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Strong foundations: early childhood care and education

Early childhood health, nutrition and education

Matthew Jukes
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Matthew Jukes
Email: m.jukes@imperial.ac.uk

Partnership for Child Development
Department of Infectious Disease Epidemiology
Imperial College School of Medicine
Norfolk Place
London W2 1PG

School of Lifelong Education and International Development
Institute of Education
20 Bedford Way
London WC1H 0AL

ABSTRACT

Before children reach school age they must negotiate threats from a number of diseases. More than 50% of child deaths are caused by pneumonia, diarrhea, malaria, measles, malnutrition and HIV. Health and nutrition can affect education in many ways. In resource-poor countries, physical and mental disability can be a major barrier to schooling. This can result from iodine or folate deficiency or rubella infectious in utero or from cerebral malaria, polio or meningitis infections postnatally. Malaria infection, undernutrition and orphanhood can influence the likelihood and timing of enrolment. School readiness depends on cognitive, motor and socio-emotional development which can be affected by, among other things, undernutrition, iron deficiency anemia and malaria. There is clear evidence of the benefits of preschool health and nutrition interventions to tackle these three conditions, with economic returns to $1 spent estimated at $3 for nutritional supplementation and $14 for iron supplementation. For malnourished children, psychosocial stimulation can be as effective as nutritional supplementation in compensating for delayed cognitive development. In general, interventions in this age group have substantial and consistent effects on development and education which are generally larger than for school-age children. Effects are seen in all dimensions of school readiness – cognitive, motor and socioemotional development – but are perhaps greatest for motor development. The interventions are highly cost-effective compared with other educational interventions. They also have a greater impact on the most disadvantaged children and can help to promote equity in educational outcomes. Early childhood health and nutrition interventions have the potential to make a major contribution to achieving Education for All.

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ABBREVIATIONS

ACT	Artemisinin-based combination therapy
AIDS	Acquired immunodeficiency syndrome
ARI	Acute respiratory infection
ART	Anti-retroviral therapy
ARTI	Acute respiratory tract infection
CDC	Centre for disease control and prevention
CRS	Congenital Rubella syndrome
DFID	Department for International Development
DQ	Development quotient
ECD	Early childhood development
EPI	Expanded program of immunization
FRESH	Focusing resources on effective school health
HIV	Human immunodeficiency virus
IMCI	Integrated management of childhood illnesses
IQ	Intelligence quotient
LRTI	Lower respiratory tract infection
MCH	Maternal child health
MDG	Millennium development goals
OME	Otitis media with effusion
OR	Odds ration
SD	Standard deviation
SES	Socio-economic status
STI	Sexually transmitted infection
UNICEF	United Nations Children's Fund
UNAIDS	Joint United Nations Program on HIV/AIDS
UTI	Urinary tract infection
WHO	World Health Organization

Introduction

Public health interventions to promote child survival have long been a priority for governments and development agencies. However, beyond issues of mortality, the role of health and nutrition in promoting child development and educational outcomes is increasingly being recognized (Bundy, 1997; Bundy & Guyatt, 1996). This paper reviews the main health and nutrition problems facing children from before birth until they enter school. The ways in which these conditions affect both children's access to education and their cognitive, motor and socioemotional development are assessed. Evidence of the impact of health and nutrition interventions on child development is reviewed and the potential for their inclusion in ECD programs is considered.

1. *Health and nutrition problems in preschool children*

It is becoming apparent that treating health and nutrition problems in pre-school children (< five years old) is important for two reasons. First, these children account for more than 50% of the global gap in mortality between the poorest and richest quintiles of the world's population and second, they bear 30% of the total burden of disease in poor countries. There are an estimated 600 million preschool children worldwide (US Census Bureau, 2002) and they have several-fold higher case fatality rates for many infections therefore keeping them healthy gives them a better survival rate in childhood and adulthood. Of the 10.5 million children that died in 1999, 99% were from developing countries and of these 36% were in Asia and 33% in Africa. More than 50% of all child deaths (< 5 years old) are due to five communicable diseases, which are treatable and preventable. These are pneumonia, diarrhea, measles, malaria and HIV/AIDS. There is substantial evidence that reduced

breastfeeding, low birth weight, underweight, stunting, iron and iodine deficiency are associated with long term deficits in cognition and school achievement (see below) and there are data suggesting that early childhood diarrheal infections can affect physical fitness in early school age years (6-9) (Stephenson, Latham, & Ottesen, 2000).

Out of 100 children born in each year, 30 will most likely suffer from malnutrition in their first five years of life, 26 will not be immunized against the basic childhood diseases, 19 will lack access to safe drinking water and 40 to adequate sanitation and 17 will never go to school. In developing countries, every fourth child lives in abject poverty, in families with an income of less than $1 a day. As a consequence nearly 11 million children each year – about 30,000 children a day – die before reaching their fifth birthday, mostly from preventable causes. Of these children, 4 million die in their first month of life. In many of the world's poorest countries, child mortality rates have either not changed or else they have worsened. In sub-Saharan Africa, child mortality averages 173 deaths per 1,000 live births, and in South Asia 98 deaths per 1,000 – many times the industrialized country average of 7 deaths per 1,000. Eminently treatable and preventable conditions, such as pneumonia, diarrhea, malaria, measles and malnutrition are leading killers of children

The following is a summary of the most common early childhood diseases.

Pneumonia

Pneumonia, or inflammation of the lung, is caused by one of two infections *Streptococcus pneumoniae* or *Haemophilus influenzae* (Shann, 1986). Approximately 5-10% of all children less than 5 years old develop pneumonia each year and acute

respiratory tract infections (ARTI) cause approximately 2 million deaths each year among children under 5 years old making them together one of the leading causes of death in this age group (CDC, 2003). About 1% of pneumonia cases result in sequelae (e.g., bronchiectasis), which increase the risk of recurrent infections. There has been some decrease in the number of pneumonia deaths over the last decade due to more widespread use of antibiotics; however the increasing prevalence of HIV infection in Africa has likely led to an increase in bacterial pneumonia there. Nearly 75% of pneumonia deaths occur among infants under 1 year old. The risk also increases with malnutrition, malaria, and suppressed immunity. Treatment is with oral antibiotics in mild cases, or in more severe cases, hospitalization and intravenous antibiotics.

Diarrhea

Diarrhea is caused by several important bacterial and protozoan infections including *Vibrio cholerae, Escherichia coli* (0157), *Giardia lamblia, Cryptosporisium parvum* and *Entamoeba histolytica*. It is estimated to cause up to 2.5 million deaths a year in preschool children (21% of total deaths of under 5 year olds) (Parashar, Bresee, & Glass, 2003). There has been a decline over the last ten years, attributed to use of oral rehydration therapy, improved nutrition, immunization and sanitation/hygiene. Treatment is with oral rehydration therapy most importantly, given as soon as possible, and drugs aimed at the causative organism: antibiotics in the case of *V. cholerae* or *E. coli*, or antiprotozoans in the case of *G. lamblia*, *C. parvum* and *E. histolytica*. However, currently only around 30% of under fives with diarrhea use oral rehydration (see Table 2).

<u>Malaria</u>

Malaria is a life-threatening parasitic disease caused by *Plasmodium* spp. and transmitted by mosquitoes. It accounts for one in five of all childhood deaths in Africa. Anemia, low birth-weight, epilepsy, and neurological problems, all frequent consequences of malaria, compromise the health and development of millions of children throughout the tropical world. Malaria symptoms appear about 9 to 14 days after the infectious mosquito bite, although this varies with different *Plasmodium* species. Typically, malaria produces fever, headache, vomiting and other flu-like symptoms. If drugs are not available for treatment or the parasites are resistant to them, the infection can progress rapidly to become life-threatening. Malaria can kill by infecting and destroying red blood cells (anemia) and by clogging the capillaries that carry blood to the brain (cerebral malaria) or other vital organs. Treatment, if delivered quickly after the onset of a fever, is with antimalarials. However the rise of drug resistance in many areas means the most successful treatment regime recommended by the WHO is with combination therapy, preferably with artemisinin-based combination therapy (ACT) (WHO, 2001). It is vital in the treatment of malaria, to provide rapid diagnosis and prompt treatment but these are proving to be the greatest challenges in malaria prevention.

Today approximately 40% of the world's population, mostly those living in the world's poorest countries, is at risk of malaria. It is found throughout the tropical and sub-tropical regions of the world and causes more than 300 million acute episodes and at least one million deaths annually, ninety per cent of which occur in Sub Saharan Africa among young children. Malaria kills an African child every 30 seconds. Many children who survive an episode of severe malaria suffer from learning impairments or brain damage (discussed below). Pregnant women and their unborn children are

also particularly vulnerable to malaria, which is a major cause of perinatal mortality, low birth weight and maternal anemia. In sub-Saharan Africa 14% of under-fives sleep under a bednet, 2% sleep under a bednet treated with insecticide and 38% of those with fever receive anti-malaria drugs (see Table 2).

Measles

Forty years after effective vaccines were licensed, measles, caused by the measles virus, continues to cause death and severe disease in children worldwide. The main symptoms of measles are a running nose, cough, conjunctivitis and high fever, leading up to the appearance of a skin rash. Complications from measles can occur in almost every organ system. Pneumonia, croup, and encephalitis are common causes of death; encephalitis is the most common cause of long-term sequelae. Measles remains a common cause of blindness in developing countries. Complication rates are higher in those <5 and >20 years old, although croup and otitis media are more common in those <2 years old and encephalitis in older children and adults. Complication rates are increased by immune deficiency disorders, malnutrition, vitamin A deficiency, intense exposures to measles, and lack of previous measles vaccination. Case-fatality rates have decreased with improvements in socioeconomic status in many countries but remain high in developing countries. In 2000, the World Health Organization estimated that 30–40 million persons developed measles, resulting in 777,000 child deaths, most in sub-Saharan Africa. High case-fatality rates in developing countries are due to a young age at infection, crowding, underlying immune deficiency disorders, vitamin A deficiency, and lack of access to medical care. An estimated 125 million preschool-aged children are thought to have vitamin A deficiency, placing them at high risk for death, severe infection, or blindness as a result of measles

(because vitamin A is important for the strength of the skin and membranes of the eye, respiratory tree and gut; Perry & Halsey, 2004). In developing countries, measles case-fatality rates are 10- to 100-fold higher than in developed countries. While there is no specific treatment for measles infection, prevention is by vaccination and treating the secondary (bacterial) infections and fever in infected children is recommended as well as vitamin A supplementation, to reduce the incidence of measles-associated deaths in the developing world. Eradication of measles by vaccination would be a major public health accomplishment. To prevent epidemics occurring 85% herd immunity is required which is equivalent to 98% coverage rate of immunization. Worldwide, 77% of children under one year of age receive measles vaccines (Table 2). The figure is 67% in least developed countries but great improvements have been seen particularly in sub-Saharan Africa where coverage rose from 48% in 1998 to 62% in 2002 (UNICEF, 2006).

     <u>Malnutrition and other perinatal conditions.</u>

Perinatal conditions are the major cause of death among children under 5, accounting for more than 1 in 5 deaths. Most deaths are the result of poor maternal health and nutrition, inadequate care during pregnancy and delivery, lack of essential care for the newborn baby, infections, birth injury, asphyxia and problems relating to premature births. Malnutrition is most easily measured as underweight, defined as weight 2 SDs below the mean weight for age of the National Center for Health Statistics and World Health Organization (WHO) reference population. Childhood underweight is internationally recognized as an important public health problem and its devastating effects on human performance, health, and survival are well established. It is estimated that about 53% of all deaths in young children are contributed to by

underweight, varying from 45% for deaths due to measles to 61% for deaths due to diarrhea. The vast majority of underweight children live in developing regions, mainly in Asia and Africa. The projected trends in the prevalence of underweight children combined with the different population growth these regions are experiencing (increasing in Africa, decreasing in Asia) will narrow the gap between their respective contributions to the total number of underweight children. While in 1990, of 100 underweight children, 80 were estimated to live in Asia and 16 in Africa; in 2015, these numbers are expected to change to 60 and 38, respectively, if recent trends continue (de Onis, Blossner, Borghi, Frongillo, & Morris, 2004). The majority of low birth weight in developing countries is due to low *in utero* growth rates, which is affected by maternal undernutrition, malaria, anemia and chronic/acute infections, such as STI's and UTI's. Consequences of low birth weight are impaired immune function, poor cognitive development for neonates and infants, increased risk of diarrheal diseases and pneumonia/LRTI's.

Recent statistics (UNICEF, 2006) indicate that the prevalence of moderate and severe stunting in under-fives is 42% in least developed countries (44% in South Asia and 38% in sub-Saharan Africa; Table 1). This figure has reduced from 47% (52% in South Asia and 41% in sub-Saharan Africa) since 1998. Prevalence of moderate and severe underweight has fallen to 36% (46% in South Asia, 28% in sub-Saharan Africa) from 40% (51% in South Asia, 32% in sub-Saharan Africa) since 1998. In terms of micronutrient deficiencies, the most common is iron deficiency, with a worldwide prevalence of two billion. Forty to fifty percent of under-fives in developing countries are thought to be iron deficient (UNICEF, 1998).

<u>HIV/AIDS.</u>

Every day more than 1500 children become infected with HIV (UNAIDS, 2002a).

