HK J Paediatr (new series) 2017;**22**:14-25

Effectiveness of Early Childhood Interventions in Promoting Cognitive Development in Developing Countries: A Systematic Review and Meta-analysis

N ***Rao***, J ***Sun***, EE ***Chen***, P ***Ip***

Abstract ***Objective:*** A systematic review and meta-analysis were conducted to compare the effectiveness of different types of early childhood interventions in enhancing cognitive development of children in developing countries, and to identify factors related to intervention efficacy. ***Method:*** The meta-analysis included 106 interventions from 62 studies in 30 developing countries, published between 1992 and 2012. Participants included 43,696 children below 8 years. ***Results:*** Results indicated that comprehensive programs were the most effective (g=1.05), followed by child-focused education and stimulation (g=0.64), parent-focused support (g=0.44), income supplementation (g=0.23), and nutrition and health interventions (g=0.11), respectively. ***Conclusions:*** Early childhood development interventions were effective in improving cognitive development of children in developing countries. The largest effect sizes were associated with comprehensive programs which may be scaled up, taking into account the country context.

Key words Cognitive development; Developing countries; Early childhood intervention; Meta-analysis

Introduction

The foundations of optimal health, development, and educational success are laid in early childhood and research has shown that environmental stimulation directly influences the human brain, which develops very rapidly during the critical early years of life.[1] Hence, effective interventions implemented during a child's early years can have long-term benefits for development.[2-4] Studies that have investigated economic returns on investment, for instance, indicate higher returns to society when the investment is incurred in early childhood than in adulthood.[5] These findings have led to a growing recognition of the importance of early childhood development (ECD) as well as an increased investment in ECD interventions in both developed and developing countries. Many of these interventions have focused on promoting cognitive development.

Typical cognitive development can be broadly defined as expected gains in language, thinking, and understanding, and *atypical development* as a delay in the expected gains. In developing countries, an estimated 200 million children under the age of 5 do not achieve their expected level of cognitive development due to poverty, stunting, and lack of learning opportunities.[6] These children typically have limited access to resources for learning at home and in the community. Research has shown that early adversity – such

Faculty of Education, The University of Hong Kong, Hong Kong, China

N **Rao** (劉麗薇) *PhD, FBPS*

Education University of Hong Kong, Hong Kong, China

J **Sun** (孫瑾) *PhD*

The Hong Kong University of Science and Technology, Hong Kong, China

EE **Chen** (陳伊慈) *EdD*

Department of Paediatrics and Adolescent Medicine, LKS Faculty of Medicine, The University of Hong Kong, Hong Kong, China

P **Ip** (葉柏強) *MBBS, MPH*

Correspondence to: Prof N **Rao** or Dr P **Ip**

Received October 6, 2015

as maternal depression, domestic violence, drug abuse, and poverty – can have a debilitating impact on children's physical and cognitive development, leading to developmental delays and chronic health problems, such as coronary heart disease, diabetes, and depression in later life.[7-10] To tackle this problem, increasing resources have been allocated to ECD intervention programs in developing countries over the years.[11] These interventions have been largely adapted from models used in developed countries. However, interventions that originate in developed countries may not work or be as effective in developing countries, given their disparate socioeconomic and cultural backgrounds.

Along with an increase in interventions conducted with children in developing countries, studies examining effectiveness of these various ECD programs have been accumulating rapidly as well. In particular, recent studies have demonstrated the importance of early nutrition and interventions involving developmental stimulation for children from low- and middle-income countries. One systematic review and meta-analysis, conducted by Grantham-McGregor and colleagues,[12] investigated the effects of integrated child development and nutrition interventions on child development. This review examined 20 studies published from 2000 to 2013, all of which were (a) conducted in developing countries; (b) targeted children 5 years and under and/or pregnant women; (c) had components of nutrition and stimulation to the interventions; and (d) administered measures on child development and health or nutrition outcomes. Another similar systematic review and meta-analysis study, conducted by Aboud and Yousafzai,[13] also focused on the impact of nutrition and stimulation interventions on cognitive development in children. The authors included 21 stimulation interventions and 18 nutrition interventions implemented after 2000, involving (a) children who received the intervention from birth to 24 months, and with follow-up within one year; (b) children who were not premature and did not have serious health problems; and (c) measure of mental development outcome of cognition or language. The results from both studies demonstrated that nutrition and stimulation interventions benefited development of participants in the intervention.[12,13] However, questions remain about comparative effectiveness of other types of ECD interventions, including preschool and parenting interventions that do not have a supplementary nutrition component.

There is currently a paucity of research comparing the effectiveness of different types of ECD interventions in enhancing the cognitive development of children growing up in developing countries. We sought to address this knowledge gap in the current study and conducted a high-quality systematic review and quantitative analysis of relevant studies on ECD interventions in developing countries. Through our review and analysis, we aim to shed insight into (a) the types of interventions being implemented and evaluated in developing countries; (b) the effectiveness of these intervention types with regards to children's cognitive development; and (c) the conditions under which ECD interventions are effective in achieving expected outcomes in cognitive development for these young children. To our knowledge, our study is the first to consider the differential effectiveness of different forms of intervention on cognitive development.

Any systematic review of published literature on the relationship between ECD interventions and cognitive development must proceed from an articulated conceptual position. We drew upon Gottlieb's experiential canalisation model,[8,9] Blair and Raver's analysis,[7] and the work of Walker et al,[10] to develop a conceptual framework to identify and situate evidence. In Gottlieb's experiential canalisation model,[8,9] biology and experience mutually influence each other during the developmental process. Adversity releases stress hormones that influence neural systems, which in turn affect cognitive and socio-emotional development.[7] Walker et al[10] identified several developmental risk and protective factors that affect the developing brain at different developmentally sensitive periods for optimal learning. The effects of these risk factors are moderated by intensity, timing, and duration of adversity, as well as the child's reactivity to them. Risk influences genetic expression (phenotypes), which in turn affect brain structure and function and child development. Being exposed to early adversity (e.g., maternal depression, domestic violence, drug abuse, having a single caregiver, poverty) is associated with developmental delays, and chronic health problems such as coronary heart disease, diabetes, and depression later in life. We assumed that ECD interventions are designed to protect children from negative consequences of living in disadvantaged situations, especially poverty, by reducing detrimental influences of risk factors and bolstering effects of protective factors on child development.[10]

The effectiveness of ECD programs is often moderated by participants' unique characteristics, e.g., gender and socio-economic status, and specific components of interventions, e.g., intensity, curriculum, and medium of instruction.[14-16] Hence, we considered both participant characteristics and intervention components in our systematic review and meta-analysis.

