Investment in child and adolescent health and development: key messages from *Disease Control Priorities*, 3rd Edition

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The realisation of human potential for development requires age-specific investment throughout the 8000 days of childhood and adolescence. Focus on the first 1000 days is an essential but insufficient investment. Intervention is also required in three later phases: the middle childhood growth and consolidation phase (5–9 years), when infection and malnutrition constrain growth, and mortality is higher than previously recognised; the adolescent growth spurt (10–14 years), when substantial changes place commensurate demands on good diet and health; and the adolescent phase of growth and consolidation (15–19 years), when new responses are needed to support brain maturation, intense social engagement, and emotional control. Two cost-efficient packages, one delivered through schools and one focusing on later adolescence, would provide phase-specific support across the life cycle, securing the gains of investment in the first 1000 days, enabling substantial catch-up from early growth failure, and leveraging improved learning from concomitant education investments.

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Introduction

Society and the common legal definition seem to have defined maturity correctly: it takes around 18–21 years for a human being to reach adulthood. The evidence shows a need to invest in the crucial development period from conception to 2 years (the first 1000 days) and during important phases over the next 7000 days. Similar to the fact that babies are not merely small people (ie, they need special and different types of care), growing children and adolescents are also not merely short adults—they too have crucial phases of development that require specific interventions. To ensure that life's journey begins right is essential, but provision of support to guide development during the next 7000 days is also essential to achieving full potential as an adult. Our thesis is that research and action on child health and development should evolve from a narrow emphasis on the first 1000 days (an age-siloed approach) to holistic concern over the first 8000 days (an approach that embraces the needs across the lifecycle).

We present an overview of the analyses from volume 8 of *Disease Control Priorities*, 3rd edition, published by the World Bank, entitled Child and Adolescent Health and Development.[1] This volume identifies cost-effective, scalable health interventions during middle childhood (5–9 years) and adolescence (10–19 years) that can promote physical, cognitive, and intellectual development. In 30 chapters, the volume explores the health and developmental needs of individuals in middle childhood and adolescence and presents evidence for a package of investments to address priority health needs, expanding on other work in this area, such as the *Lancet* Commission on adolescent health and wellbeing.[1,2] The analyses suggest that modest health investments are essential to attain maximum benefit from investments in schooling for individuals aged 5–19 years, such as those proposed by the International Commission on Financing Global Education Opportunity.[3] Volume 8 shares contributors to both Commissions, and complements volume 2 in the DCP3 series, entitled Reproductive, Maternal, Newborn and Child Health,[4,5] which focuses on health in children under 5 years. Figure 1 sets out the sequential phases of development and proposes a standardised age nomenclature; the current absence of which serves to emphasise the neglect of some age groups.

This Review summarises the main conclusions of volume 8 and is intended to map the evidence and analyses published in detail in the 30 chapters. The analysis

Key messages

- It takes some 8000 days for a child to develop into an adult. Sensitive phases shape development throughout this period, and age-appropriate and condition-specific support is required throughout if a child is to achieve full potential as an adult.
- Investment in health during the first 1000 days is widely recognised as a high priority, but investments are often neglected in the following 7000 days of middle childhood and adolescence. This neglect is also reflected in the investment in research on these age groups.
- At least three phases are crucial to health and development during the next 7000 days, each requiring a condition-specific and age-specific response: middle childhood growth and consolidation phase (5–9 years) when infection and malnutrition remain key constraints on development, and mortality rates are higher than previously realised; adolescent growth spurt (10–14 years) when body mass increases rapidly and substantial physiological and behavioural changes associated with puberty occur; and adolescent growth and consolidation phase (15–19 years), which brings further brain restructuring, linked with exploration, experimentation, and initiation of behaviours that are lifelong determinants of health.
- Broadening of investment in human development to include scalable interventions during the next 7000 days can be achieved cost-effectively. Two essential packages were identified: the first package addresses the needs in middle childhood and early adolescence through a school-based approach; the second focuses on older adolescents (15–19 years) through a mixed approach also involving the community, media and health systems. Both packages offer high cost-effectiveness and benefit-cost ratios.
- Well designed health interventions in middle childhood and adolescence can leverage the current substantial investment in education, and improved design of educational programmes can improve health. The potential synergy between health and education is undervalued and the returns on co-investment are rarely optimised.