Children may acquire HIV during pregnancy, labor, delivery or breastfeeding, with

estimates of Mother to Child Transmission (MTCT) at between 15 to 25% without the

use of antiretroviral drugs. Other routes of infection are through blood transfusion,

the use of contaminated syringes and needles, and child sexual abuse (UNAIDS,

2002b).   Children with HIV infection suffer the same common childhood diseases as

other children, but more frequently, with greater intensity and often with a poorer

response to drugs. Illnesses that are rarely fatal in healthy children will cause high

mortality on the HIV-infected child. Without access to antiretroviral (ARV) therapy

disease progression is rapid and 45% of infected children will die before the age of

two (UNAIDS, 2002a). Prevention of MTCT is best effected by preventing infection

in women or preventing unintentional pregnancies in HIV-positive women or by

treating the mother with ARV therapy during pregnancy, birth and administered to the

baby post parturition. To reduce the impact of HIV infection on children, early

diagnosis is requisite and the child should receive good nutrition and appropriate

immunizations and drug therapy for treating common childhood infections (UNAIDS,

2002a).

Summary

More than 50% of all child deaths (< 5 years old) are due to five communicable

diseases. These are pneumonia, diarrhea, measles, malaria and HIV/AIDS. Five to ten

percent of under-fives develop pneumonia each year, with 2 million deaths overall

due to ARTIs (acute respiratory tract infections) . Two and a half million deaths are

due to diarrhea, accounting for 21% of all deaths in under fives. Only 30% of this age

group use oral rehydration to treat diarrhea. Malaria causes 3 million acute episodes and 1 million deaths, mostly in under fives. In sub-Saharan Africa, only 2% of this age group sleeps under an insecticide-treated bed net. Around 800,000 childhood deaths are caused by measles, a figure which is increased by the high prevalence of vitamin A deficiency amongst preschool children, at 125 million worldwide. Sixty seven percent of children under one year receive measles vaccinations in least developed countries, a figure which has increased substantially over the past decade. Malnutrition and other perinatal conditions account for 20% of childhood deaths. Underweight is estimated to contribute to 53% of all childhood deaths. The prevalences of moderate-severe stunting and underweight are 40% and 36% respectively. Both figures have fallen by around 6% since 1998. Forty to fifty percent of under fives are iron deficient, with implications for their development. Mortality due to all these diseases is increased by HIV infection. Fifteen hundren children become infected with HIV every day. Forty five percent of these will die before age two without access to antiretroviral therapy. All these leading causes of childhood illness are both preventable and treatable.

2. Impact of Health and Nutrition on Education

Common conditions of poor health and nutrition can affect education in a number of ways. First, children's health and nutrition has an impact on their access to school. Second, children's 'school readiness' can be affected by their health and nutrition. This may have knock-on effects for their educational achievement and attainment, particularly where effects of disease and poor nutrition on brain development persist as cognitive impairments or emotional problems throughout the

school-age years. We shall deal in turn with impact on educational access and school readiness.

Health, Nutrition and Educational access

Children who do not attend school fail to do so for many reasons. These include the direct costs of sending children to school, requirement for children to work, conflict and the perception of the value of education and of school quality. However both disease and poor nutrition can have a major effect on children's chances of enrolling in school.

There are a number of ways in which the health of children before they enter school can affect the likelihood of enrolling. For example, parents may choose not to invest in the education of children who are ill or – where illness affects mental or physical abilities – those who are less able than their siblings. But one of the most apparent ways in which children's chances of enrolling in school are affected by ill-health is where disease leads to serious physical or mental disabilities. Such conditions typically affect children's educational opportunities to a greater extent in low-income countries than in high-income countries. This is not only because poorly-resourced schools lack the facilities to cater for the special needs of children with disabilities but also because of the stigma that can be attached to these children, either from parents who do not think the child's education is worth investing in or from fellow schoolchildren and teachers who do not wish to have them in their schools (DFID, 2001).

Little is known about the extent of disabilities in low-income countries but evidence suggests that a significant number of children are affected. For example, studies have found prevalences of serious mental retardation ranging from 5 children per 1000 in Bangladesh, to 17 per 1,000 in Jamaica, 19 per 1,000 in Pakistan (Durkin,

2002) and a study in South Africa (Christianson et al., 2000) found around 35 children per 1,000 had intellectual disabilities. We now consider the diseases of early childhood that can influence a child's chances of enrolling in school, either by causing severe physical or mental retardation or by through more subtle effects that affect parental decisions about their children's schooling.

Nutrition and School Enrolment

Micronutrients

It is clear that micronutrient deficiencies and their interactions with infections play a major role in the cause of disability in low-income countries. The World Health Organization estimates that vitamin A deficiency causes around 350,000 (~70%) of new cases of blindness or partial blindness occurring in children each year. In addition to the direct effects of vitamin A deficiency on vision, it also contributes to childhood disability by increasing the risk of measles and other serious childhood infections that can result in long-term disability. Currently 76% of children aged 6-59 months receive Vitamin A supplementation in least developed countries, with figures of 58% in South Asia and 64% in sub-Saharan Africa (Table 1).

The public health benefits of adequate iodine intake have long been understood but iodine deficiency remains prevalent in many low-income countries and is the leading cause of preventable mental retardation, worldwide. In utero exposure to maternal iodine deficiency during the first two trimesters of pregnancy can damage the developing brain, causing permanent cognitive disability as well as motor, hearing and speech disabilities (Cao et al., 1994). Such iodine deficiency disorders can be totally eliminated by preventative measures using iodine administered in salt, oil or some other vehicle. In 1996, WHO reported that 56% of the population of 83

developing countries now had adequate access to iodized salt. This represents an increase of 750 million since 1990 with an additional protection of 12 million children (Hetzel, 2000). More recent figures indicate that 68% of the households in the world consume iodized salt. This includes 64% of households in Sub-Saharan Africa, 49% in South Asia and 53% in least developed countries overall (Table 1).

Folate deficiency very early in pregnancy can lead to neural tube defects, such as spina bi-fida, which result in motor disability and in some cases intellectual impairment in offspring. Data from South Africa put the prevalence between 0.63 and 1.74 per 1000 live births, with higher prevalence for whites of European descent compared to black Africans (Buccimazza, Molteno, Dunne, & Viljoen, 1994). More than half the cases of neural tube deficits can be prevented by giving supplementation of 400 micrograms of folic acid per day to women of childbearing age around the time of conception (Wald, 1991).

Early childhood stunting

A number of studies across Asia and Africa have found that stunted children (those with a low height for their age) enroll in school later than other children (Glewwe & Jacoby, 1995; Jamison, 1986; Moock & Leslie, 1986; Partnership for Child Development, 1999). Evidence from an external cause of nutritional deficit (a price shock in Pakistan) suggests that late enrollment is actually a consequence of stunting and not just a co-occurring consequence of poverty (Alderman, Behrman, Lavy, & Menon, 2001). Furthermore, whereas poor children are often found to forego schooling to engage in economic activities such as fishing or farming, a study in Tanzania (Jukes, in press) found that stunted children were less likely to engage in these activities as well as less likely to enroll in school. It is likely that these findings result from parental perceptions of their children's suitability for schooling and other

activities. In Zanzibar, parents who enroll only some of their children in school, enroll those they see as having the higher developmental levels at age of school entry (Jukes, in prep). Smaller children are perceived as physically and perhaps mentally immature: anecdotal reports from a number of African countries suggest that children are considered ready for school when they are able to reach over their heads and touch one ear with the opposite arm, something determined by their physical stature. It may also reflect concerns about smaller children being able to walk safely over the long distances that are typical of journeys to school in the rural areas of many developing countries. Another factor that may explain the relationship between stunting and school enrolment is that parents consider investing in healthy children's education most cost effective and thus these children are prioritized above their less healthy siblings when decisions about school enrolment are made. Both of these explanations are consistent with the finding that the school enrolment of girls is delayed more by stunting than for boys (Alderman et al., 2001), presumably reflecting parents increased unwillingness either to invest in girls' education or to allow young girls to walk long distances to school. Whatever the explanation, the finding that girls are differentially disadvantaged is of concern, given international targets to eliminate gender disparities in access to education in the next few years.

Most of the evidence discussed above concerns the stunting of children as they enter school or after a few years of primary schooling. This is likely to be indicative of the children's nutritional status during the preschool years because stunting results from chronic undernutrition often over a period of several years. However, one study directly addresses the relationship between undernutrition of younger children and their subsequent enrolment. This study in the Philippines (Mendez & Adair, 1999)

found that children who were severely stunted before age 2 were more likely to enroll in school late, to repeat a grade and to be absent from school.

The notion that parents are reluctant to invest in educating the least healthy of their children could apply equally to other conditions affecting children of pre-school and school age. There is limited information about other problems of health and nutrition affecting school enrolment. One study in Zanzibar found that out of school children were twice as likely to be infected with helminths than their in-school peers (Montresor et al., 2001). Another study in Tanzania found that out of school children were more wasted (a low weight for their height) and more anemic than children in school (Beasley et al., 2000). However, in both of these cases it is not clear whether the health of children influenced their school enrolment or that both were consequences of poverty.

Infection and disability

Prenatal infections

There are several infectious diseases which can lead to disabilities at birth. Congenial rubella syndrome (CRS) leads to deafness, cataracts, visual impairments, mental retardation and heart defects and is caused by maternal rubella infection in the early stages of pregnancy. Estimates (Cutts & Vynnycky, 1999) suggest that 110,000 cases of CRS occur every year in developing countries. Rubella can be controlled effectively though vaccination. Currently (in 2001) less than a third of low-income countries include rubella in their national immunization programs, with virtually no countries in sub-Saharan Africa or South Asia systematically vaccinating against rubella. However, in countries with high transmission rates, immunity is also high and large scale vaccination programs may not necessarily be the best response.

Deafness and mental retardation can also be caused by congenital syphilis. It is estimated that around 10% of pregnant woman in many parts of sub-Saharan Africa are infected with syphilis (Walker & Walker, 2002) with around 12 million new infections each year (Enders & Hagedorn, 2002), although rising levels of HIV infection are likely to result in an increased prevalence of syphilis. There are well-established procedures of antenatal screening and treatment with penicillin (Watson-Jones et al., 2002) for the prevention of congenital syphilis but coverage is currently poor.

Postnatal infections

The most common infectious disease causing mental disability is malaria. In its most extreme form malaria attacks the brain (cerebral malaria) and can lead to neurological damage or death. In sub-Saharan Africa, cerebral malaria annually affects 575,000 children under 5 years of age of whom 110,000 die. The survivors suffer developmental and behavioral impairments: each year, 9,000-19,000 children (more than 2% of survivors) less than 5 years of age in Africa experience neurological complications lasting for more than 6 months (Murphy & Breman, 2001). These include hemiplegic cerebral palsy (involving paralysis of one side of the body), cortical blindness, motor coordination problems (ataxia) and language problems (aphasia) (Brewster, Kwiatkowski, & White, 1990). Such complications affect children's chances of going to school. A study in Kenya found that children who had suffered severe episodes of malaria with a high risk of neurological damage were less likely to have been enrolled in school than children with low levels of malaria infection (Holding et al., in press). One explanation for this is that parents recognize the cognitive delays suffered by their children and accordingly delay or abandon plans for their school enrolment.

Clear evidence of the impact of early childhood malaria on educational access comes from recent work in the Gambia (Jukes et al., submitted). In this study, children aged 6 months -5 years were given anti-malaria drugs during consecutive malaria transmission seasons to protect them from malaria infection. The children were then followed for 15 years. This study found that prevention of early childhood malaria through regular chemoprophylaxis led to children staying at school for around one additional year (see Figure 1). The results also suggested a differential impact on school enrolment by gender, although with borderline statistical significance. At the time children in the study were attending school, in the early 1990s, gender differences in school enrolment in the Gambia were substantial. In this study, girls were six times less likely to be enrolled in school than boys. However, prevention of malaria doubled girls' chances of school enrolment. This is one of the clearest examples of how improving children's health in the preschool years can lead to increased participation in primary schooling.
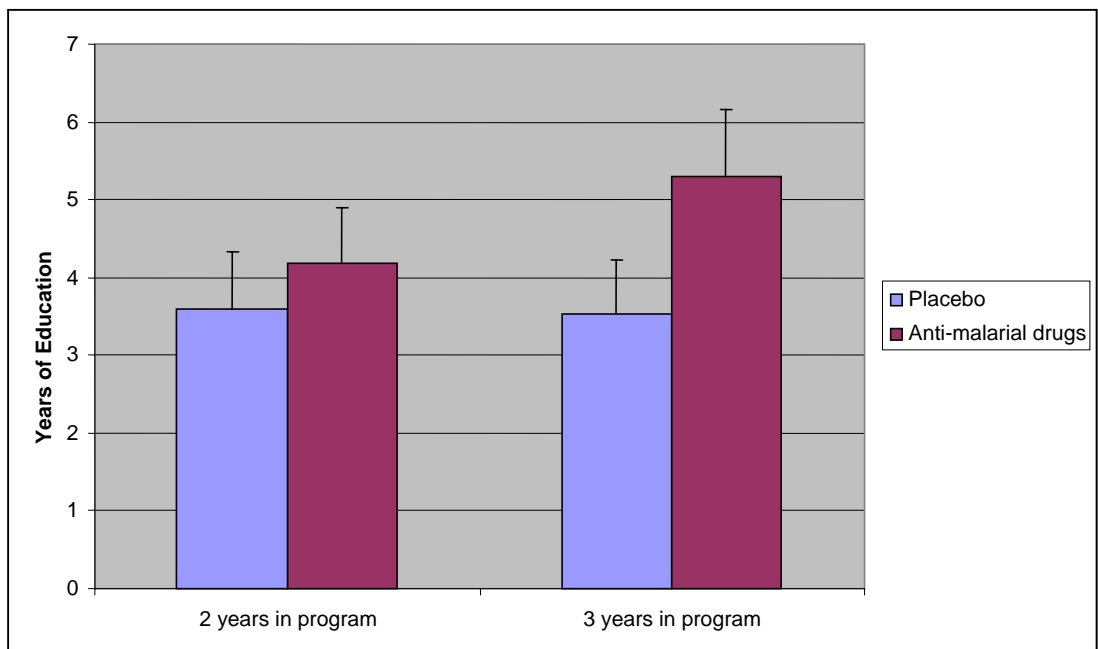

Figure 1. Impact of early childhood malaria prevention on years of schooling in the Gambia.