In addition, risk and protective factors for typical cognitive development and interventions are frequently situated at different socio-ecological levels,[17] ranging from the most proximal levels of family and school, to distal levels including culture, the GDP of the country, and the role of the state. There are marked variations in economic development across countries and regions of the world. For instance, a child who is raised in sub-Saharan Africa has fewer distal protective factors (e.g., food security, compulsory pre-school education) than a child who is raised in the United States. Therefore, we also considered broader social and cultural contexts in which intervention participants live, including indices of human development (e.g., perinatal mortality rates) in our investigation.

Methods

Search Strategy and Selection Criteria

We did a systematic review and meta-analysis in accordance with the PRISMA (*P*referred *R*eporting *I*tems for *S*ystematic Reviews and *M*eta-*A*nalyses) guidelines, and a predetermined protocol. We defined *ECD interventions* as any kind of intervention designed to promote typical cognitive development, implemented from birth up to 8 years of age. We conducted a systematic search of the literature to identify quantitative evidence for the impact of ECD interventions on the cognitive development of children in developing countries. The level of a country's economic development was classified with reference to World Bank data.[18] The search strategy was developed primarily using the EPPI-Centre's (2007, updated 2010) guidelines[19] for conducting systematic reviews, consisting of the following approaches: (a) electronic database searching; (b) hand searching of key journals; (c) searching of specialist websites; and (d) sending requests for information to personal contacts, authors, and experts in the field.

We accessed nine electronic databases to search for peer-reviewed studies: Academic Search Elite/EBSCO host, the Cochrane Reviews, Dragon (The University of Hong Kong Libraries Catalogue), Google Scholar, JSTOR, ProQuest, PsycINFO, PubMed, and Web of Science. In searching these databases, we generally focused on studies that had a greater emphasis on mental stimulation and interventions relating to learning opportunities and outcomes. Data from developing countries indicate that poorest children are most disadvantaged in terms of attendance in early childhood programs, and less than half of children have expected levels of competency in literacy and numeracy.[20] Hence, we used search terms that reflected our two variables of interest. The first variable of interest, *Early Childhood Development*, included the following terms: early childhood program, preschool experience, early intervention, early childhood education, early learning, early cognitive stimulation, nutritional supplementation, early childhood health intervention, home-visiting program, parental support and education, early reading program, breakfast program, lunch program, income supplement, and cash transfer. The second variable of interest, *Cognitive Development*, included the following terms: school readiness, cognitive development, academic achievement, learning outcomes, child development, intelligence, language development, literacy, mathematics achievement, problem solving skills, attention and executive functions, basic concepts, IQ, DQ, thinking, communication skills, vocabulary, brain development, and neural development. It should be noted that commonly used tools to assess IQ and DQ, such as the Bayley Scales of Infant Development, do include tests of psycho-motor functioning while other tools assess perceptual development. Therefore, we must acknowledge that among the studies included in our meta-analysis that used IQ or DQ as an outcome measure, it is likely that the composite measure of cognitive development included performance on psycho-motor tasks.

To ensure that our literature search was comprehensive, we then conducted a hand search of relevant studies cited in reference lists of selected research papers, using a snowball method to identify suitable studies. We also examined specialist websites, including the following: the UNICEF Evaluation Database, UNESCO, the World Bank, the Brookings Institute, Save the Children, Bernard van Leer, the National Institute of Early Education Research (NIEER), The Consultative Group on Early Childhood Care and Development, Young Lives, Pratham, 3ie- International Initiative for Impact Evaluation, the Open Society Institute, and Plan International. The NGOs above have tended to focus on care and education for children of our targeted age range. By searching through these specialist websites, we were able to include the broader "grey literature" (i.e., conference proceedings, research reports, and policy papers) in order to reduce the potential effects of publication bias. Finally, we contacted scholars who were considered experts in the field to provide additional reports and articles.

In 1990, the World Declaration on Education for All conference convened by the World Bank in Jomtien Thailand was a watershed moment for early childhood development. The declaration affirmed the importance of early learning with the statement, "Learning begins at birth." We used a

standardised procedure and specific criteria were applied to select relevant studies that were published after the landmark declaration, between January 1, 1992 and December 31, 2012 (see Appendix for the complete list of selection criteria). The screening was conducted in four steps. First, the title of each article was checked to see if the study fit the required study selection criteria; studies that were clear misfits were removed. Second, all members of our multi-disciplinary research team were consulted to ensure that as many studies on the topic as possible were included for further screening. Third, two members of the team (JS and EC) screened the study abstracts to exclude those studies not fitting the selection criteria. At the fourth step, the full text of the study was screened by the same two team members (JS and EC) and assessed to determine whether the study should be included for quality assessment and, finally, the systematic review and meta-analysis.

Data Extraction

To ensure a systematic and objective evaluation, we designed a comprehensive coding scheme to quantify the interventions carried out in the studies, identifying the following characteristics for each study (see eTable S1): (a) the number of subjects in the intervention and control arms; (b) the effect sizes; and (c) the following nine design characteristics: ages of target children (missing data 0.7%); duration of intervention (missing data 4.8%); intensity of intervention (missing data 69.1%); interval between intervention and assessment; location of intervention; background characteristics of change agent; minimal qualifications of change agent (missing data 44.4%); provision of guidance to change agent (missing data 20.1%); and fidelity of implementation (missing data 28.2). Rigor of the study (no missing data) and soundness of the study (no missing data) were combined to index the overall quality of the study. The interventions identified in studies were coded by six team members (including JS, EC, and PI), and over half of the coding was randomly selected and checked by a "gold standard" coder (trained by NR) to ensure consistency and accuracy in coding. At the end of the coding process, all the coding and studies selected for detailed coding were reviewed independently by all team members.

In addition, a subgroup analysis was conducted to examine the effect of the country context on intervention outcomes. The overall development parameters of a country, including the Human Development Index (HDI) and the perinatal mortality rate, were used in the analyses. The HDI contains (a) an income component (gross national income, or GNI, per capita) and (b) a non-income component (comprising of health, or life expectancy at birth, and education, or years of schooling) (see eTables S2-S4). The perinatal mortality rate is a key indicator of the country's health status (see eTable S5). Information on the HDI and perinatal mortality rate were obtained from the United Nations Human Development Report 2011[21] and the World Health Organization Neonatal and Perinatal Mortality Report, respectively.[22]

Statistical Analysis

The effectiveness of ECD interventions was typically assessed by comparing the developmental outcomes of treatment and control groups. To examine the degree of variability in the success of the interventions across studies, we restricted our analyses to studies that enabled us to calculate at least one intervention effect size. We used the specific cognitive outcome effect size as the unit of analysis rather than the interventions per se; thus, one study with multiple interventions and cognitive assessments could contribute more than one effect size.