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uses four key tools—cost-effectiveness, extended cost-effectiveness, benefit-cost analysis, and returns on investment—to identify and prioritise investments at different ages, and to propose delivery platforms and essential packages that are costed, scalable, and relevant to low-resource settings. These analyses suggest that returns on existing public investment in health lag far behind the potential because of declining investment after 5 years of age. This bias in investments is paralleled by a similar bias in research interest. Around 99% of publications in Google Scholar and 95% in PubMed that specify age during the first 20 years of life focus on children under 5 years (table 1). This strong bias towards early childhood in health literature might have been helpful in the successful drive of the Millennium Development Goal to reduce mortality of children under 5 years, but might also have caused the public health community to lose sight of the fact that the subsequent decades of growth and development in the transition to adulthood also involve complex processes and crucial periods that are sensitive to intervention.

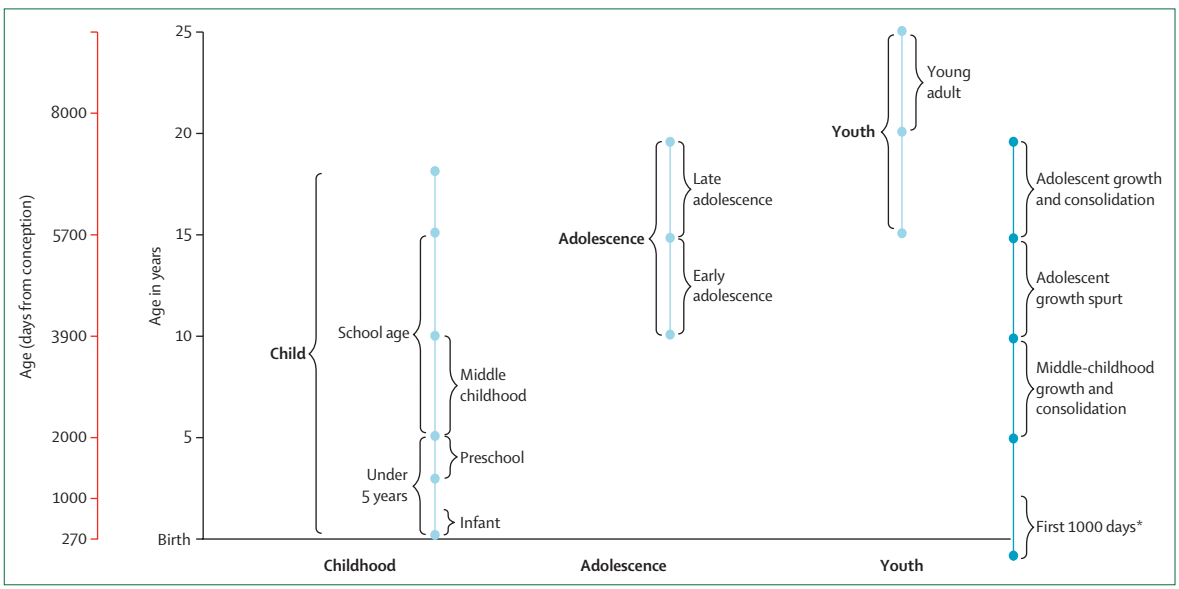

Figure 1: **Nomenclature concerning age and four key phases of child and adolescent development**
The first 1000 and 8000 days are typically measured from time of conception. The other age ranges are measured from birth. The alignment between age groups and four key phases are crucial to development. These phases are used as an organising principle for intervention throughout volume 8. Consistency is surprisingly absent in the language used to describe the phases of childhood, perhaps reflecting the historically narrow focus on the early years. The neglect of children aged 5–9 years is reflected in the absence of a commonly-accepted name for this age group. This figure illustrates the nomenclature used in this Review, which we have aligned with the definitions and use outlined in the 2016 *Lancet Commission* on adolescent health and wellbeing—ie, use of "middle childhood" to reflect 5–9 years of age. We also refer to children and adolescents between 5 and 14 years as "school-age" since in low-income and lower-middle-income countries this age-range represents children in primary school, due to high grade-repetition, late entry to school, and dropout. As income levels rise and secondary schooling enrolment increases, children attending school will typically include those older than 14 years. Data are typically reported in age quintiles, so the oldest age group reported among adolescents is 15–19 years, which is also the oldest age group included in the analyses reported here. In practice, some aspects of development continue into the early 20s, and so into the late Youth or Young Adult categories which are not considered in the present analyses. Source: Bundy et al, 2017.[6]