Malaria can be prevented. Use of insecticide-treated bed nets is effective (Shiff et al., 1996) and is listed as one of the MDG quick wins (UN Millennium Project, 2000). Use of anti-malarial drugs for intermittent preventive treatment or to treat clinical attacks may help reduce the burden of this disease (Brooker et al., 2000).

Other childhood diseases cause mental and physical disabilities which are likely to affect chances of school enrolment in resource-poor settings. Poliomyelitis (polio) is a highly infectious disease caused by a virus which invades the nervous system and causes irreversible paralysis (usually of the legs) in around 1 in 200 cases. Children under 5 are most vulnerable to infection. Polio can be effectively controlled by use of an oral vaccine. The Global Polio Eradication Initiative has been successful with estimated number of cases reduced from 350,000 at its launch in 1988 to under 500 cases in 2001. The number of 1-year-old children immunized against polio in Sub-Saharan Africa rose from 48% in 1998 to 60% in 2003 (UNICEF, 2006). In South Asia, immunization levels have remained at around 70% (see Table 2). The initiative's aim of eradication by 2005 received a setback due to an outbreak in Nigeria which spread to 13 other countries in Africa. In many of these the spread of the disease has now been halted and Somalia is the only country where infection numbers are still increasing (Global Polio Eradication Initiative, 2006).

Meningitis is another disease that directly affects the developing brain. Meningitis is an inflammation of the lining around the brain and spinal cord caused by a number of different types of infections, but two types are predominant: pneumococcal meningitis and *haemophilus influenzae* type b (Hib) meningitis. The disease often occurs in epidemics and is most prevalent in the "meningitis belt", an area extending across Africa from Ethiopia to Senegal. Globally, there are around 500,000 cases of meningitis each year, with very young children being at the greatest

risk. Overall, around 10% of cases are fatal and 10-15% of survivors suffer persistent neurological defects including hearing loss, speech disorders, mental retardation, seizures and motor impairment. However problems may be more severe in developing countries. A study in the Gambia found that death occurred in 48% of children with pneumococcal meningitis and 58% of survivors had clinical sequelae, which in half of these cases prevented normal adaptation to social life. With Hib meningitis, 27% of children died and 38% of survivors had clinical sequelae, which prevented normal adaptation to social life in a quarter of cases (Goetghebuer et al., 2000). Hib meningitis and (the less prevalent) meningococcal meningitis are vaccine preventable. There is currently no vaccine for pneumococcal meningitis.

Neurological problems can also be caused by encephalitis. This is an inflammation of the brain caused primarily by viral infections and can lead to seizures, cognitive and motor disabilities, coma and blindness in survivors. A vaccine exists for Japanese encephalitis virus which is the leading cause of encephalitis in Asia.

Nutrition and Pre-School Attendance

Two recent studies provide examples of how programs to improve children's nutritional status can have beneficial effects on attendance of preschool institutions. One study in informal settlements in East Delhi gave a course of iron supplementation and deworming treatment to children attending preschools run by women from the local community. Attendance of the preschools rose by 5.8% from levels of around 70% representing a one fifth reduction in absenteeism (Bobonis, Miguel, & Sharma, submitted). A school feeding program in Kenya also found improvements in attendance as a result of the intervention. The program offered children a cup of

porridge for breakfast. School participation was 35.9% where meals were provided and 27.4% in comparison schools, indicating an improvement in attendance of around one third. Improvements in participation resulted both from attracting new children to the school and by improving the attendance of children already enrolled. It is likely that attendance improved due to the incentive to attend provided by the school breakfast, rather than as a result of improved health of children (Vermeersch & Kremer, 2004).

Studies of other health and nutrition conditions in preschool children are lacking. However, it is likely that conditions affecting school-age children's attendance are also a problem for preschool children. Both stunting (Yoshizawa & Mon, 2002) and anemia (Hutchinson, Powell, Walker, Chang, & Grantham McGregor, 1997) are associated with poor attendance of primary schools, and both conditions are prevalent in younger children. Interventions that have been shown to improve attendance at school include school feeding programs (Jacoby, Cueto, & Pollitt, 1998; Powell, Walker, Chang, & Grantham-McGregor, 1998; Simeon, 1998) and programs micronutrient supplementation targeted at prevention of diarrhea and acute respiratory infections (van Stuijvenberg et al., 1999).

<u>HIV/AIDS</u>

There is increasing evidence of the impact the HIV/AIDS pandemic is having on children's schooling. Children from AIDS-afflicted families suffer from the stigma attached to the disease, with some children turned away from school. However, the disease probably has its greatest effect on children's education when one or more parents die. In Malawi, 9.1 percent of children were found to drop out of school the year following the death of one parent. Those who had lost both parents were twice as

likely to drop out, with 17.1 percent of children leaving school in the following year (Harris & Schubert, 2001). In Tanzania, the primary school enrolment of maternal orphans was delayed although they were not more likely to drop out of school once enrolled (Ainsworth, Beegle, & Koda., 2001). In Zimbabwe, orphanhood was found to decrease the likelihood of school completion due to gaps in support from the extended family. However, school completion was sustained - particularly for female orphans – where orphanhood resulted in a female-headed household and greater access to external resources (Nyamukapa & Gregson, 2005). Few data exist on the impact of orphanhood on ECD attendance but it is likely to be similar to effects found in primary school age children. Given that user fees are more common for ECD programs than for primary schooling, the economic impact of parental death on school attendance may be greater.

Health, Nutrition and School readiness

School readiness refers to a range of competencies that preschool children should possess in order to benefit from the school environment. In order to be ready for school, in this sense, children require certain cognitive skills, such as language abilities and numeracy, a level of physical and motor development, and appropriate socio-emotional development. Each of these factors will be given individual consideration in reviewing the evidence for an effect of preschool health and nutrition on school readiness.

Undernutrition

Effects on cognitive development

Undernutrition (also called 'Protein Energy Malnutrition') is a general term applied to children with heights and weights below age-referenced criteria. It typically

results from a severe or chronic lack of a range of essential nutrients rather than from a just a lack of protein. This complicates the discussion of the cognitive consequences of undernutrition because several different causal factors may be involved, each potentially associated with a different means of affecting brain and behavior.

Undernutrition impairs children's mental development in the early years. A low height or weight for age is associated with impairment in developmental levels of young children (see Simeon & Grantham-McGregor, 1990, for a review). For example, in Guatemala the length and weight of 1-2 yr olds was related to their scores on a test on infant mental development (Lasky et al., 1981).

Children hospitalized with severe malnutrition show lower developmental levels, but not more so than in children hospitalized for other reasons (Grantham-McGregor, Stewart, & Desai, 1978). Similarly, on recovery the development levels of severely malnourished children remain impaired but this is likely attributable to chronic undernutrition rather than the acute episode itself (Grantham-McGregor, Powell, & Fletcher, 1989).

Quality evidence of the relationship between nutrition and cognitive development comes from intervention trials that fall into two categories: preventative and therapeutic. We will look at these in turn. In many countries steps have been taken to prevent malnutrition in children by beginning nutritional supplementation in pregnancy and continuing in infancy. This approach has been successful in improving the motor development of infants in Taiwan by 8 months of age (Joos, Pollitt, Mueller, & Albright, 1983). In Guatemala a similar supplementation program found small improvements in cognitive function for children between 3 and 7 years (Freeman, Klein, Townsend, & Lechtig, 1980).

Supplementation in Mexico from shortly after birth and throughout the first three years was found to improve children's school performance and language skills (Chavez & Martinez, 1981). In addition, from 8 months of age supplemented children became increasingly active and by 2 years of age were showing eight times more activity than non-supplemented children. A similar program with high-risk mothers in Bogota, Colombia was successful in improving the mental development of their children at 18 months and also their language skills at 36 months (Waber et al., 1981). One group of mothers in this study received education on how to stimulate cognitive development in their children. This program improved children's language skills at 18 months and 36 months. In addition the nutritional supplementation and maternal education program worked synergistically: supplementation improved the effectiveness of stimulation (or vice versa) such that the benefit of receiving both interventions was greater than the sum of the independent benefits of the two interventions. A final finding is worthy of note from this study: Overall girls benefited more from the program than boys. This study is fairly unusual in reporting such an effect. However, if gender differences were found to be common in children's response to nutritional supplementation this would have important implications for the gender equity goals of Education for All.

One study in Kenya (Vermeersch & Kremer, 2004) found a benefit of a school feeding program for children's educational outcomes. Children were given a breakfast meal through and ECD class and improvement was found in educational achievement but not in tests of cognitive function, and was only evident in schools with an experienced teacher. The improvement in educational achievement was around 0.4 SD.

Results from therapeutic trials also provide strong evidence of a link between nutritional supplementation and cognitive development. These studies have typically involved remedial nutritional supplementation to malnourished children. In Bogotá, Colombia children from a poor urban area who underwent four periods of an educational stimulation and nutritional supplementation program between the ages of 42 and 84 months showed a gain in general cognitive ability of 0.80 SD in comparison with a group who received the same treatment for only one period between the ages of 74 and 84 months (McKay, Sinisterra, McKay, Gomez, & Lloreda, 1978). In so doing, these children closed the gap in IQ between themselves and a group of richer urban children. In this study, children received both nutritional supplements and education and it is not possible to decipher which of these two interventions was most influential in improving children's cognitive abilities. A more recent study in Jamaica helped resolve this issue by giving poor, urban and undernourished children aged 9-24 months a two-year program of either nutritional supplements, stimulations, both interventions or neither intervention. The gains in overall development quotient (DQ - an IQ equivalent for infants and young children) were impressive. Nutritional supplementation accounted for an increase of 6.1 DQ points (0.66 SD) over 2 years, whilst stimulation improved DQ by 7.3 points (0.79 SD). The effects of the two interventions were additive (receiving both interventions was better than receiving only one of them) but there was no interaction between them (nutritional supplementation did not improve the effectiveness of the stimulation program, for example). Significantly, the children who did receive both treatments effectively closed the gap in DQ between themselves and adequately nourished children (Grantham-McGregor, Powell, Walker, & Himes, 1991).

Long-term effects on cognition

The above studies show that undernutrition leads to impaired school readiness in terms of cognition. The reason for concern about delayed school readiness is that children are likely to perform less well at school as a result. But is there evidence of this? It is certainly possible that differences in school readiness at the age of school entry may lead to poor achievement which in turn leads to drop out and repetition and thus deficits become compounded. On the other hand, mental development can be quite robust to early difficulties. For example, large differences in language abilities in the preschool years typically even out in the early years of primary school. The next section reviews the evidence that preschool undernutrition has long term effects.

Beginning with the most profound nutritional insults, severe malnutrition in early childhood has a long term effect on development. Children in Jamaica who had suffered from severe malnutrition between the ages of 6 and 24 months were found to lag behind adequately nourished children who had been hospitalized for other reasons at ages 7, 8, 9 and 14 on range of IQ tests. At 14 years they were substantially delayed in overall IQ (1.50 SDs below the control group), vocabulary (1.33 SDs) and tests of educational achievement, even after accounting for differences in the background of the two groups of children (Grantham-McGregor, Powell, Walker, Chang, & Fletcher, 1994). These are substantial differences. Similar results have been found in a more than a dozen other studies (Grantham-McGregor, 1995).

Results of interventions strengthen the evidence for a long-term effect of nutrition on cognition and also demonstrate the potential for reducing the gap between severely undernourished children and their peers. The study in Jamaica found that a 3-year program to teach mothers how to improve the development of their child (aged 6-24 months at the beginning of the program) conferred significant long-term benefits

on undernourished children. At age 14 the undernourished children whose mothers had taken part in the education program were only 0.28 SDs behind adequately nourished children on overall IQ scores and 0.68 SDs ahead of undernourished children who had not taken part in the intervention.