We calculated the effect size for each intervention using Cohen's *d* (see eData analyses), defined as the difference between the means of the treatment and control groups divided by the pooled standard deviation (*SD*) of the population from which the groups were sampled. We estimated the effect size based on sample *SD*s for unknown population *SD*s. The slight bias in Cohen's *d* for small samples was corrected using the method proposed by Hedges and Olkin.[23] We estimated the weighted average (with the precision of the individual effect sizes as weights) of effect sizes for all and individual type interventions using multilevel meta-analysis models. Positive values indicated a beneficial intervention for a given treatment group, whereas negative values indicated no benefit. The heterogeneity of the intervention effect size was empirically examined using the I^2 statistic, defined as the percentage of inconsistency across interventions.[24] We considered whether intervention characteristics and country context modified intervention effectiveness for all and individual intervention types using multilevel meta-regressions in a two-step approach. In the first step, simple meta-regression models were fitted to identify potential effect modifiers. These factors were input into multiple meta-regression models to eliminate confounding in the second step. The nested structure of effect size, intervention, and studies were adjusted as random factors in meta-analysis and meta-regression models. Publication bias was detected using funnel plots (see eFigures S1-S5) and Egger's regression test.

Results

Our search strategy identified 3431 unique publications, the titles and abstracts of which were screened for inclusion. The full text of 142 publications was retrieved, of which 114 met the inclusion criteria. After stringent quality assessment, 111 publications were included for the systematic review, and of these, 70 with necessary information for effect size calculation were included in the meta-analysis (Figure 1). These 70 publications reported 62 independent studies on 106 ECD interventions from which we extracted 586 effect sizes. For all of the interventions, measures of cognitive development were categorised to reflect the following eight outcomes: cognitive; executive function (EF); intellectual quotient (IQ); language; literacy; reasoning and problem-solving; school readiness; and subject and learning achievement. After the systematic review, the ECD interventions were categorised into five broad categories: (a) *parent-focused education and support* (22 interventions), (b) *child-focused*

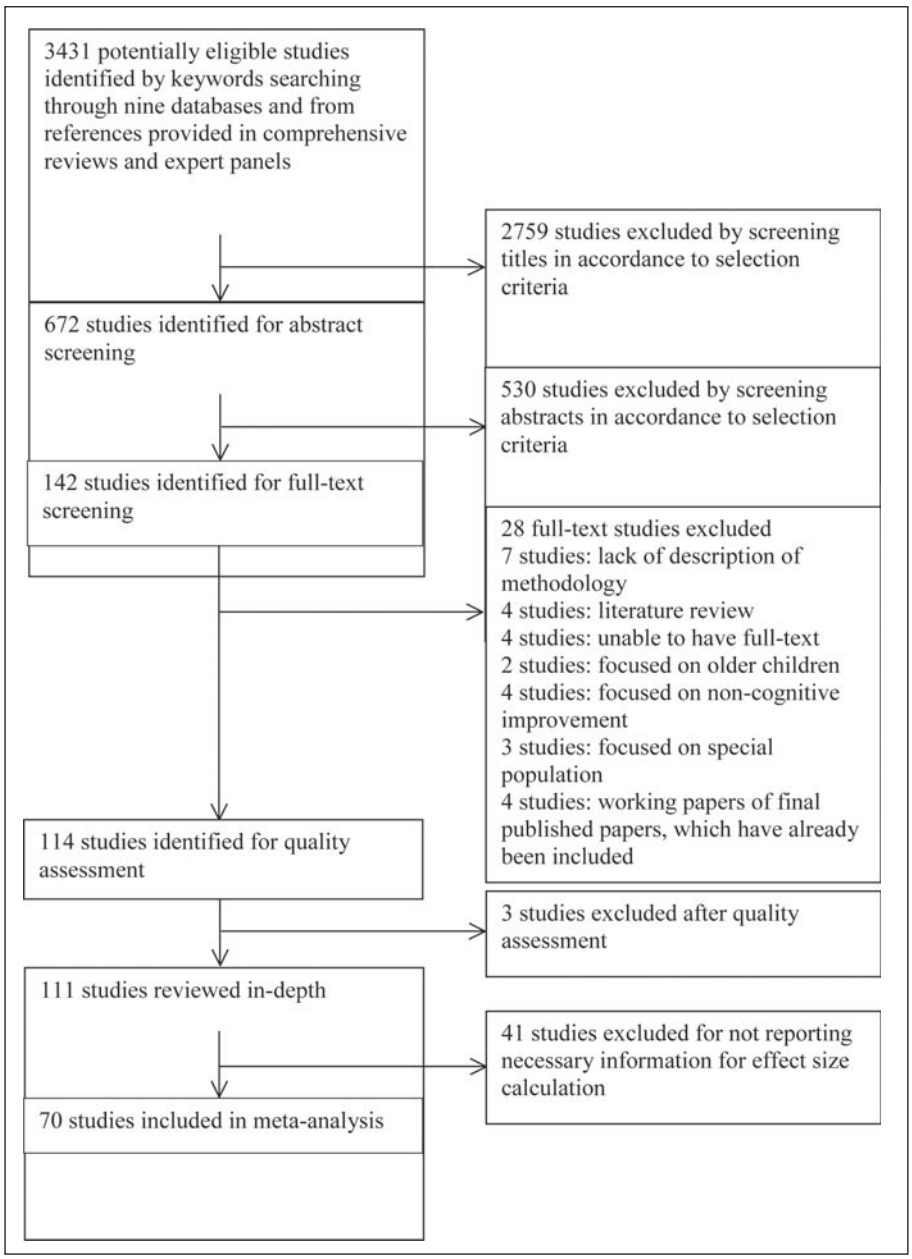

Figure 1 Study selection.

stimulation and education (37 interventions), (c) *nutrition and health* (38 interventions), (d) *income supplementation,* including cash transfers (5 interventions), and (e) *comprehensive programs* (4 interventions). Detailed characteristics of the 106 interventions from 70 publications are provided in the Supplement (see eTable S6).