	Google Scholar						PubMed					
	Mortality		Cause of death		Health		Mortality		Cause of death		Health	
	Number	%	Number	%	Number	%	Number	%	Number	%	Number	%
<5 years*	939 400	98·81	55 900	94·62	2 705 100	99·17	59 836	93·95	8374	94·29	129 332	95·33
5–9 years	1520	0·16	405	0·69	3240	0·12	3262	5·12	383	4·31	4751	3·50
10–14 years	2760	0·29	784	1·33	6120	0·22	333	0·52	65	0·73	750	0·55
15–19 years	7050	0·74	1990	3·37	13 300	0·49	261	0·41	59	0·66	829	0·61
Total	950 730	100	59 079	100	2 727 760	100	63 692	100	8881	100	135 741	100

LLMICs=low-income and lower-middle-income countries. Details on publications since 2004 that include the terms health, mortality, or cause of death, and specify the age range in years. The age-specific availability of publications might reflect an absence of interest or research funding and attention to health in middle childhood and adolescence, resulting in insufficient data. The analyses for the Global Burden of Disease 2013 came to a similar conclusion and highlighted that: most of the unique data sources for risk factors at ages 15–19 years were from school-based surveys; children younger than 5 years had the most data available of any age group; and adolescents aged 10–14 years had the fewest data sources.[7] The 2007 World Development Report, Development and the Next Generation, similarly found severe shortcomings of the data of these age groups,[8] whereas Hill and colleagues[9] found no empirical studies of mortality rates in ages 5–14 years in countries without vital statistics, which is most LLMICs.
*Includes infant and neonatal.

Table 1: **Analysis of published literature describing health and mortality in individuals aged 0–19 years**

This volume focuses on scientific evidence; however, local contexts are also important for developing practical policies, including culture, beliefs, lifestyles, and health systems, as well as other key determinants such as sex, race, ethnicity, sexuality, geography, socioeconomic status, and disability.[10] Some groups that tend to be marginalised and overlooked when planning intervention, such as ethnic minorities, those who are lesbian, gay, bisexual, or transgender, persons with disabilities, or youth in conflicts areas and refugees, are likely to have greater need for health and development support. To support these analyses, we developed a conceptual framework to explore the processes and inputs that establish physical and cognitive growth from birth to adulthood (figure 2). The framework emphasises that age-specific intervention is necessary during several key development phases after the first 1000 days. The World Bank developed figure 3 to guide strategy and policy of human development,[16] and illustrates how key health and educational interventions might be timed according to different sensitivities at various ages. Figure 3 also indicates school participation at different ages for populations in low-income and lower-middle-income countries (LLMICs) showing why schools and the education sector can be important delivery platforms for reaching children in middle childhood and adolescence.

Early intervention is essential to set human development on an effective trajectory. However, the emphasis on the proposition that harm experienced in early life is irreversible is not only weakly supported by the evidence but also has led to inadequate emphasis on investigation of interventions later in childhood. The panel outlines a