It is clear that severe malnutrition has a substantial long-term effect on child development. Of potentially greater concern is the effect that mild and moderate malnutrition has on child development, given the high prevalence of this condition amongst children in developing countries. This issue has again been addressed by researchers in Jamaica who followed 127 undernourished children for 8 years. As discussed above, these children received a two year program of nutritional supplementation, psychosocial stimulation, both interventions or neither intervention. Four years after the end of interventions, perceptual/motor skills – but not other cognitive skills - were superior in those children who had received stimulation (Grantham-McGregor, Walker, Chang, & Powell, 1997). The same skills were also superior for children who had originally received a nutritional supplement and whose mothers had the highest verbal intelligence. One explanation for this interaction was that the most intelligent mothers were also the ones giving children the most stimulation. There were no effects of the intervention on general cognitive abilities or on memory, although each intervention group had higher scores than the control subjects on more of these cognitive tests than would be expected by chance. Thus, stimulation and to a lesser extent supplementation – had modest effects on children's cognitive abilities over 4 years.

The study also compared the stunted children taking part in the original intervention with other children from similar backgrounds, but who were known not to be stunted at the time of the interventions. These non-stunted children had higher

scores on the general cognitive factor than previously stunted children, although were no better in perceptual-motor skills or memory.

There were similar findings eight years after the end of the intervention. Children who received stimulation as infants had a higher IQ (by 0.42 SD) at ages 11-12 years whilst supplementation had no effect on cognitive abilities of children at this age. Again, children who were stunted before two years of age had a lower IQ (by 0.60 SD) and performed more poorly on 8 out of 9 cognitive tests (effect size range 0.38 SD to 0.61 SD) at age 11-12 than children who were not stunted before two years of age (Walker, Grantham-McGregor, Powell, & Chang, 2000).
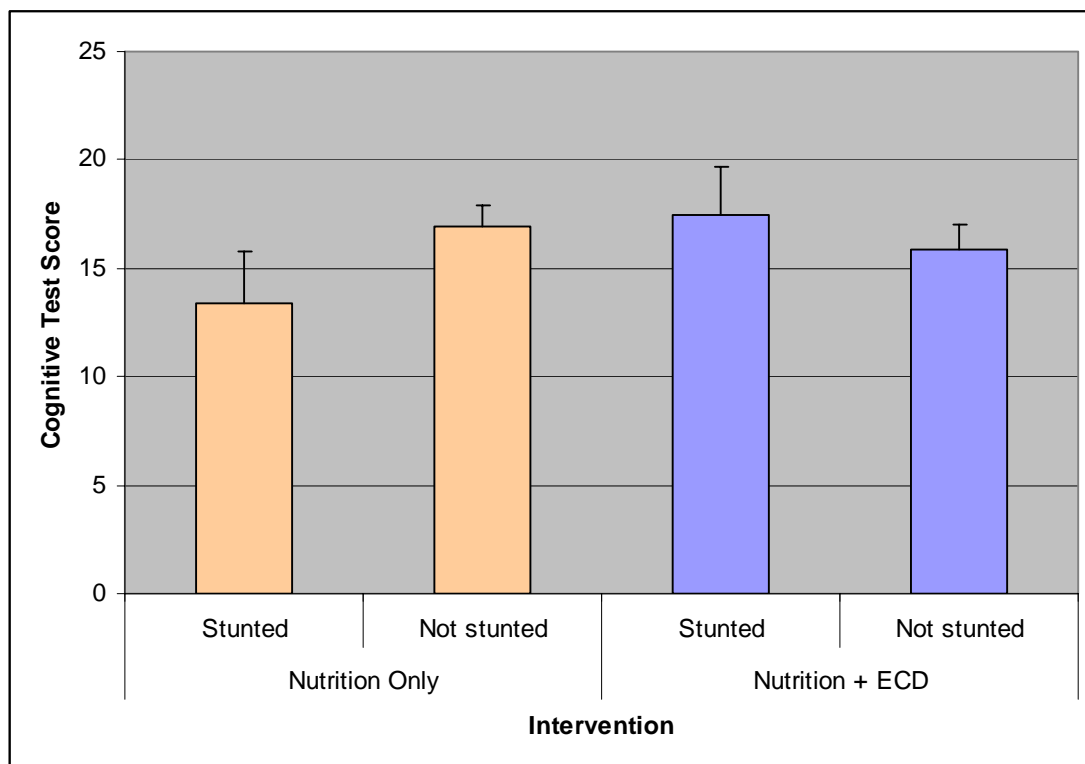

Figure 2. Impact of two preschool interventions in Vietnam on cognitive abilities of children aged 6-8yrs

A more recent study in Vietnam (Watanabe, Flores, Fujiwara, & Lien, 2005) adds to our understanding of the interaction between educational and nutritional interventions in early childhood. In this study children aged 0-3 years in five

communities were given nutritional supplements. In two of these communities children took part in an ECD project at ages 4-5 years. At ages 6-8 years those who had received both interventions scored 0.25 SD higher on the Raven's Progressive Matrices Test (a test of non-verbal reasoning) than those who had received only the nutritional intervention. The effect was particularly pronounced for those who were stunted at the time of testing. Amongst stunted children, those who had received both interventions scored significantly better (0.67 SD) than those who had only received the nutrition intervention. Furthermore, the ECD intervention appeared to counteract the impact of stunting on cognitive abilities, whereas those who had received nutritional supplements but no ECD intervention showed a large (~0.5SD) difference between stunted and non-stunted children (Figure 2).

In another long-term follow-up study in Guatemala, children given nutritional supplements prenatally and in the immediate postnatal period (up to 2 years) were found to perform better as adolescents (aged 13-19 years) on tests of vocabulary, numeracy, knowledge and reading achievement (Pollitt, Gorman, Engle, Rivera, & Martorell, 1995). Interestingly, these benefits were found only for those children of low socioeconomic status. In tests of reading and vocabulary, the effect of supplements was most evident for children with the highest levels of education. Performance in tests of memory and reaction time were better in supplemented children, although the improvement did not depend on socioeconomic status or education. A later study of women in this cohort (Li, Barnhart, Stein, & Martorell, 2003) found a positive effect of the nutritional intervention on educational achievement but only for those who had completed primary school.

The studies in Jamaica and Guatemala show that a fairly sustained program of nutritional supplementation and/or psychosocial stimulation, lasting for two years, can

have long-term benefits for children's development. A study in Indonesia shows that even a 3 month program of supplementation can have long term effects (Pollitt, Watkins, & Husaini, 1997). Children supplemented before 18 months were found to have improved performance on a test of working memory at age 8, although no effect was observed on other measures of information processing, vocabulary, verbal fluency and arithmetic.

Undernutrition and motor development

Motor development is an important aspect of school readiness and can often be closely associated with cognitive development. Three studies were found that reported the impact of nutritional supplementation on motor development. Two of the studies were reported above and found a greater impact of the intervention on motor development than on cognitive development. A third study found an impact on motor development but not on cognitive development. The first study is the preventative trial in Columbia (Waber et al., 1981). At 18 month this program was successful in improving the motor development of their children to a greater extent than their mental development. In another preventative trial in West Java, Indonesia (Husaini et al., 1991) a short term intervention – only 90 days of nutritional supplementation beginning after pregnancy - found improvements in the motor development of children at between 6 and 20 months of age. No impact was found on mental development. Finally, in the Jamaican study, giving nutritional supplementation and/or psychosocial stimulation to undernourished children, larger gains were found for the locomotor sub-scale of the assessment battery than for mental development – a 12.4 point (1.04 SD) increase was found due to supplementation (compared with 6.1 points for mental development) and 10.3 points (0.87 SD) due to stimulation (compared with 7.1 points for mental development). A possible interpretation of these

results is that nutritional supplementation is more important for motor development than for mental development. Four years after the end of interventions, motor skills were superior in those children who had received stimulation (Grantham-McGregor et al., 1997).

Socio-emotional development

Evidence on the social and emotional development is more scarce than evidence on mental and motor development. This is due in part to the difficulty in measuring development in this domain and the time-consuming observation techniques that are typically involved. But some evidence suggests that both chronic and acute malnutrition is associated with changes in social and emotional development in young children. For example, in Kenya, undernourished infants were found to be less sociable than adequately nourished infants (Whaley, Sigman, Espinosa, & Neumann, 1998). Acute episodes of severe undernutrition can lead to increased apathy, decreased activity and a less frequent and less thorough exploration of the environment (Grantham-McGregor, 1995). After the acute episode, all behavior returns to normal except for the thoroughness of exploration of the environment.

Similar to motor and cognitive development, aspects of social and emotional behavior can be improved by interventions. The program in Mexico (Chavez & Martinez, 1981) which gave nutritional supplements from shortly after birth and throughout the first three years was found to improve adaptive behavior and personal and social behavior in addition to the cognitive improvements reported above. Similarly, the supplementation program with high-risk mothers in Bogota, Columbia found improvements in personal and social skills as well as the cognitive and motor improvements reported above (Waber et al., 1981).

Children who enter school with poor socio-emotional developmental levels are a concern because they are less able to adapt to the school and less able to learn. The link between socio-emotional development and cognitive development is clear. For example in Kenya, children who were undernourished at 6 months were also less sociable, and those who were less sociable at 6 months had lower development scores at 30 months and poorer verbal comprehension scores at 5 years (Whaley et al., 1998). But, poor socio-emotional development is a concern in its own right for the school-age child. And there is good evidence from Jamaica that nutritional deficiencies in early childhood have a long term impact on socio-emotional outcomes. Children who were stunted before aged 2 in this study were more likely to have conduct disorders aged 11-12 years (Chang, Walker, Grantham-McGregor, & Powell, 2002). But those who received psychosocial stimulation during early childhood as part of this program were found in a recent follow-up to be less anxious and depressed with fewer problems of poor attention and low self-esteem (Walker, Chang-Lopez, Powell, Simonoff, & Grantham-McGregor., submitted). There were no such beneficial effects from children who received nutritional supplementation as part of this program.

It is not clear from this study how such long term effects arose. It is possible that they represent the continuation of social and emotional benefits of the psychosocial intervention which were already evident in early childhood. Alternatively, they may have resulted from, for example, improved cognitive abilities that resulted from the intervention and led to increased self-esteem and other positive psychosocial outcomes. However, taking findings of short-term and long-term effects together, there is strong evidence that undernutrition can lead to poor socio-emotional outcomes which will affect school readiness.

Timing

It might be expected that nutritional deficits in the first year of life have the greatest impact on development. However, evidence does not bear this out. A study in Colombia found that giving nutritional supplements to children between 6 months and 36 months of age had a greater impact on cognitive development at 36 months than supplements given to the mother in the third trimester of pregnancy and then to the child up to 6 months of age and the same impact as a continuous supplementation running from the third trimester of pregnancy to 36 months (Waber et al., 1981). A longer-term study in the Philippines found that malnutrition in the second year of life actually had a greater impact on the performance of 8 year-olds on a non-verbal test of intelligence than malnutrition in the first year of life (Glewwe & King, 2001).

Other studies support early supplementation. In Indonesia children supplemented before – but not after - 18 months of age were found to have improved performance on a test of working memory at age 8 years (Pollitt et al., 1997). Another study in the Philippines found that children stunted in the first six months more likely than those stunted later on to have impaired cognitive performance at 8 years of age (Mendez & Adair, 1999). This however was explained by the fact the children suffering the earliest bouts of malnutrition also suffered the most severe and persistent malnutrition. A confounding factor such as this is a reminder of the difficulty in interpreting findings related to timing effects of nutritional deficiencies on cognitive development. At present, there is no strong evidence that early (1st year of life) interventions with children suffering from or at risk of malnutrition are more effective than interventions at a later age.

Maternal behavior

A child's development is shaped by a complex interaction of factors in its environment. Just as a child's active interaction with its environment is crucial for development so is the active engagement of others in their environment. Nutrition can play a part in this too. In Egypt and in Kenya maternal behavior towards toddlers was found to be influenced by the nutritional intake of the child more than that of the mother (Wachs et al., 1992), with poorly nourished children more likely to be carried by their mother and in general stay closer to their mother than adequately nourished children (Grantham McGregor, Schofield, & Haggard, 1989).

In addition to the effect child malnutrition has on maternal behavior, evidence from Mexico suggests that mothers of malnourished children behavior differently towards their children even before the onset of malnutrition (Cravioto & Arrieta, 1979). They were less likely than other mothers to reward the successes of their child, were less affectionate and talked less to them. This could be because mothers of children who become malnourished are less well educated than other mothers (Grantham-McGregor et al., 1994). In addition, mothers of malnourished children may often be poorly nourished themselves, which in turn affects their behavior. In Kenya, it was found that although toddlers were protected from the effects of temporary food shortages, their mothers were not and maternal nutritional deficiencies led to changes in the quality of mother-child interactions (McDonald, Sigman, Espinosa, & Neumann, 1994).

These findings have clear implications for children's development. We have seen that psychosocial stimulation is perhaps the most important factor preventing poor cognitive outcomes in malnourished children. If these children typically receive

poor levels of stimulation from their parents – for whatever reason – the lack of
stimulation is likely to compound the effects of nutrition on their development.

Low birth weight

A number of the intervention studies reported above begin nutritional
supplementation before birth in recognition of the importance of prenatal nutrition.
Children with a low birth weight (LBW) or more generally, those born small for their
gestational age (SGA) have poor developmental outcomes with implications for
school readiness. Differences between SGA babies and those of normal birthweight
typically do not appear in the first year of life (Grantham-McGregor, 1998), although
this can depend on environmental factors. In Brazil, developmental delays were
observed only in SGA babies who also received little stimulation in the home.
Similarly, low birth weight affects infant development to a greater extent in the homes
of illiterate mothers as compared to literature mothers. Deficits in developmental
levels appear with high-risk infants in the second year with clear significant
differences apparent by the third year. Some deficits were also found in the
development levels of SGA babies between the ages of 4 and 7.