We found a wide variation in the overall effectiveness of the reported ECD interventions for improving cognitive development (overall I^2=91.7. Comprehensive programs showed the largest beneficial effects (g=1.05, 95% CI=0.50 to 1.61), followed by child-focused stimulation and education interventions (g=0.64, 95% CI=0.42 to 0.85), parent-focused education and support interventions ($g_{unbiased}$=0.44, 95% CI=0.26 to 0.61), income supplementation (g=0.23, 95% CI=0.05 to 0.40), and nutrition and health interventions ($g_{unbiased}$= 0.11, 95% CI=0.03 to 0.19) (Figure 2). Forest plots of individual studies could be found in the Supplement (eFigure S1 to S5). In general, ECD interventions were significant for school readiness outcome measures when the interventions were examined together, g=1.17 (95% CI 0.94 to 1.41), and for child-focused education and stimulation interventions, g=1.08 (95% CI 0.79 to 1.37) (Table 1).

Several overarching similarities across the four comprehensive interventions may explain why they were more effective than individual interventions. First, all of the interventions evaluated were part of large national programs designed to benefit a sizable number of children. For instance, two of the interventions evaluated were examples of the Integrated Child Development Services in India, which served approximately 64.9 million children (ranging from 6 months to 6 years) when the studies were conducted. Second, comprehensive programs combined different interventions (including child-focused educational interventions, parent-focused interventions, and nutrition and health interventions) and targeted children across a range of ages. Third, most of the interventions fostered community involvement, encouraging those who stood to benefit from them to become directly involved as change agents (i.e., as early childhood educators). That is, there are interrelationships among socioeconomic circumstances, health conditions, and cognitive development in the comprehensive programs; and the individual interventions may have built on one another to strengthen the overall program.

Table 1 shows the univariate meta-regression results. After adjusting study and intervention cluster effects, overall intervention effectiveness were associated with assessment type, intervention type, and countries' perinatal mortality. The effectiveness of parent-focused interventions was associated with age of target children while the effectiveness of child-focused educational intervention effectiveness was associated with type of assessment type and countries' perinatal mortality rate. No significant associations could be identified for nutrition and health interventions. Significant factors for overall and child-focused educational intervention effectiveness were further analysed in multiple meta-regression models. Table 2 shows the multiple meta-regression model estimates. After mutual adjustments, overall ECD interventions were more effective in improving school readiness compared with other outcomes; comprehensive programs were more effective than all other intervention types (p=0.003 to <0.0001). We also found that interventions implemented in countries with higher perinatal mortality were significantly more effective: for every 10 per 100,000 increase in a country's perinatal mortality, the effectiveness will be 0.01 larger (p=0.02, Figure 3). Similar associations were also found in child-focused educational interventions.

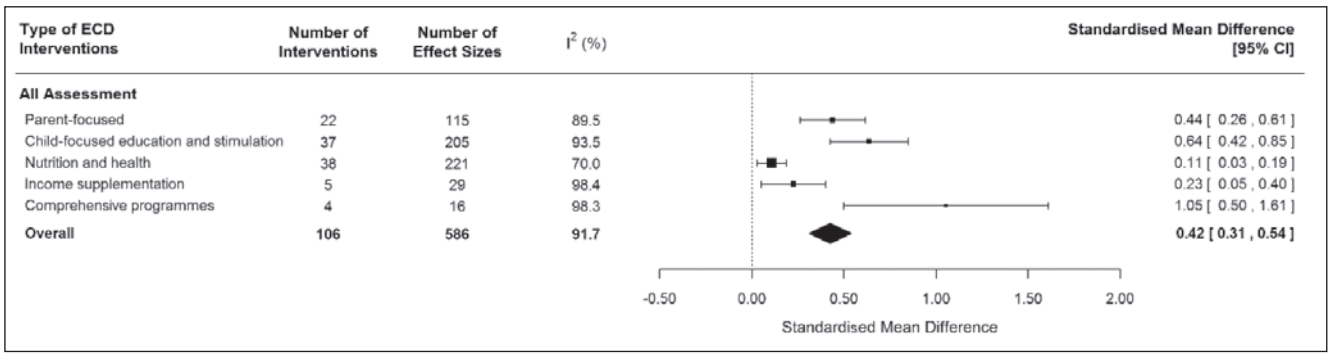

Figure 2 Effectiveness of different types of ECD interventions.

Table 1 Univariate analysis on effect modifications of intervention characteristics and country contexts on ECD intervention effectiveness