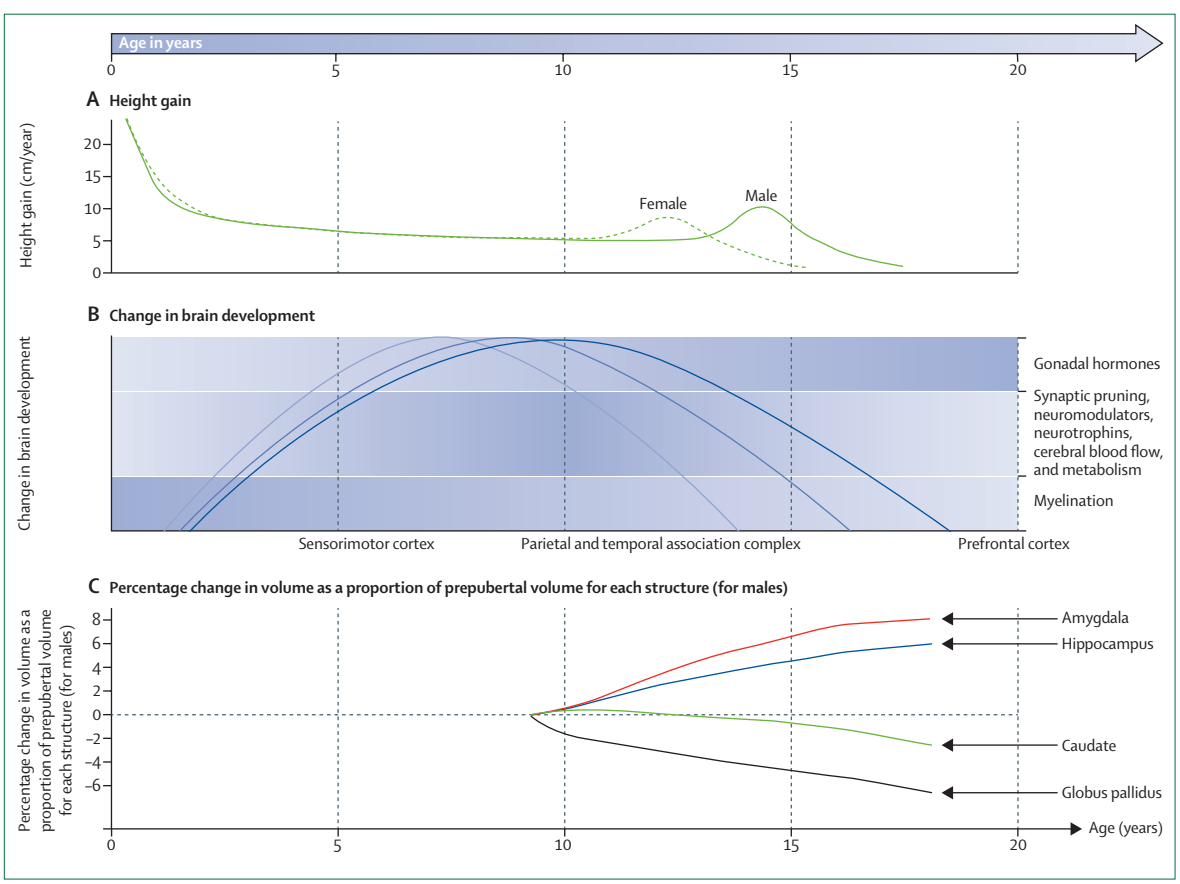

Figure 2: **Human development to 20 years**

(A) Rates of physical growth are highest below 2 years, emphasising the importance of the first 1000 days. However, at the peak of the adolescent growth spurt, the growth rate for girls is similar to, and for boys exceeds, the rate at 2 years and happens in different ways.[11] Evidence presented in volume 8 shows that human growth remains plastic throughout much of childhood, with potentially important catch-up growth.[12] (B) Studies over the past 15 years show that crucial phases of brain development occur beyond the first 1000 days, and in some cases long after. By 6 years, the brain has reached approximately 95% of its adult size. Thereafter the neural connections are of growing importance[13] and different parts of the brain develop at different rates. (C) A sequence of brain development occurs and the growth in middle childhood and adolescence differs from growth in early life.[14] The panel shows the association between the size of subcortical regions for adolescent boys; the patterns are similar for girls but occur at earlier ages than boys because of different patterns of puberty. The regions associated with movement (such as the caudate and Globus pallidus) shrink during early adolescence because they increase in efficiency as functions mature. Conversely, regions associated with memory, decision making, and emotional reactions (hippocampus and amygdala) continue to develop and grow during adolescence. The onset of hormonal changes of puberty in middle childhood causes a new phase of brain development in which the individual's interaction with the social, cultural, and educational environment shapes the processes of myelination and synaptic pruning of centres involved in emotional processing and high executive functioning.[15] *Progressive shading indicates when activity is most intense (darkest shading). Sources: (A) adapted from Tanner (1990);[11] (B) adapted from Grigorenko (2017);[13] (C) adapted from Goddings and colleagues (2014).[14]