Breast feeding

The percentage of infants who are exclusively breastfed in the first 6 months of
life has fallen from 43% in 1998 to 34% in 2004 (UNICEF, 2006). In Western and
Central Africa the figure is only 20%. This is of concern because breast feeding is
associated with a moderate long-term improvement in cognitive development. A
review of 17 studies in developed countries estimated that breast-feeding led to an
improvement of 3.2 IQ points (~0.21 SD), which was fairly stable across the lifespan

from 3 to 50 years of age (Anderson, Johnstone, & Remley, 1999). Low birth weight babies benefit most from breastfeeding, gaining 5.2 IQ points (0.35 SD) compared with a gain of 2.7 points (0.18 SD) for children of normal birthweight.

The effects of breastfeeding also depend on the length of time that infants were breastfed. Scandinavian children breast fed for longer than 6 months were found to have improved cognitive tests outcomes at 5 years compared with children who were breastfed for less than 3 months (Angelsen, Vik, Jacobsen, & Bakketeig, 2001). However, it is difficult to be certain about such findings since mothers who choose to breastfeed are often more educated or more wealthy and this could explain some of the difference in IQ scores (Jain, Concato, & Leventhal, 2002) although review studies do attempt to account for such factors in their estimates of IQ differences (Anderson et al., 1999). In general, the evidence is not conclusive but is strongly suggestive of a link between breastfeeding and cognitive ability in later life.

Iron Deficiency Anemia

Iron deficiency and mental development: Children < 2 yrs

A number of studies have found that infants with iron deficiency have lower developmental levels than iron-replete children. Lower scores on the Mental Development Index and the Psychomotor Development Index of the Bayley Infant Development Scales have been found with 12 month old children in Chile (Walter, 1989), 12-23 month old children in Costa Rica and (Lozoff et al., 1987), 6-24 month old children in Guatemala (Lozoff, Brittenham, Viteri, Wolf, & Urrutia, 1982), and 12-18 month old children in Indonesia (Idjradinata & Pollitt, 1993).

Only one rigorous randomized controlled trial has been conducted on the impact of iron supplementation on children under two years of age in low-income countries

that has met rigorous criteria for experimental design (a double blind randomized controlled trial). This study in Indonesia (Idjradinata & Pollitt, 1993) gave iron supplementation (iron sulfate) or placebo to iron deficient children aged 12-18 months. Those receiving iron supplementation showed impressive gains in the Bayley Scales of Infant Development. Their Mental Development Index rose by 19.3 point (1.3 SD). This represents a substantial improvement by children receiving iron supplementation. At the end of the 4 month trial these children had similar developmental levels to those who were not iron deficient in the first place.

Other studies have conducted supplementation trials over a similar time period (>= 12 weeks), although none had the same rigorous experimental design. One other study in Indonesia succeeded in eliminating differences between iron deficient and iron replete children after supplementation, whilst in two other studies, in Chile (Walter, 1989) and Costa Rica (Lozoff et al., 1987), there was no observed effect of supplementation. However, in the Costa Rica study, children whose iron status recovered completely also showed improvement in their mental and psychomotor development indices. A number of shorter term trials (< 15 days) have also been conducted. There is no evidence of improvement of iron deficient children in such trials (Grantham-McGregor & Ani, 2001).

Taken together, the evidence from all trials suggests that iron supplementation can improve the development of children under 2 years of age if sustained over a sufficiently long period of time (~ 12 weeks).

Iron deficiency and mental development: Children aged 2-6 yrs

A number of studies have compared iron deficient/anemic children with iron-replete children. Working in the preschool age group, Pollitt (1986) found that Guatemalan children with iron deficiency anemia took longer to learn a

discrimination task than their iron replete peers. The difference between the two groups was substantial in this (> 3 SD), although there were no differences in two other tests. Similarly, Soewondo (1989) found that Indonesian children with iron deficiency anemia were slower than iron replete children in a categorization task, although the two groups performed similarly on tests of learning and vocabulary. No such differences were found with younger children in one study in India (Seshadri & Gopaldas, 1989).

All five studies in the preschool age group have found improvements in the cognitive function of iron deficient children following iron supplementation, including improvements in a learning task (Pollitt et al., 1986; Soewondo et al., 1989) and in an IQ test (Seshadri & Gopaldas, 1989, Studies 1 and 2). One study in Zanzibar (Stoltzfus et al., 2001) gave 12 months of iron supplementation and deworming treatment to children aged 6-59 months from a population in which iron deficiency was common. They found that iron supplementation improved preschoolers' language outcomes by 0.14 SD.

One study has looked at the impact of iron supplementation in a preschool setting. This study (Jukes, Sharma, Miguel, & Bobonis, in prep) was conducted with 2-6 year olds in informal settlements in East Delhi. Children who received 30 days of iron supplementation had improved attention in class, as rated by their teachers. The improvement was around 0.18 SD in comparison with the control group. However, there was no impact on a measure of general cognitive development.

All these studies indicate that iron deficiency can lead to substantial impairments in cognitive development which are likely to impair children's readiness for school. What is the evidence that such deficiencies have long term implications for children's school achievement?

The most comprehensive study to address this question followed a group of Costa Rican infants for more than 10 years (Lozoff, Jimenez, Hagen, Mollen, & Wolf, 2000; Lozoff, Jimenez, & Wolf, 1991). At 12-24 months of age, 30 of the group of 191 infants had moderate anemia and received treatment. At age 5 years, formerly anemic infants performed more poorly on a range of tests of non-verbal intelligence after accounting for differences between the two groups in a number of variables such as socio-economic status, birthweight, maternal IQ, height and education. Verbal skills were more equally matched between groups. At age 11-12 years the formerly anemic group performed more poorly in writing and arithmetic, and spatial memory. Older children only were poorer in a selective attention test.

A number of other studies have found similar long term effects of iron deficiency (Grantham-McGregor & Ani, 2001). Anemic infants in Chile (de Andraca Oyarzun, Gonzalez Lopez, & Salas Aliaga, 1991) were later found to have lower IQs and poorer performance on a range of tests of verbal and visual abilities at 5 years of age. Studies have attempted to quantify the relationship between infant anemia and later cognitive impairment. A study with infants in Israel (Palti, Pevsner, & Adler, 1983) found that a reduction in hemoglobin levels of 10 g/l at 9 months was associated with a reduction of 1.75 IQ points at 5 years of age (although no effect on developmental levels was found at 2 and 3 years of age). Children in the anemic group were found to be learning less well and to be less task-oriented than control children in second grade (Palti, Meijer, & Adler, 1985).

The results from these studies should be interpreted with a degree of caution. None of the studies reported in this section allows causal inferences to be drawn. In each study, the anemic group most likely differed from the control groups on a number of background variables such as socioeconomic status. One study (de

Andraca Oyarzun et al., 1991) found that in comparison to the control group the homes of anemic infants were less stimulating and their mothers were more depressed and less affectionate. Thus we cannot be sure that differences in performance between groups are not attributable to these other background characteristics, even though comprehensive attempts were made to control for them statistically in most studies.

Notwithstanding this caveat, the evidence of the effect of anemia and iron deficiency on the brain, on the behaviors of infants, preschoolers and their caregivers and the suggestion that the effect is a long-term one combine to make a persuasive case for early intervention to prevent iron deficiency.

Iron deficiency and motor development

Iron supplementation is found to have a substantial impact on the motor development of infants and also a significant effect on older preschool children. One study in Indonesia gave iron supplementation (iron sulfate) or placebo to iron deficient children aged 12-18 months and scores on the Psychomotor Development Index of the Bayley Scales of Infant Development rose by 23.5 points (1.6 SD). Most studies find cognitive or motor impacts of around 0.2-0.4 SD but this study in Indonesia shows that iron supplementation can have truly substantial effects on development.

A study with older (6-59 months) preschool children in Zanzibar (Stoltzfus et al., 2001) found that 12 months of iron supplementation and deworming treatment improved preschoolers' motor outcomes by 0.18 SD respectively.

Such effects found with children of enrollment age persist into the school-age years. In Costa Rica, formerly anemic infants performed poorly on motor tests at 5 years of age (Lozoff et al., 1991) and again aged 11-12 years (Lozoff et al., 2000).

Anemic infants in Chile (de Andraca Oyarzun et al., 1991) were also later found to perform poorly on a range of tests of motor function.

Socio-emotional development

There is clear evidence that iron deficiency anemia affects social and emotional development. In Costa Rica (Lozoff et al., 1987), infants with iron-deficiency anemia were found to maintain closer contact with caregivers; to show less pleasure and delight; to be more wary, hesitant, and easily tired; to make fewer attempts at test items; to be less attentive to instructions and demonstrations; and to be less playful. In addition, adults were found to behave differently towards iron deficient children, showing less affect and being less active in their interactions with these children. Such findings have serious implications for the amount of stimulation children receive, both from their own exploration of the environment and in the stimulation they receive from their caregivers.

When these infant were followed up at age 11-12 yrs (Lozoff et al., 2000), the formerly anemic group was more likely to have a number of behavioral problems. They were more anxious and depressed, had more attention problems, social problems and behavioral problems overall. They were also more likely to repeat grades at school and to be referred for special service.

Iodine deficiency

Iodine is required for the synthesis of thyroid hormones. These hormones, in turn, are required for brain development, which occurs during fetal and early postnatal life (Delange, 2000). Mental development is affected by both maternal hypothyroidism (a deficiency in maternal thyroid activity), which affects development of the fetal brain during the third trimester, and hypothyroidism in the newborn which

affects postnatal brain development. In either case, a spectrum of neurological disorder can ensue, from severe mental retardation associated with cretinism (discussed above) to more subtle neurological impairments. Nearly 50 million people suffer from IDD related brain damage. A relatively small proportion of these (<10%) are cretins with the remainder suffering more mild impairments.

Iodine supplementation in pregnancy reduces cretinism and improves IQ and school achievement between 8 and 15 years later in one study (Greene, 1984) and between 14-16 years of age in another (Pharoah & Connolly, 1987)

The clear evidence from these intervention studies is supported by findings of impaired cognitive function in adults and children living in iodine deficient areas. An estimate based on an analysis of 21 studies suggests that general intelligence is 0.40 SDs lower in iodine deficient areas (Bleichrodt & Born, 1996). However, there is no clear evidence for the cognitive benefits of targeting preschool children with iodine supplementation.

Other micronutrients

Few other micronutrients have been studied in relation to their effect on the cognitive development of young children. There is a growing literature on zinc and mental development. In the UK, children with dyslexia were found to be deficient in zinc and have higher concentrations of toxic metals in their sweat and hair (Grant et al., 1988). Animal studies show that zinc deficiency in offspring causes impaired learning which can be corrected by zinc supplementation (Grant, 2004).

One study has been conducted to investigate the impact of maternal zinc supplementation on cognitive development. This study in Bangladesh (Hamadani, Fuchs, Osendarp, Huda, & Grantham-McGregor, 2002; Hamadani et al., 2001) gave

zinc (30 mg daily) or placebo (cellulose) to pregnant women from 4 months' gestation to delivery. At six months, the children whose mothers had been given zinc supplementation had poorer outcomes in both mental development and psychomotor development indices. This is likely due to an imbalance of micronutrients and warns against the targeting of a single micronutrient deficiency for supplementation.

<u>Disease</u>

Cognitive impacts of Malaria

 The most significant infectious disease for the mental development of young children is cerebral malaria. In addition to the mortality and severe neurological sequelae, many other children suffer more subtle cognitive deficits which may affect their ability to learn later on in life. In Kenya, children aged 6-7 years were studied 3-4 years after hospitalization due to cerebral malaria with impaired consciousness (Holding, Stevenson, Peshu, & Marsh, 1999). They were 4.5 times more likely than other children from similar backgrounds to suffer cognitive impairment ranging from severe learning difficulties requiring care to mild cognitive impairments. Almost half of such children had had no neurological problems at the time of hospitalization. Similarly, in Senegal children aged 5-12 were found to have impaired cognitive abilities due to a bout of cerebral malaria with coma before the age of five, possibly due to a primary deficit in attentional abilities (Boivin, 2002). A third study in the Gambia looked at children who suffered from cerebral malaria that was not accompanied by neurological symptoms at the time (Muntendam, Jaffar, Bleichrodt, & van Hensbroek, 1996). These children had poorer balance 3.4 years after recovery implying some impaired motor development. However, no other cognitive deficit was found. In addition to the direct effects on cognitive function, an episode of cerebral

malaria can leave an individual with an increased chance of epileptic episodes which in turn can lead to cognitive impairment (Holding & Snow, 2001).

Cerebral malaria is clearly a major cause of cognitive impairment in preschool children. However, the incidence of serious attacks of malaria declines sharply in the school years. Is there evidence that early childhood malaria continues to be a problem for children's learning? Only one study has investigated the long-term impact of early childhood malaria prevention on subsequent cognitive development. This study in the Gambia (Jukes et al., submitted) found that children who were protected from malaria for 3 consecutive transmission seasons before the age of 5 had improved cognitive performance at age 17-21. For those who had received the longest protection from malaria, the improvement in cognitive function was around 0.4 SD.