	All Interventions (n_{study}=62, $n_{intervention}$=106, $n_{effect\ size}$=586)				Parent-focused (n_{study}=16, $n_{intervention}$=22, $n_{effect\ size}$=115)				Child-focused Education and Stimulation (n_{study}=20, $n_{intervention}$=37, $n_{effect\ size}$=205)				Nutrition and Health (n_{study}=20, $n_{intervention}$=38, $n_{effect\ size}$=221)			
	Coefficient	95%CI Lower Bound	95%CI Upper Bound	p	Coefficient	95%CI Lower Bound	95%CI Upper Bound	p	Coefficient	95%CI Lower Bound	95%CI Upper Bound	p	Coefficient	95%CI Lower Bound	95%CI Upper Bound	p
Assessment Type																
Cognitive	0		Reference		0		Reference		0		Reference		0		Reference	
Executive Function	0.04	-0.17	0.26	0.69	0.13	-0.40	0.67	0.62	1.01	-0.11	2.13	0.08	-0.13	-0.35	0.09	0.24
IQ	0.13	-0.08	0.35	0.22	0.51	-0.09	1.11	0.09	0.03	-0.49	0.55	0.90	-0.01	-0.25	0.22	0.92
Language	0.12	-0.06	0.31	0.19	-0.06	-0.56	0.44	0.81	0.05	-0.26	0.35	0.76	0.05	-0.19	0.28	0.68
Literacy	0.06	-0.13	0.26	0.52	0.24	-0.33	0.80	0.41	-0.06	-0.35	0.23	0.70	-0.03	-0.28	0.22	0.80
Reasoning & Problem Solving	0.14	-0.07	0.35	0.18	0.38	-0.15	0.91	0.16	-0.03	-0.39	0.32	0.85	0.01	-0.22	0.24	0.92
School Readiness	**1.17**	**0.94**	**1.41**	**<0.0001**	–	–	–	–	**1.08**	**0.79**	**1.37**	**<0.0001**	–	–	–	–
Subject & Learning Achievement	0.12	-0.08	0.33	0.23	0.09	-0.62	0.80	0.80	0.01	-0.29	0.31	0.94	-0.09	-0.38	0.20	0.54
Intervention Type																
Parent-focused	**-0.59**	**-1.00**	**-0.17**	**0.01**	–	–	–	–	–	–	–	–	–	–	–	–
Child-focused Education and Support	**-0.41**	**-0.82**	**-0.01**	**0.04**	–	–	–	–	–	–	–	–	–	–	–	–
Nutrition and Health	**-0.86**	**-1.26**	**-0.46**	**<0.0001**	–	–	–	–	–	–	–	–	–	–	–	–
Income Supplementation	**-0.83**	**-1.31**	**-0.35**	**0.001**	–	–	–	–	–	–	–	–	–	–	–	–
Comprehensive	0		Reference													
Assessment Timing																
Immediate after Intervention	0		Reference		0		Reference		0		Reference		0		Reference	
Follow-up	-0.09	-0.25	0.07	0.29	0.09	-0.31	0.48	0.67	-0.13	-0.35	0.09	0.26	0.06	-0.08	0.21	0.40
Age of Target Children																
0 to 1	0		Reference		0		Reference		0		Reference		0			
2 to 5	0.16	-0.15	0.48	0.31	-0.45	-0.86	-0.05	0.03	0.30	-0.75	1.35	0.57	0.39	-0.31	1.08	0.27
6 to 8	0.06	-0.30	0.41	0.75	-	-	-	-	0.20	-0.88	1.28	0.72	0.01	-0.32	0.34	0.97
Mixed	0.05	-0.13	0.22	0.59	-0.49	-0.79	-0.20	0.00	0.43	-0.61	1.46	0.42	-0.02	-0.16	0.12	0.77
Duration	-0.004	-0.01	0.002	0.21	-0.01	-0.04	0.01	0.24	-0.01	-0.03	0.01	0.19	0.00	-0.01	0.01	0.85
Intensity (Hours per week)	–	–	–	–	-0.14	-1.85	1.57	0.87	-0.01	-0.04	0.02	0.48	–	–	–	–
Region																
Rural	0		Reference		0		Reference		0	Reference		0	Reference			
Urban	-0.02	-0.27	0.23	0.85	0.24	-0.16	0.63	0.24	-0.27	-0.76	0.22	0.28	0.04	-0.14	0.23	0.64
Non-specific	-0.06	-0.47	0.34	0.76	–	–	–	–	-0.43	-1.01	0.15	0.14	0.21	-0.17	0.58	0.28
Minimum Qualification of Change Agent																
No requirement	0	Reference		0	Reference		0	Reference		0	Reference					
Secondary school graduate or below	0.03	-0.33	0.38	0.88	0.19	-0.34	0.72	0.48	-0.25	-0.86	0.37	0.43	–	–	–	–
Tertiary graduate or professional	0.26	-0.06	0.58	0.11	0.53	-0.044	1.11	0.07	0.19	-0.34	0.72	0.47	-0.07	-0.34	0.21	0.62
Mixed	0.05	-0.19	0.29	0.70	0.13	-0.31	0.58	0.56	-0.01	-0.46	0.44	0.97	0.09	-0.37	0.55	0.70
Guidance Provided to Changing Agents																
None	0		Reference		0		Reference		0		Reference		0		Reference	
Once	0.01	-0.17	0.18	0.93	-0.30	-0.81	0.22	0.26	-0.11	-0.70	0.49	0.72	0.07	-0.07	0.21	0.31
More than once	0.09	-0.12	0.29	0.40	-0.33	-0.83	0.16	0.19	-0.04	-0.55	0.46	0.87	-0.03	-0.25	0.18	0.76
Fidelity of Program	-0.09	-0.32	0.14	0.45	0.05	-0.34	0.45	0.79	0.00	-0.41	0.42	0.99	-0.12	-0.30	0.07	0.21
Study Design Rigor	-0.01	-0.09	0.06	0.69	0.11	-0.09	0.31	0.27	0.00	-0.20	0.20	0.99	-0.02	-0.10	0.06	0.65
Study Design Soundness	-0.08	-0.26	0.11	0.40	0.09	-0.39	0.57	0.71	-0.04	-0.33	0.24	0.76	-0.03	-0.64	0.58	0.92
Human Development Index	-0.61	-1.45	0.23	0.16	0.82	-1.07	2.71	0.40	-0.69	-2.23	0.85	0.38	0.41	-0.39	1.20	0.32
Human Development Index (Non-income)	-0.84	-1.70	0.03	0.06	0.92	-0.96	2.80	0.34	-0.99	-2.65	0.67	0.24	0.36	-0.44	1.17	0.38
GNI per capita (per USD 1,000)	-0.01	-0.04	0.02	0.58	0.02	-0.04	0.07	0.59	-0.01	-0.06	0.04	0.69	0.02	-0.01	0.05	0.16
Perinatal Mortality (per 100,000 children)	**0.01**	**0.003**	**0.01**	**0.002**	0.00	-0.01	0.01	0.39	**0.01**	**0.004**	**0.02**	**0.004**	0.00	-0.01	0.00	0.81

Estimated using multilevel meta-regressions with nested intervention and study clustering effects adjusted using random factors.

Discussion

In our systematic review and meta-analysis, the effect sizes for ECD interventions in developing countries varied, similar to previous findings from developed countries.[25] However, we also found several key differences in intervention impact between developing and developed countries. These differences must be acknowledged, as ECD interventions in developing countries have generally been modelled on strategies from developed countries. For instance, comprehensive intervention programs in developing countries produced significant improvements in children's cognitive development, in line with the observations of Engle et al.[26] By contrast, the findings from developed countries showed no solid evidence of any advantages of comprehensive programs over other ECD interventions. In the U.S., for instance, large-scale comprehensive programs for children from poorer and disadvantaged families, such as Head Start, have not documented benefits over and above single interventions such as child-focused educational programs.[27] The seeming ineffectiveness of comprehensive programs in developed countries might explain the dearth of comprehensive programs in developing countries.

