estimate that the loss in adult income from being stunted but not in poverty is 22·2%, the loss from living in poverty but not being stunted is 5·9% and from being both stunted and in poverty is 30·1% (table 6). Taking into account the number of children who are stunted, living in poverty, or both (table 6), we calculate the average deficit in adult yearly income for all 219 million disadvantaged children to be 19·8%. This estimate is limited by the scarcity of data for the loss of learning ability of children in poverty, and almost certainly underestimates the true loss.

Clearly, disadvantaged children are destined not only to be less educated and have poorer cognitive function than their peers but also to be less productive. In consideration of the total cost to society of poor early child development, we need to take into account that the next generation will be affected, sustaining existing inequities in society with their attendant problems.[67] Where large numbers of children are affected, national development will also be substantially affected. These costs have to be weighed against those of interventions.

Conclusion

Many children in developing countries are exposed to multiple risks for poor development including poverty and poor health and nutrition. There are few national data for children's development but our conservative estimate is that more than 200 million children under 5 years of age in developing countries are not developing to their full potential. Sub-Saharan African countries have the highest percentage of disadvantaged children but the largest number live in south Asia. The children will subsequently do poorly in school and are likely to transfer poverty to the next generation. We estimate that this loss of human potential is associated with more than a 20% deficit in adult income and will have implications for national development. The proximal causes of poor child development are analysed in the second paper in this series.

The problem of poor child development will remain unless a substantial effort is made to mount appropriate integrated programmes. There is increasing evidence that early interventions can help prevent the loss of potential in affected children and improvements can happen rapidly (see third paper in this series). In view of the high cost of poor child development, both economically and in terms of equity and individual well-being, and the availability of effective interventions, we can no longer justify inactivity.

Conflict of interest statement

We declare that we have no conflict of interest.

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