The focus here has been on preschool children but malaria can threaten development from before birth. An indirect pathway by which children can be affected by malaria is as a result of infection during pregnancy. Pregnant women are twice as likely as nonpregnant women to be bitten by mosquitoes (Ansell, Hamilton, Pinder, Walraven, & Lindsay, 2002) increasing their vulnerability to malaria infection. This increases the likelihood of still birth. If children survive they have an increased chance of having low birth weight. As demonstrated in the previous section, this is associated with a long-term impairment to cognitive development.

Socio-emotional impacts of malaria

The effects of cerebral malaria extend beyond the cognitive domain. Psychotic episodes have been reported following bouts of cerebral malaria in Nigeria (Sowunmi, 1993; Sowunmi, Ohaeri, & Falade, 1995). However, it is not clear to what extent such episodes are common in preschool children or if other socio-emotional sequelae are present in this age group.

Cognitive impacts of HIV infection

There is little evidence on this issue from developing countries but research in high-income countries has demonstrated that HIV infections are associated with lower IQ and academic achievement and impaired language in the late preschool and early school-age years (Wolters, Brouwers, Moss, & Pizzo, 1995) and with poorer visual-motor functioning in older children (Frank, Foley, & Kuchuk, 1997). This is likely to be due in part to the effects of HIV on cognitive development before children enroll in school. Studies including children from infancy to school-age find that such deficits in cognitive function can be reduced or reversed with antiretroviral therapy (Pizzo et al., 1988; Stolar & Fernandez, 1997; Wolters, Brouwers, Moss, & Pizzo, 1994). A wide age range of children took part in these studies, spanning preschool and the school-age years. It seems likely that therapy directed specifically at pre-school children will be beneficial, although one study (Brady et al., 1996) found that improvement in cognitive abilities in response to 36 months of ART was greater for children older than 6 years compared with younger children.

HIV infection and socio-emotional development

A number of studies have found that the adaptive behavior (skills required for everyday activities) of children living with HIV improves after treatment. In one study (Wolters et al., 1994), after 6 months of zidovudine treatment, almost all behavioral domains assessed (communication, daily living, socialization, but not motor skills) showed significant improvement overall. In another study infants with HIV-associated encephalopathy (degenerative brain disease) were rated as more apathetic and nonsocial in their behavior than nonencephalopathic infants. Older children (mean age around 8 years) with encephalopathy had significantly higher scores on scales measuring depression, autism, and irritability compared to

nonencephalopathic patients from this age group. A subgroup of patients showed a significant decrease in these elevated scores after a 6-month course of AZT.

Orphanhood

HIV/AIDS brings with it many other factors that may affect children's education. Children living with HIV/AIDS are more likely than other children to have lost one or both parents. Evidence suggests that children living with HIV/AIDS suffer from psychosocial problems. One study in Tanzania has found increased rates of depression in AIDS orphans (Makame, Ani, & Grantham-McGregor, 2002). A more recent study in Zimbabwe (Nyamukapa et al., submitted) found that orphans had a higher rating on a measure of depression than non-orphans by 0.13 SD for boys and 0.20 SD for girls. Female orphans were also more likely to suffer from poor self-esteem. Both of these studies were conducted with older children. Further evidence is required for preschool children.

Worms

Evidence on the cognitive impact of worm infections comes mainly from the school-age years. School children in South America, Africa and South-East Asia who are infected with worms perform poorly in tests of cognitive function (Watkins & Pollitt, 1997). When infected children are given deworming treatment, immediate educational and cognitive benefits are apparent only for children with heavy worm burdens or with nutritional deficits in addition to worm infections (Dickson, Awasthi, Williamson, Demellweek, & Garner, 2000; Nokes et al., 1992; Nokes et al., 1999; Simeon, Grantham McGregor, Callender, & Wong, 1995; Simeon, Grantham McGregor, & Wong, 1995). One study in Jamaica (Nokes et al., 1999) found around a 0.25 SD increase in three memory tests attributable to treatment for moderate to heavy

infection with whipworm (*Trichuris trichiura*). But for most children, treatment alone cannot eradicate the cumulative effects of lifelong infection nor compensate for years of missed learning opportunities. Deworming does not lead inevitably to improved cognitive development but it does provide children with the potential to learn. Children in Tanzania who were given deworming treatment did not improve their performance in various cognitive tests but did they benefit more from a teaching session in which they were shown how to perform the tests (Partnership for Child Development, submitted). Performance on reasoning tasks at the end of the study was around 0.25 SD higher in treated children than in those who still carried worm infection. The treated children's performance was similar to children who began the study without infection. This suggests that children are more ready to learn after treatment for worm infections and that they may be able to catch up with uninfected peers if this learning potential is exploited effectively in the classroom.

It is likely that worm infections have a similar impact for preschool children. Infections are prevalent in this age group although worm loads typically do not reach peak intensity until the school-age years. A study in Kenya showed that 28% of 460 preschool children (0.5 – 5 years) harbored hookworm infection, 76% were anemic and that anemia was more severe in those children with hookworm (Brooker et al., 1999). Evidence of a cognitive impact of worm infections in preschoolers is not clear. Two studies (Jukes et al., in prep; Stoltzfus et al., 2001) have demonstrated cognitive improvements in preschool children following combined treatment for worm infections and iron deficiency anemia. However, neither study was able to disentangle the effects of the two treatments.

Other parasitic infections

Infection with *Giardia lamblia* has been associated with mental development. Giardia is a protozoan parasite that is ingested and inhabits the gastrointestinal tract. They contribute significantly to caseloads of diarrhea. One study in Peru (Berkman, Lescano, Gilman, Lopez, & Black, 2002) followed a cohort of children some of whom had had diarrheal diseases, parasitic infection and severe malnutrition in the first two years of life. Severe malnutrition at this age was associated with an IQ 10 points (0.67 SD) lower at age 9 years. Those who had suffered two or more episodes of *Giardia lamblia* per year scored 4.1 points (0.27 SD) lower than children with one episode or fewer per year. It is likely that this association is due to Giarda infection causing, or acting as an index of, malnutrition.

Otitis Media (Glue Ear)

Otitis media is an inflammation of the middle ear cavity often resulting from spread of infection from the nose or throat. In acute cases pus is produced pressurizing the eardrum and causing perforation in chronic cases.

Otitis media is common in developed and developing countries (Berman, 1995). Around 6% of primary school and pre-school children were found to have chronic Otitis media with effusion in Vietnam (Balle et al., 2000) and South India (Rupa, Jacob, & Joseph, 1999). In Tanzania, 9.4% of rural and 1.4% of urban school children were found to have chronic otitis media with effusion (OME).

OME has mild effects on language development (Casby, 2001) and other cognitive skills. The effect depends on the length of infection and caregiver environment (Roberts et al., 1998). Children from low SES backgrounds are more likely to suffer effects of OME. Although research has not documented the effect of

OME on cognitive development in developing countries, this result suggests that the effect may be greater than in developed countries.

Meningitis

Meningitis was discussed above in the context of its high prevalence in developing countries, the associated mortality and the risk of severe neurological problems for survivors. Other survivors of meningitis do not have obvious neurological problems and yet suffer long-term behavioral problems.

In Ghana, survivors of meningitis aged 2-73 were more likely to suffer from feelings of tiredness (OR= 1.47) and were more often reported by relatives to have insomnia (OR = 2.31) (Hodgson et al., 2001). However, meningitis infection did not affect school attendance amongst school-age cases.

Studies in developed countries have found that children who appear well after bacterial meningitis have more non-specific symptoms like headache, and more signs and symptoms indicating inattention, hyperactivity and impulsiveness than their siblings (Berg, Trollfors, Hugosson, Fernell, & Svensson, 2002). Survivors of bacterial or viral meningitis go on to perform more poorly at school, to be more likely to repeat a grade and to be referred to a special needs school. They are also more likely to have behavioral problems in the home (Koomen, Grobbee, Jennekens-Schinkel, Roord, & van Furth, 2003). Cognitive abilities are also affected. Survivors of meningitis have lower IQs than their peers (~0.3 SDs) at ages 7 and 12 years (Grimwood, Anderson, Anderson, Tan, & Nolan, 2000) with no sign of the gap narrowing with age. Conversely behavioral problems of meningitis survivors are greater than their peers and actually increase with age.

Summary

Health, Nutrition and School Enrollment

School enrolment is most profoundly affected by physical or mental disability in children. There are several micronutrient deficiencies leading to disability. Vitamin A deficiency causes around 350,000 (~70%) of new cases of blindness or partial blindness each year in children. Currently 76% of children aged 6-59 months receive Vitamin A supplementation in least developed countries. Maternal and child iodine is the leading cause of preventable mental retardation. Sixty eight of the households in the world consume iodized salt. Folate deficiency in utero can also lead to disability in the form of spina bi-fida. Health and nutrition can also affect parental enrolment decisions. Children who are stunted are more likely to enroll in school late. The delay is larger for girls than boys.

Prenatal infections also cause disability. There are 110,000 cases of congenital rubella syndrome in developing countries leading to disabilities at birth. In some areas of sub-Saharan Africa 10% of pregnant women have syphilis which can lead to childhood deafness and mental retardation. Postnatally, malaria is the most important cause of mental retardation. In sub-Saharan Africa, cerebral malaria affects 575,000 children under five annually with neurological problems occurring in 9,000-19,000. Treating malaria improves girls' chances of going to school and increases the length of time spent at school by both boys and girls. Polio causes paralysis in around 1 in 200 cases. New cases of polio have been reduced from 350,000 in 1988 to under 500 in 2001 with increased vaccination coverage, particularly in sub-Saharan Africa. Meningitis affects half a million people annually, with very young children at the greatest risk. Ten to fifteen percent of cases result in mental disability.

Disease also affects educational participation at the preschool level. Programs of iron supplementation and of school feeding increase children's attendance at preschools. School enrolment is also likely to be affected in children made vulnerable by parent HIV infection.

<u>Health, Nutrition and School Readiness</u>

Undernutrition impairs all aspects of school readiness - cognitive, motor and socioemotional development. Preventative nutritional supplementation improves cognitive development and educational achievement of preschoolers, with girls benefiting more than boys where gender differences are found. Maternal education to improve stimulation of children works synergistically with nutritional supplementation in improving cognitive development. Therapeutic trials of severely undernourished children find that both nutritional supplementation and psychosocial stimulation/ECD education programs have substantial effects (~0.7 SD) on cognitive development. The most disadvantaged children require both interventions to catch up with better nourished peers. For moderately undernourished children, psychosocial stimulation and to a lesser extent nutritional supplementation had modest effects on cognitive development. The effects of psychosocial stimulation on cognitive development have been found to persist for 14 years. Nutritional supplementation has a long-term effect for children of low SES only. Motor development is also improved by nutritional supplementation and psychosocial stimulation perhaps to a larger extent (~0.8-1 SD) than cognitive development. The effects on motor development persist in the long term Such interventions also improve children's personal and social behavior and psychosocial stimulation of undernourished young children leads to improved psychosocial outcomes 14 years later. Evidence on timing of interventions does not

suggest that prenatal and perinatal supplementation are more effective than supplementation later in childhood. Maternal behavior is also related to child nutrition. Mothers stay closer to malnourished children and provide them with less stimulation. Maternal nutrition and behavior play a role in other ways. Low birthweight and reduced breastfeeding are both associated with poor cognitive development in the long term. In the case of low birthweight, effects are greater for mothers with less education. The impact of low birthweight on cognitive development can be reduced by prolonged breastfeeding.

Iron deficiency anemia impairs cognitive development. There is some evidence that sustained iron supplementation before 2 years of age improves cognitive development substantially (1.3 SD) and robust evidence for the effect of supplementation in children aged 2-6 years. In preschool settings, iron supplementation can improve attention in class. Iron deficient infants grow up to have poorer cognitive abilities in the long term. However, no study has demonstrated the long term effects of supplementation. Programs of iron supplementation also have substantial effects (1.6 SD) on motor development of infants, often greater than the effect on cognitive development. Iron deficiency also affects young children's social and emotional behavior and in the long term, iron deficiency leads to an increased incidence of psychosocial problems. Mothers tend to show less affection and be less active in their interactions with iron deficient infants.

Other micronutrients are implicated in impairments of cognitive development. Children's cognitive abilities are poorer in iodine-deficient areas although there is no strong evidence of a cognitive benefit of iodine supplementation programs in young children. One study found a harmful effect of zinc supplementation on cognitive development, possibly by creating a nutritional imbalance.

Among infections in the preschool years, malaria is the leading cause of cognitive impairment. Survivors of cerebral malaria have impaired cognitive abilities, particularly attention. Motor abilities are also affected. Malaria prevention in young children has been shown to improve cognitive abilities 14 years later. HIV infection is associated with impaired cognitive development and increased psychosocial disorders in developed countries. Antiretroviral therapy (ART) can improve cognitive abilities and adaptive behavior. Orhpanhood related to parental HIV infection increases incidence of psychosocial disorders in children. Evidence suggests that worm infections are likely to have a cognitive impact although few studies have been conducted in the preschool age-group. Giardia infection, implicated in diarrheal diseases, is associated with a long-term impact on IQ (4.1 IQ points or 0.27 SD). Otitis media (glue ear) can impair language development of children, particular those living in poor households. Meningitis also affects children's development in the long term. Both sleep problems and educational achievement are affected.