Table 2 Multivariate analysis on effect modifications of intervention characteristics and country contexts on ECD intervention effectiveness

	Coefficient	95%CI Lower Bound	95%CI Upper Bound	p-value	
All Interventions					
Model Intercept	0.78	0.38	1.17	0.0001	***
Assessment Type					
Cognitive	0		Reference		
Executive Function	0.02	-0.17	0.21	0.83	
IQ	0.10	-0.10	0.30	0.32	
Language	0.09	-0.08	0.25	0.31	
Literacy	0.02	-0.15	0.20	0.79	
Reasoning & Problem Solving	0.12	-0.07	0.30	0.22	
School Readiness	1.13	0.91	1.36	<0.0001	***
Subject & Learning Achievement	0.08	-0.10	0.27	0.38	
Intervention Type					
Parent-focused	-0.61	-1.00	-0.22	0.002	**
Child-focused Education and Stimulation	-0.61	-1.00	-0.21	0.003	**
Nutrition and Health	-0.86	-1.24	-0.48	<0.0001	***
Income Supplementation	-0.76	-1.22	-0.31	0.001	**
Comprehensive	0	Reference			
Perinatal Mortality Rate	0.005	0.0009	0.01	0.02	*
Child-focused Education and Stimulation					
Model Intercept	-0.24	-0.78	0.30	0.38	
Assessment Type					
Cognitive	0		Reference		
Executive Function	1.04	-0.06	2.14	0.06	
IQ	-0.02	-0.53	0.48	0.93	
Language	0.06	-0.23	0.35	0.67	
Literacy	-0.06	-0.33	0.22	0.68	
Reasoning & Problem Solving	-0.02	-0.37	0.32	0.89	
School Readiness	1.08	0.80	1.36	<0.0001	***
Subject & Learning Achievement	0.01	-0.28	0.29	0.96	
Perinatal Mortality (per 100,000 children)	0.01	0.01	0.02	0.001	***

All factors were mutually adjusted; intervention and study cluster effects were adjusted as random factors

*=p<0.05; **=p<0.01; ***=p<0.001

Our analyses, however, suggest that the scaling up of comprehensive programs in developing countries to better support children's cognitive development should be given adequate consideration. From the publications reviewed, it was not possible to determine cost of all the programs, and differences in the populations served, intervention timing, and dosage must also be acknowledged. These factors may also influence intervention effectiveness. However, comprehensive programs provided a wide range of services, covering different key dimensions of the child's development. Hence, the beneficial effect in one dimension of development would less likely be masked by a deficiency in another dimension. Alternatively, the beneficial effect of an intervention targeting one domain of development may lead to other positive developments in another domain. For example, children who receive nutritional supplementation may have more energy and improved health, which may in turn improve their attention and learning skills. Such improvements could make these children more responsive to educational interventions. To summarise, children in developing countries could benefit more overall from diverse interventions.[28]

Child-focused educational programs in developed countries report effect sizes of about 0.35,[29] whereas our meta-analysis revealed that in developing countries, these programs had a larger effect size of 0.64. Additionally, amongst the children in developing countries, child-focused educational interventions had larger effects on the cognitive development of children from low-income families. These findings are in line with our expectation that children from economically impoverished environments benefit more from early educational interventions than children from developed countries. That is, ECD interventions are important to minimise cognitive limitations in disadvantaged children.[30]

Parent-focused interventions in developing countries had relatively smaller average effect sizes than child-focused interventions. This may be due to large variations in the design of parent-focused interventions. In contrast to other studies, we did not find that these interventions were more effective with highly qualified educators,[31-33] potentially because of generally low levels of training or lack of variability in developing country contexts. We did find that the age of the child targeted for intervention was significant for parent-focused interventions compared to other types of interventions; early parenting programs that enhance parent-infant interaction can, in turn, foster learning

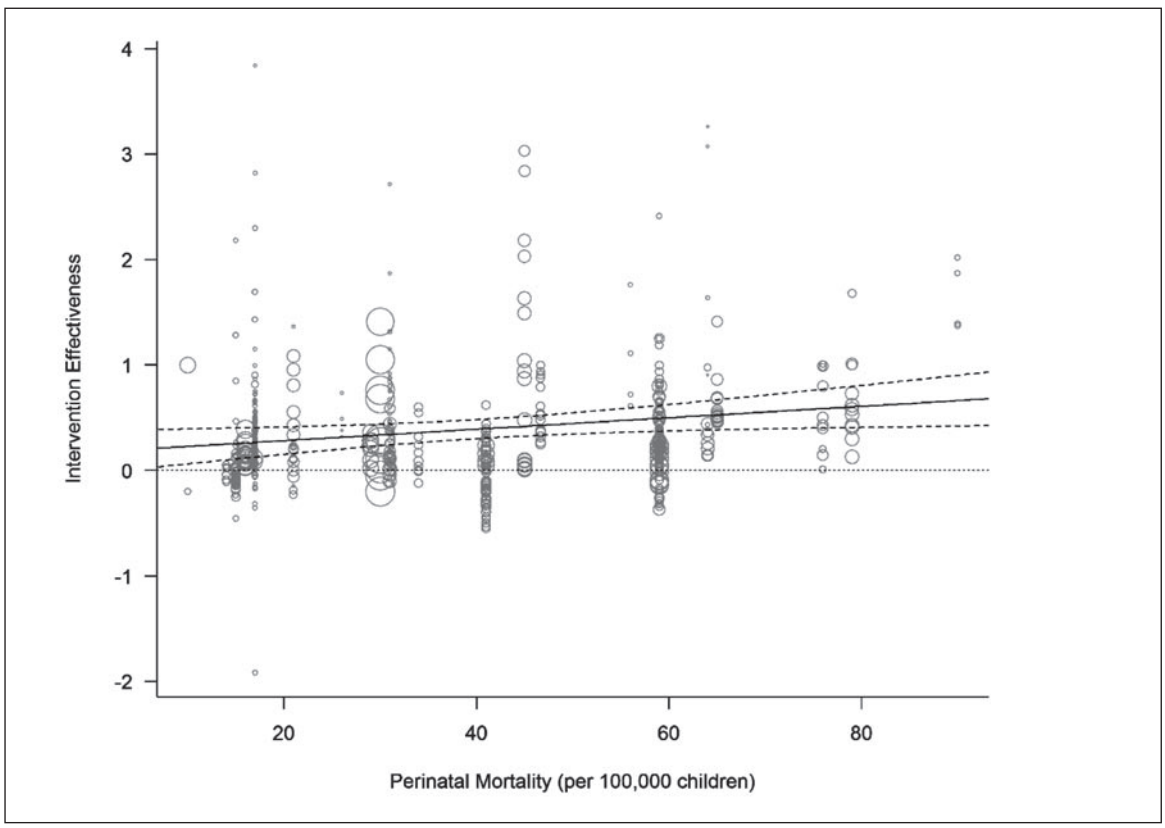

Figure 3 Association between a country's perinatal mortality rate and ECD intervention effectiveness interventions.

achievement and the development of executive function.[34] Hence, adequate attention should be given to the timing of providing parenting interventions to promote typical cognitive development.[35]

Finally, our systematic review and meta-analysis showed that nutrition and health programs for children were effective in improving their cognitive development. Children not only benefited directly from the health effects of nutritional supplements, but also showed significant cognitive gains within the short assessment periods. This finding is encouraging because compared to other types of ECD interventions, nutritional supplements can easily be delivered to children in developing countries, regardless of the country's HDI. The Copenhagen Consensus, a panel of renowned economists, assessed the cost-benefit of various development strategies worldwide. In 2004 and 2008, they ranked schemes for preventing malnutrition (including nutritional interventions) among those programs with the highest rate of economic return on investment to productivity and cognitive development.[36,37] Although nutrition and health programs in children had relatively small effect sizes in the studies in our meta-analysis, evidence of improvements in cognitive development may become more evident in later life, and relatively less observable in these short-term studies. For example, a cohort study from Guatemala found that nutritional supplementation before the age of 3 had beneficial effects on schooling, reading, and intelligence when tested during adulthood (25-42 years).[38] Therefore, we cannot underestimate the long-term beneficial effects of early nutritional intervention.

Overall, a positive relationship between intervention effectiveness and a country's perinatal mortality rate was found, especially for child-focused educational interventions. The perinatal mortality rate is a good indicator of a country's health status.[39] A child's developing brain is particularly vulnerable to poor, suboptimal learning environments,[40] thus interventions that enhance a child's early learning environment by providing more cognitive stimulation, would be expected to produce greater developmental gains in children from the most disadvantaged countries with higher perinatal mortality rate.

In the light of the evidence reviewed, we recommend the scaling up of comprehensive intervention programs in developing countries to minimise the loss of children's developmental potential. Policymakers should improve the quality and focus of programs, particularly the qualifications of change agents, and prioritise ECD interventions that take into consideration the country context. Finally, implementation research should inform the adoption, replication, and expansion of evidence-based programs. Our systematic review and meta-analysis also highlight the importance of conducting rigorous research on the impact of early childhood interventions on their targeted communities. We focused on quantitative studies in our review, but recognise that qualitative studies are crucial for gaining deeper, more nuanced insight into early childhood interventions. Future reviews should include qualitative work as well to gain a more comprehensive understanding and to better inform policymakers about the effects of early childhood interventions on cognitive development. Together, we can create and support policies and programs that truly benefit future generations around the world.

Acknowledgement

Data for this paper are based on a rigorous literature review commissioned by the UK Department for International Development (DFID) in 2013. We would like to thank the DFID, the funding source, for all the support provided. We would also like to thank the late Patrice L. Engle for her everlasting friendship and contribution to the study design. We thank other members of the review team: Jessie Wong, Brendan Weekes, Sheldon Shaeffer, Mary Young, Mark Bray, and Diana Lee. We are grateful for the assistance of Rosa Wong, Frederick Ho, Shuling Gao, and Daniel Mark and for the support from Eva Oberg and Penny Robertson from DFID.

Declaration of Interest

All authors declare: that they had financial support from DFID for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work; no other relationships or activities that could appear to have influenced the submitted work.

Online Supplementary

eTable S1. Coding scheme

eTable S2. List of countries categorised into quartiles according to the Human Development Index 2011

eTable S3. List of countries categorised into quartiles according to the Non-income Human Development Index 2011

eTable S4. List of countries categorized into quartiles according to the GNI per capita in 2011

eTable S5. List of countries categorized into quartiles according to the perinatal mortality rate in 2006

eTable S6. Characteristics of the 106 interventions from 62 studies

eTable S7. Effectiveness of ECD interventions on different cognitive outcome

eData analyses

eFigure S1. Funnel plot for parent-focused interventions

eFigure S2. Funnel plot for child-focused education and stimulation interventions

eFigure S3. Funnel plot for nutrition and health interventions

eFigure S4. Funnel plot for interventions with income supplementation

eFigure S5. Funnel plot for comprehensive interventions

eFigure S6. Association between countries' perinatal mortality and ECD intervention effectiveness

eFigure S7. Forest plot for parent-focused interventions

eFigure S8. Forest plot for child-focused education and stimulation interventions

eFigure S9. Forest plot for nutrition and health interventions

eFigure S10. Forest plot for interventions with income supplementation

eFigure S11. Forest plot for comprehensive interventions

eTables and eFigures can be visited at the following link: http://www.hkjpaed.org/pdf/2017_supplementary.pdf

References

1. Phillips DA, Shonkoff JP. From neurons to neighborhoods: the Science of early childhood development. Washington: National Academies Press, 2000.
2. Camilli G, Vargas S, Ryan S, Barnett WS. Meta-analysis of the effects of early education interventions on cognitive and social development. Teach Coll Rec 2010;112:579-620.
3. Engle PL, Black MM, Behrman JR, et al; International Child Development Steering Group. Strategies to avoid the loss of developmental potential in more than 200 million children in the developing world. Lancet 2007;369:229-42.
4. Engle PL, Fernald LC, Alderman H, et al; Global Child Development Steering Group. Strategies for reducing inequalities and improving developmental outcomes for young children in low-income and middle-income countries. Lancet 2011;378:1339-53.
5. Heckman JJ. Skill formation and the economics of investing in disadvantaged children. Science 2006;312:1900-2.
6. Grantham-McGregor S, Cheung YB, Cueto S, Glewwe P, Richter L, Strupp B; International Child Development Steering Group. Developmental potential in the first 5 years for children in developing countries. Lancet 2007;369:60-70.
7. Blair C, Raver CC. Child development in the context of adversity: experiential canalization of brain and behaviour. Am Psychol 2012;67:309-18.
8. Gottlieb G. Experiential canalization of behavioral development: theory. Dev Psychol 1991;27:4-13.
9. Gottlieb G. Synthesizing nature–nurture: prenatal roots of instinctive behavior. Mahwah: Erlbaum, 1997.
10. Walker SP, Wachs TD, Grantham-McGregor S, et al. Inequality in early childhood: risk and protective factors for early child development. Lancet 2011;378:1325-38.
11. Sayre RK, Devercelli AE, Neuman MJ. Investing in early childhood development: review of the world bank's recent experience. Washington: World Bank, 2015.
12. Grantham-McGregor SM, Fernald LC, Kagawa RM, Walker S. Effects of integrated child development and nutrition interventions on child development and nutritional status. Ann Ny Acad Sci 2014;1308:11-32.
13. Aboud FE, Yousafzai AK. Global health and development in early childhood. Annu Rev Psychol 2015;66:433-57.
14. Cannon JS, Jacknowitz A, Painter G. Is full better than half? Examining the longitudinal effects of full-day kindergarten attendance. J Policy Anal Manag 2006;25:299-321.
15. Schady NR, Paxson CH. Does money matter? The effects of cash transfers on child health and development in rural Ecuador. World Bank Policy Research Working Paper 4226. Washington, DC: World Bank Development Research Group; 2007.
16. Votruba-Drzal E, Li-Grining CP, Maldonado-Carreño C. A developmental perspective on full-day vs. part-day kindergarten and children's academic trajectories through fifth grade. Child Dev 2008;79:957-78.
17. Bronfenbrenner U. Contexts of child rearing: problems and prospects. Am Psychol 1979;34:844-50.
18. World Bank. Country and lending groups [Internet]. The World Bank Group; 2014 [cited 2015 June 30]. Available from: http://data.worldbank.org/about/country-and-lending-groups.
19. EPPI-Centre. EPPI-Centre methods for conducting systematic reviews [Internet]. The University of London; 2007 [updated 2010; cited 2015 June 30]. Available from: http://eppi.ioe.ac.uk/cms/Portals/0/PDF%20reviews%20and%20summaries/EPPI-Centre_Review_Methods_1_1.pdf.
20. UNICEF. Early childhood development: as statistical snapshot-building better brains and sustainable outcomes for children [Internet]. UNICEF: New York; 2014[cited 2015 June 30]. Available from: http://www.unicef.org/earlychildhood/files/ECD_Brochure_FINAL_LR.pdf.