3. Programmatic Responses

Addressing the educational consequences of health and nutrition problems outlined in the previous sections requires an integrated life-cycle approach including MCH and IMCI during infancy, ECD and ECCE during early childhood moving to FRESH and school health programs during the school-age years. However, the focus of this report is on interventions that can be delivered through ECD programs.

Interventions: What works?

Table 3 summarizes the impact of health interventions on cognitive development in early childhood. Only studies giving strong evidence from experimental interventions are included. Such evidence is available for four types of intervention: iron supplementation, iron supplementation and deworming, psychosocial stimulation of malnourished children and nutritional supplementation. Most interventions are aimed at a specific target group (iron deficient or malnourished children) although two interventions are aimed at all children in a community. The first striking thing about the table is that all studies have demonstrated a positive impact. Note this table is not a selective account of health interventions that have worked. Rather, it is a summary of all experimental interventions found in the literature. In contrast with interventions in other age groups it is notable that a positive impact on at least one cognitive test was found in every case. The size of the impacts are also worthy of note. Where the size of the impact is quantified, all interventions aimed at nutritionally disadvantaged groups improve cognitive abilities by at least two thirds of a standard deviation. In the context of the literature on improving cognitive abilities these are remarkably large effects, equivalent to an increase of 10 IQ points or lifting a child from the 25th percentile to the 50th percentile of the ability distribution. The two studies that showed modest effects were targeted at a community cohort rather than a nutritionally disadvantaged population.

Table 3. Impact of health interventions on development during early childhood

Study	Country	Intervention	Age	Sample Characteristics	Effect size	Outcomes
Jukes et al. in prep	India	Iron (30d) + deworming	2-6 yrs	ECD pupils	0.18 SD	Attention
Seshadri and Golpadas #1	India	Iron (60d)	5-8 yrs	Anemic vs. Non-anemic	+ve	IQ
Seshadri and Golpadas #2	India	Iron (60d)	5-6 yrs	Anemic vs. non-anemic boys	0.33SD 0.67 SD	Verbal IQ Performance IQ
Soewondo	Indonesia	Iron (56d)	4yrs	Anemic vs. Non-anemic	+ve No effect	Learning task 3 cognitive tests
Stoltzfus	Zanzibar	12 mo iron + deworming	6-59 mo	Community	0.14 SD	Language
McKay 1978	Columbia	Nutrition + Education from 42 mo	84 mo	Malnourished	0.80 SD	Cognitive ability
Grantham McGregor 1991	Jamaica	Psychosocial stimulation	9-24 mo	Malnourished	0.67 SD	Mental development
Grantham McGregor 1991	Jamaica	Nutritional Supplementation	9-24 mo	Malnourished	0.79 SD	Mental development
Vermeersch and Kremer, 2004	Kenya	School Feeding	4-6	ECD pupils	0.4 SD (for sub sample)	Educational achievement

Table 4 shows the studies which have followed up preschool health interventions and assessed their cognitive impact in the long term. Three of the studies tracked participants to adolescence and found that improvements in cognitive function persisted. Both studies in Jamaica found sizeable long term effects of psychosocial stimulation or education but no effects of nutritional supplementation. The malaria prevention study in the Gambia is of interest because relatively large impacts were found even though the intervention was provided for a community cohort rather than targeted at a sub-population. All four studies support the hypothesis that the cognitive benefits of preschool health interventions in terms of school readiness carry through to benefit children's education in the long term.

Table 4. Long-term impact of health interventions in early childhood on cognitive and educational outcomes.

Study	Country	Intervention	Age	Sample Characteristics	Effect size	Outcomes
Grantham-McGregor et al., 1994	Jamaica	Maternal Education	14	Severely Malnourished	0.68	IQ
Walker et al 2000	Jamaica	Stimulation	11-12	Stunted	0.38	IQ
Chang et al 2002					No effect	Education tests
Pollitt et al, 1997	Indonesia	Nutritional Supplements	8	Initially > 18 months	+ve	Working memory
Jukes et al., submitted	Gambia	Malaria prevention	14-19	Community cohort	0.25-0.4	Cognitive function

Evidence presented in this report shows clear benefits for education of tackling three health and nutrition conditions in early childhood: undernutrition, anemia and malaria. Table 5 illustrates the scale of the impact of these three conditions by combining data on prevalence and on the cognitive impact of treating the conditions. The table shows that for each condition at least 190 million children under 5 suffer cognitive deficits equivalent to between 3 and 24 IQ points. The shift in ability distribution caused by these diseases creates between 2.5 million and 61 million additional cases of mental retardation (IQ < 70).

Table 5. Estimated global impact of malaria, anemia and stunting on cognitive development.

	Developing Country Prevalence	Total Cases (millions)[1]	Effect size		Equivalent loss in IQ points per child		Additional cases of mental retardation (millions)[2]	
			Lower estimate	Upper estimate	Lower estimate	Upper estimate	Lower estimate	Upper estimate
Malaria	~ 50%	270	0.2	0.4	3	6	3.56	8.65
Stunting	31%	190	0.2	1.6	3	24	2.50	61.15
Anemia	40%	219	0.3	0.7	4.5	10.5	4.78	16.22

[1] Based on a developing country population of under-5s of 548 million (UNICEF, 2006)

[2] Using the definition of mental retardation as IQ < 70.

All three conditions are easily preventable. Here we outline current best practice for addressing these conditions.

Undernutrition

The most obvious way in which ECD programs can address chronic undernutrition is through school-based feeding programs. Evidence discussed shows such programs can be effective in improving child development and school readiness. However, such programs can be costly and often difficult to sustain. Experience from programs with school-age children (Del Rosso, 1999) suggests that these programs are most effective when significant cost burdens are borne by the community. One example has been presented in this review of a preschool feeding program partly funded by parents which had a significant impact on preschool attendance and achievement (Vermeersch & Kremer, 2004).

Beyond school feeding, current recommendation are for counseling mothers and caretakers to improve feeding practices and improved management of malnutrition (WHO, 2006a).

<u>Iron deficiency anemia</u>

Supplementation with iron, for example through ingestion of ferrous sulfate or folic acid, is an effective way of combating iron deficiency anemia. This intervention has been used successfully in India at a cost of around $2 per child. Cost can be further reduced and sustainability improved through teacher delivery of supplements in ECD programs. Iron deficiency anemia can also be controlled through fortification of food with iron.

Where malaria is common, iron supplementation can have adverse consequences for mortality and morbidity (Sazawal et al., 2006) and current recommendations are that caution should be exercised when providing supplementation in such areas. Programs in these areas should be targeted at those who are anemic or are at risk of iron deficiency (WHO, 2006b).

<u>Malaria</u>

Current priorities for malaria control in endemic areas include the use of insecticide-treated bed nets and prompt and effective treatment, including presumptive treatment, with artemisinin-based combination therapy. ECD programs may have a role for promoting both of these strategies. Intermittent preventative treatment (Chandramohan, 2005) has been successful in controlling malaria amongst infants but further research is required, particularly in the preschool age-group.

Health or Education Interventions: Targeting Disease or Symptoms?

It might be expected that tackling the root cause of a disease is more important than dealing with its consequences for development, as sure as prevention is better than cure. However, the one study to test this hypothesis in the long term found the reverse. The study of malnourished children in Jamaica found a long-term effect of psychosocial stimulation but no long term effect of nutritional supplementation. Both interventions had an immediate effect on the developmental levels of its preschool participants but the effects of the nutritional supplement waned with time in an interesting way. Eight years after the intervention nutritional supplements had an effect on cognitive ability only for children whose mothers had high verbal intelligence (a proxy for the amount of stimulation they would have received). In the later follow-ups no impact of the nutritional supplements was apparent. It seems that stimulation is a key part of intervention. We saw in the review of literature that nutritional problems have serious consequences for the amount of stimulation children receive. Perhaps the crucial element in combating this effect is to ensure that young children receive sufficient stimulation.

There is certainly plenty of evidence in support of an interaction between health and education interventions. Low birth weight has been shown in separate studies to be a risk factor for mental development only for children who also received insufficient stimulation in the home and (in a separate study) only for children of illiterate mothers. A study in Vietnam found that nutritional supplementation alone was insufficient to equalize cognitive performance between stunted and non stunted children. Only in villages receiving both nutritional supplementation and an ECD intervention did cognitive development improve in both stunted and non-stunted

children. In another example from Kenya, the educational achievement of children benefited from a school feeding program only in schools with experienced teachers. Related to this, the study of the long term effect of nutritional supplements in three villages in Guatemala found that supplementation only had a long term effect for participants who subsequently went on to have the most schooling.

These findings parallel others from school-age children. For example, a study with school children in Tanzania (Grigorenko et al., in press; Partnership for Child Development, submitted) found that deworming alone was insufficient to improve the cognitive abilities of children infected with these parasites. Whereas, a teaching intervention combined with the deworming did improved reasoning skills.

These findings have programmatic implications. First, it is clearly more effective to prevent the onset of health and nutrition problems rather than to remediate them. Second, where remediation is necessarily, or where health or nutrition problems commonly reoccur (for example with seasonal variations in nutritional intake or in the transmission of disease, or where communities are constantly exposed to diseases for which there are no simple preventative measures), educational interventions, such as ECD programs should be considered as important as health interventions in the programmatic response to problems of health and nutrition. It is worth bearing this in mind when considering the cost-effectiveness of interventions in the following sections.

Promoting Equity through Preschool Health Interventions

The burden of disease is borne disproportionately by the poor. In addition, the impact of disease on education is greatest for the poor. In the preceding review we saw examples where lack of breastfeeding, or Otitis media infection led to cognitive impairments only for children of the least educated mothers. There are also examples

where the impact of one condition is greater for children suffering from other problems of health or nutrition (Jukes, Drake, & Bundy, in press; Jukes et al., 2002). Conversely, preschool health interventions tend to provide the greatest benefit to disadvantaged children. For example, long-term educational benefits of a nutritional supplementation program in Guatemala were found only for those children of low socioeconomic status. Many other examples exist in the literature on school-age children. For example, giving breakfast to children in Jamaican schools improved cognitive function on the same day to a greater extent for children with chronic malnutrition (Simeon & Grantham McGregor, 1989). Similarly, gender differences in the effect of interventions favor girls. For example, iron supplementation is found to improve preschool attendance for girls more than boys (Bobonis et al., submitted) and malaria prevention increases enrolment for girls but not boys (Jukes et al., submitted).

Health and nutrition interventions therefore offer a way of promoting equity in education and by benefiting vulnerable children to the greatest extent. If ECD health and nutrition projects are explicitly targeted at the poorest in society (or at least ensure that coverage extends to the rural poor and other hard-to-reach group) the impact of equity will be all the greater.

Economic Benefits of Preschool Health Interventions

We saw in Table 4 that long term improvements in cognitive abilities of the order of 0.25-0.4 SD ensue from preschool health programs. This improvement in cognitive abilities may translate into improved earnings, which is typically used as a measure of the economic benefits of interventions. For the United States, Zax and Rees (2002) estimate that an increase in IQ of one standard deviation is associated with an increase in wages of over 11%, falling to 6% when controlling for other

covariates. Similar estimates for the relationship between IQ and earnings have been made for Pakistan (Alderman, Behrman, Khan, Ross, & Sabot, 1997), Indonesia (Behrman & Deolalikar, 1995), and in a review of developing countries (Glewwe, 2002). In a study of wages in South Africa, Moll (1998) finds that an increase of one standard deviation in literacy and numeracy scores was associated with a 35% increase in wages. Extrapolating this result, a 0.25 SD increase in IQ, which is a conservative estimate of the benefit resulting from a preschool health intervention, would lead to a 5-10% increase in wages.

Years of schooling can also be improved by preschool health interventions. Two examples of this were discussed above. Malaria chemoprophylaxis given in early childhood led to an increase of just over 1 year in primary schooling in the Gambia (Jukes et al., submitted). Iron supplementation was associated with an increase of 5.8% in rates of participation at pre-school in Delhi (Bobonis et al., submitted). A cost benefit analysis of this study is reported in the next section.

Even without studies supporting the direct link between preschool health interventions and school participation, the relationship can be estimated indirectly by considering the impact of interventions on test scores and the implications of improved test scores for school participation. In a study of adults in South Africa (Moll 1998), each additional year of primary schooling was associated with a more modest 0.1 SD increase in cognitive test scores. According to these estimates, a typical increase of 0.25 SD associated with a school health input is equivalent to an additional 2.5 years of schooling.

Other studies have assessed the relationship between achievement early on in school and likelihood of subsequent school completion. Liddell and Rae (Liddell & Rae, 2001) assessed the direct impact of test scores on grade progression in Africa.

Children were assessed in Grade 2 and their progress through primary school monitored. Each additional SD scored in Grade 2 exams resulted in children being 4.8 times as likely to reach Grade 7 without repeating a year of schooling. According to these estimates, an increase of 0.25 SD in exam scores in the second grade (a typical result of a preschool health intervention) would lead to children being 1.48 times as likely to complete Grade 7. Based on this calculation, the extra cumulative years of schooling attributable to the preschool health intervention averages at 1.19 years per pupil.

Several methods of estimating the added years of schooling due to a preschool health intervention have been presented. Conservative estimates of this impact range from 1 to 2 years. Using these estimates, we can estimate benefits in wages and other life outcomes attributable to this increase in schooling. Psacharopoulos and Patrinos (2002) find that the returns to years of schooling in wages are higher in developing countries than in developed countries. For Sub-Saharan Africa, they find a 12 percent rate of return to one additional year in school, compared to 10 percent for Asian countries, 7.5 percent for OECD countries, and 12 percent for Latin America and the Caribbean.