21. Klugman J. Sustainability and equity: a better future for all [Internet]. UNDP: New York; 2011[cited 2015 June 30]. Available from: http://www.za.undp.org/content/dam/south_africa/docs/Reports/Project%20Documents/HDR_2011_EN_Complete.pdf.
22. Lander T. Neonatal and perinatal mortality: country, regional and global estimates. Geneva: WHO, 2006.
23. Hedges LV, Olkin I. Statistical methods for meta-analysis. Orlando: Academic, 1985.
24. HigginsJP, Thompson SG, Deeks JJ, Altman DG. Measuring inconsistency in meta-analyses. BMJ 2003;327:557-60.
25. Anderson LM, Shinn C, Fullilove MT, et al; Task Force on Community Preventive Services. The effectiveness of early childhood development programs: a systematic review. Am J Pre Med 2003;24:32-46.
26. Engle PL, Black MM, Behrman JR, et al; International Child Development Steering Group. Strategies to avoid the loss of developmental potential in more than 200 million children in the developing world. Lancet 2007;369:229-42.
27. Barnett WS. Long-term effects of early childhood programs on cognitive and school outcomes. Future Child 1995;5:25-50.
28. Diamond A, Lee K. Interventions shown to aid executive function development in children 4 to 12 years old. Science 2011;333: 959-64.
29. Yoshikawa H, Weiland C, Brooks-Gunn J, et al. Investing in our future: the evidence base for preschool education [Internet]. SRCD: Ann Arbor; 2013[cited 2015 June 30]. Available from: https://fcd-us.org/sites/default/files/Evidence%20Base%20on%20Preschool%20Education%20FINAL.pdf.
30. Blackman JA. Early intervention: a global perspective. Infant Young Child 2002;15:11-9.
31. Barnett WS. Better teachers, better preschools: student achievement linked to teacher qualifications [Internet]. NIEER: New Brunswick; 2003[cited 2015 June 30]. Available from: http://nieer.org/policy-issue/policy-brief-better-teachers-better-preschools-student-achievement-linked-to-teacher-qualifications.
32. Olds DL, Robinson J, O'Brien R, et al. Home visiting by paraprofessionals and by nurses: a randomized, controlled trial. Pediatrics 2002;110(3):486-96.
33. Olds DL, Robinson J, Pettitt L, et al. Effects of home visits by paraprofessionals and by nurses: age 4 follow-up results of a randomized trial. Pediatrics 2004;114:1560-8.
34. Bernier A, Carlson SM, Deschênes M, Matte-Gagné C. Social factors in the development of early executive functioning: a closer look at the caregiving environment. Dev Sci 2012;15:12-24.
35. Auerbach JA, Krimgold BK. Income, socioeconomic status, and health: exploring the relationships. National Policy Association; 2001.
36. Lomborg B. Global crises, global solutions. New York: Cambridge University Press, 2004.
37. Copenhagen Consensus Center. The world's best investment: vitamins for undernourished children, according to top economists, including 5 Nobel Laureates [Internet]. Copenhagen Consensus Center; 2014[cited 2015 June 30]. Available from: http://issuu.com/copenhagenconsensus/docs/pr30.05.08/1.
38. Maluccio JA, Hoddinott J, Behrman JR, Martorell R, Quisumbing A, Stein AD. The impact of an experimental nutritional intervention in childhood on education among Guatemalan adults. International food policy research institute (IFPRI). Food consumption and nutrition division (FCND), 2006.
39. Stiefel MC, Perla RJ, Zell BL. A healthy bottom line: healthy life expectancy as an outcome measure for health improvement efforts. Milbank Q 2010;88:30-53.
40. McEwen BS, Morrison JH. The brain on stress: vulnerability and plasticity of the prefrontal cortex over the life course. Neuron 2013;79:16-29.

Appendix. Inclusion criteria for studies

1. Interventions must have begun during the early childhood period; that is, before children were eight years of age.
2. Interventions must contain at least one of the following components: (a) parent-focused education and support; (b) child-focused education and stimulation; (c) nutrition and health; and (d) income supplementation including cash transfers.
3. The interventions could be home-, centre-, and/or community-based. Centre-based approaches involved several kinds of institutions offering early years provision, such as pre-schools, childcare centres, crèches, playgroups, day-care nurseries, and nursery schools, which serve as alternative physical and social environments for care, development, and education.
4. The interventions must have explicitly documented cognitive and/or schooling outcomes.
5. The evidence assessed linkages between participation in interventions and cognitive outcomes.
6. The studies were published after January 1992.
7. The studies provided information from a primary study which was not a literature review.
8. Research methods, statistical analyses, and findings were sufficiently detailed to provide basis for judgement about robustness of conclusions; that is, research procedures and characteristics of the sample were specified in detail, so that validity of results could be evaluated.
9. Comparisons (concurrent between groups, or before-and-after within groups) among groups of people exposed to the intervention, and those who were not exposed, or less exposed, to the intervention, were available.
10. Studies involving special populations such as Down's syndrome, cerebral palsy, autism or any specific form of disability (sensory, physical, intellectual, or psychological), extreme malnutrition were not included.