This report has focused on the educational benefits to preschool health interventions but economic benefits also result more directly from improved adult health outcomes. Studies have increasingly documented a causal impact of adult health on labor force participation, wages and productivity in developing countries (Strauss & Thomas., 1995). For example, height has been shown to affect wage-earning capacity as well as participation in the labor force for both women and men (Haddad & Bouis, 1991; Strauss & Thomas., 1995). The impact of health on productivity and earnings may be strongest in settings where low-cost health

interventions produce large impacts on health, such as low-income settings where physical endurance yields high returns in the labor market. For a 1 percent increase in height, Thomas and Strauss (1997) find a 7 percent increase in wages in Brazil compared to a 1 percent increase in the U.S.

In addition to the above discussion, a few cost benefit analyses of preschool health interventions have been published. Two relevant studies have been identified, one which estimates the economic returns to a typical nutritional intervention and the second which estimates the returns to an iron supplementation program.

In the first study, using 12 year longitudinal data from Cebu in the Philippines and intervention data from India, Glewwe et al (2001) estimated the educational returns to a preschool nutritional intervention. They estimated that a two year feeding program costing $150 would improve height by about 0.6 SD. This would yield a benefit of between $310 and $415 from increased length of schooling and between $480 and $920 if improvements in academic achievement are also taken into account. The returns would rise to between $960 and $1840 if the nutritional intervention were targeted specifically at malnourished children rather than at a population cohort. Overall, they calculated $1 dollar spent on nutritional supplementation would yield a labor market return of between $3 and $18 based on educational impacts alone (i.e. not including benefits to health).

A second study in Delhi (Bobonis et al., submitted) found that a pre-school health program increased average school participation by 7.7 and 3.2 percentage points for girls and boys respectively. Based on other data for the output per worker in India ($1037), the returns to additional years of education for girls (5%) and boys (9%) in India, and other considerations, the authors calculated that the Delhi pre-school health program would increase the net present value of lifetime wages by US$29 per child in

the treatment pre-schools, while costing only US$1.70 per child. The additional demand for education raised by the health program, they calculate, would cost $0.36 per child (for teacher's wages). Thus the total cost would be $2.06 yield a return of $29 in the labor market, or $14.07 per dollar spent. This estimation is based solely on improvements in preschool attendance and does not take into account changes found in cognitive function in the same study (Jukes et al., in prep).

This study raises an additional issue with respect to the cost benefit analysis of preschool health programs. Where health interventions are added to an existing ECD program this is likely to affect the demand for the program with consequent cost implications, particularly where user fees are payable. This was assessed in a study of a school feeding project in Kenya (Vermeersch & Kremer, 2004). Before the program began only 3.5 percent of children had paid the official fees due. Forty-six percent of children had not paid anything. After a school feeding program (providing porridge at breakfast) was introduced to some preschools in the area, attendance increased and children paid 57 percent more per day of school attendance than children from comparison schools. This was likely to be because teachers became more stringent in fee collections. Most of the money went towards higher teacher salaries percentage of the total amount of fees collected. Treatment schools also spent (non-significantly) more on non-salary items like classroom materials and construction than the comparison schools. The increase in fee paying was equivalent to around one tenth of the cost of the feeding intervention. It should be noted, however, that demand for the ECD program may have increased in part because neighboring schools were not offering the same breakfast intervention, as required by the experimental nature of the research project. Increases in demand may not be so great in real world settings with more extensive coverage.

Cost-effectiveness analyses of specific preschool health and nutrition programs are few, but other approaches can be taken to this issue. For example, analyses of the cost-effectiveness of school-age health and nutrition interventions (Bundy et al., 2006) point out that typical effects on cognitive development and educational achievement are of the order of 0.2-0.4 SDs and are of a similar magnitude to those found for other education interventions (Lockheed & Verspoor, 1991). However, nutritional supplementation and simple treatments for diseases such as worm infections can be delivered at a cost of $1-$5, compared with estimated costs for the provision of school feeding ($34), preschool education ($20-$30) and primary education ($35) in low income countries. It follows that health and nutrition interventions are comparably cost effective. Given that preschool health and nutrition interventions can be delivered at a similar cost and yield educational benefits of similar or greater magnitude, it can be concluded that such interventions are also highly cost-effective.

Summary

The review has identified four interventions for which there is strong evidence of an educational benefit: psychosocial stimulation or nutritional supplementation of undernourished children, iron supplementation and malaria prevention. The impact of these interventions on cognitive development is consistent and substantial. Each condition is suffered by around 200 million preschool children in developing countries and their prevention could result in prevention of between 2.5 million and 61 million cases of mental retardation.

Providing psychosocial stimulation or other educational programs to affected children is at least as important for their development as treating the condition they

are suffering. In some cases the impact of psychosocial stimulation on undernourished children is greater and more enduring than for nutritional supplementation. In most cases, a combination of educational and health interventions is required to promote desired levels of development.

As with preschool education programs, early childhood health and nutrition programs have the potential to promote equity in developmental outcomes. Where differential effects are found, greatest benefits are conferred on the poorest children, those with other diseases and on girls.

Economic returns to preschool health and nutrition interventions result from increased adult IQ, increased educational participation and achievement and directly though improved adult health. Estimates suggest that around a 5-10% increase in wages result from such interventions. One study estimated that $150 spent on a nutritional supplementation program in the Philippines would yield returns of between $480 and $920 ($3 to $6 per $1 spent) due to increase length of schooling and improved educational achievement. A second study in India found that an iron supplementation program effectively costing $2.06 per child would yield $29 in the labor market (or $14.07 per $1 spent). Cost-effectiveness of health interventions in preschools are complicated by the impact these interventions have on demand for ECD programs. Overall, preschool health and nutrition interventions have an impact on education of a similar magnitude to other education interventions but are significantly less costly and thus more cost-effective.

4. Conclusions and Recommendations

Extensive research has been conducted on the educational effects of early childhood health and nutrition interventions. The breadth and depth of this research allows for a number of general conclusion to be drawn.

Early childhood health and nutrition interventions have a consistently large impact on cognitive development.

Studies in this age group are remarkable because of the consistency with which health and nutrition interventions are found to have an effect on mental development. In many cases the effects found are substantial, particularly for treatment programs targeted at malnourished children. Expanded coverage of ECD health and nutrition programs is likely to have a major impact on the education of young children in developing counties.

Health and nutrition interventions have the largest impacts for the preschool age group, but are also effective in older children

Compared to school-age children, improved health and nutrition interventions bring greater and more consistent benefits for preschool children. However, this does not imply that earliest is best when it comes to the timing of health and nutrition programs. There is stronger evidence for the educational benefits of iron supplementation in the preschool age group than for infants, and nutritional supplementation is more beneficial to children aged 6 months and above than for supplementation of younger infants or in utero.

Although benefits are greatest for preschool children, there is no evidence of a critical period for intervention. Iron supplementation and deworming continue to have

educational benefits in the school-age years and there is no evidence that other health and nutrition interventions, such as malaria prevention and nutritional supplementation, cease to improve educational outcomes for older children.

Early childhood health and nutrition interventions improve all aspects of school readiness, but greatest impacts are seen for motor development.

Readiness for school requires development along many dimensions: cognitive, motor and socioemotional. Health and nutrition interventions improve all three. This review has uniquely considered the impact on these three dimensions separately. Where data are directly comparable, larger effects are found for motor development than cognitive development. This implies that motor development may be seriously delayed by poor health and nutrition. ECD programs that focus on developing motor as well as cognitive skills may guard against such developmental delays.

Early childhood health and nutrition interventions promote equity.

Improving children's health and nutrition promotes equity in two ways. First, the greatest burden of disease is harbored by the poorest children, the ones that benefit from health and nutrition programs. Second, amongst those susceptible to poor health and nutrition, treating or preventing disease confers the greatest benefit on the most vulnerable children: on the poorest, on those suffering other diseases, and on girls. This contrasts with many other educational programs where the better off are best placed to take advantage. Thus, preschool health and nutrition programs have the potential to close the gap between rich and poor, rural and urban and boys and girls, helping achieve Education for All.

The best evidence of educational benefits is found for feeding programs, iron supplementation and malaria prevention.

There is a considerable amount of evidence for the educational benefits of preschool feeding programs and iron supplementation. More recent evidence also supports the role of early childhood malaria prevention as a means of improving educational outcomes. Each of these three conditions is suffered by more than 200 million children under five years of age. Thus the total global impact of these diseases on child development is enormous.

Similar benefits may be found for other interventions, such as prevention or treatment of diarrhea and parasitic worms, however no strong evidence is available for this age group.

Preschool education programs can be as effective as health and nutrition interventions in mitigating the educational impact of poor health and nutrition.

Education interventions, such as programs of psychosocial stimulation, can be as effective as health and nutrition interventions in remediating cognitive impairments resulting from poor health and nutrition. In fact, evidence suggests that the benefits of education interventions are more enduring than nutritional supplements in their effect on the development of malnourished children. The implications of this are twofold. First, it is better for children's development to prevent disease than to treat it. Second, addressing the cognitive effects of disease requires a combined approach of educational programs and improved health and nutrition.

Early childhood health and nutrition interventions are highly cost-effective

The educational benefits of improved health and nutrition are comparable in size to those from other educational interventions, such as preschool education programs or providing textbooks for primary schools. Targeted health and nutrition programs may offer even greater benefits. Yet, the cost of such interventions is often considerably less. Where conditions can be treated with a few pills, such as with iron supplementation or deworming, costs are typically lower than $5 pre child per year and often less than $1. This contrasts with current estimates for provision of school feeding ($34), preschool education ($20-$30) and primary education ($35) in low income countries. These are not competing interventions, and quality education requires the provision of all such services. But the cost-effectiveness of health and nutrition interventions makes them a key priority for governments in low income countries.

Early childhood health and nutrition interventions clearly have a major role to play in an expanding system of early childhood development programs and their efforts to achieve quality Education for All.

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Table 1. Global Nutrition Indicators for Early Childhood (UNICEF, 2006)

	% of infants with low birthweight 1998-2004*	% of children (1996-2004*) who are:			% of under-fives (1996-2004*) suffering from:				Vitamin A supplementation coverage rate (6-59 months) 2003	% of households consuming iodized salt 1998-2004*
		exclusively breastfed (<6 months)	breastfed with complementary food (6-9 months)	still breastfeeding (20-23 months)	underweight moderate & severe	underweight severe	wasting moderate & severe	stunting moderate & severe		
SUMMARY INDICATORS										
Sub-Saharan Africa	14	30	67	53	28	8	9	38	64	64
Eastern and Southern Africa	14	41	69	58	29	8	7	41	68	60
Western and Central Africa	15	20	65	48	28	9	10	35	60	68
Middle East and North Africa	15	29	60	23	14	3	6	21	-	58
South Asia	31	38	45	69	46	16	14	44	58	49
East Asia and Pacific	7	43	44	27	15	-	-	19	73	85
Latin America and Caribbean	9	-	45	26	7	1	2	16	-	86
CEE/CIS	9	22	45	26	5	1	3	14	-	47
Industrialized countries	7	-	-	-	-	-	-	-	-	-
Developing countries	17	36	51	46	27	10	10	31	61	69
Least developed countries	19	34	63	65	36	11	10	42	76	53
World	16	36	51	46	26	10	10	31	61	68

Table 2. Global Health Indicators for Early Childhood (UNICEF, 2006)

Countries and territories	% of population using improved drinking water sources 2002			% of population using adequate sanitation facilities 2002			% of routine EPI vaccines financed by government 2003	% immunized 2003 1-year-old children					pregnant women tetanus	% under-fives with ARI	% under-fives with ARI taken to health provider 1998-2003	% under-fives with diarrhoea receiving oral rehydration and continued feeding 1994-2003	Malaria: 1999-2003		
	total	urban	rural	total	urban	rural	total	TB	DPT3	polio3	measles	hepB3					% under-fives sleeping under a bednet	% under-fives sleeping under a treated bednet	% under-fives with fever receiving anti-malarial drugs
Sub-Saharan Africa	57	82	44	36	55	26	45	74	60	63	62	30	53	14	39	32	14	2	38
Middle East and North Africa	87	95	77	72	88	52	89	88	87	87	88	71	-	12	69	-	-	-	-
South Asia	84	94	80	35	64	23	96	82	71	72	67	1	75	19	57	26	-	-	-
East Asia and Pacific	78	92	68	50	72	35	84	91	86	87	82	66	-	-	-	-	-	-	-
Latin America and Caribbean	89	95	69	75	84	44	92	96	89	91	93	73	-	-	-	36	-	-	-
CEE/CIS	91	98	79	81	92	62	89	95	88	89	90	81	-	-	-	25	-	-	-
Industrialized countries	100	100	100	100	100	100	69	-	95	93	92	62	-	-	-	-	-	-	-
Developing countries	79	92	70	49	73	31	80	85	76	77	75	40	64	16	52	31	-	-	-
Least developed countries	58	80	50	35	58	27	37	79	68	68	67	20	56	16	37	35	19	2	36
World	83	95	72	58	81	37	80	85	78	79	77	42	64	16	53	31	-	-	-