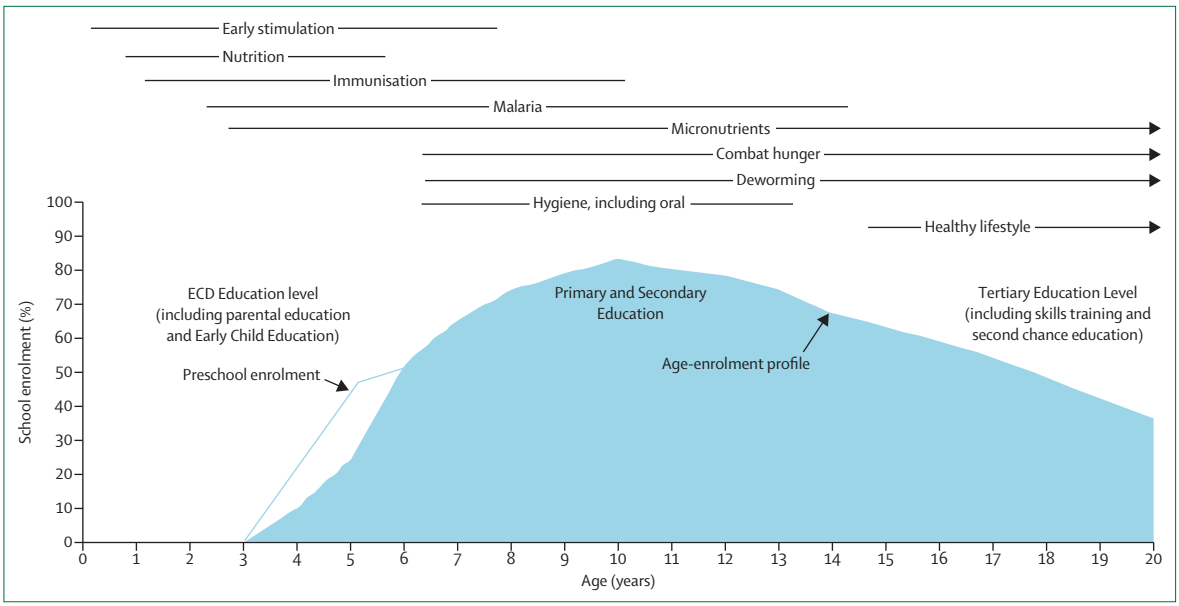

Figure 3: **Indicative rate of school enrolment in LLMICs**
ECD=early childhood development. ECE=early childhood education. This figure was developed and published by the World Bank to assist countries in taking a cross-sectoral and lifecycle approach to promote human development, especially education and health outcomes. The age-related positions and lengths of the lines are illustrative of this approach and are not precise. Source: adapted with permission from World Bank.[16]

research agenda for redressing the thinness of the extant literature. Similarly, the widely cited conceptual framework of continuously declining rates of return with age conflicts with existing knowledge of the plasticity of brain development[17,18] and of physical growth during much of middle childhood,[12,19] and does not consider the intergenerational benefits of actions in late childhood and adolescence. Evidence suggests that potential exists for substantial returns on investment throughout the first two decades of life.

The unfinished agenda of mortality reduction

During middle childhood and adolescence, the major consequences of ill health are related to morbidity rather than mortality. This association, however, does not establish that mortality is unimportant in children over 5 years of age and adolescents. A new analysis of mortality was done for this volume by use of demographic and health surveys to estimate death rates of children aged 5–19 years, in the same way that similar data are used to estimate rates for children under 5 years.[9] The estimates for 2010 suggest that total annual mortality of children aged 5–19 years in LLMICs is around 2·3 million. Deaths of children aged 5–9 years are estimated at about 935 000 deaths higher than earlier estimates for this age group. Congruence of new estimates with data of UN and the Institute for Health Metrics and Evaluation is close in children aged 10–14 years and closest for those aged 15–19 years. These results suggest that more needs to be done to understand and control mortality in the 5–19 years age group, particularly at ages 5–9 years. A natural conclusion for policy would be to extend the efforts of major national and international programmes that assess mortality rates and causes in children under 5 years to include the entire age range from birth to 19 years. The UN Interagency Group for Child Mortality Estimation, which provides estimates through the child mortality estimation database, and the Child Health Epidemiology Reference Group have focused on children under 5 years. The UN Interagency Group for Child Mortality Estimation now plans to expand its analysis to include children aged 5–19 years from 2017.[20]

Morbidity is even more poorly documented than mortality of children over 5 years. The volume explores the evidence for geographical and social differences in four key outcome measures—education, anthropometric status, micronutrient deficiency, and adolescent health—and describes major geographical variation in all four development outcomes.[21–23] However, no systematic collection of morbidity data exists for this age group, especially in LLMICs. In exploring morbidity, we begin to see that health and education are strongly linked in children aged 5–19 years; education analysis shows that individual differences in health between students contribute to differences between education outcomes, and that differences in health are amenable to intervention in the short term.

Essential package of interventions for school-age children and adolescents

The Reproductive, Maternal, Newborn and Child Health volume of DCP3[4] focuses on three essential health packages: health of children under 5 years; reproductive health; and maternal and newborn health. We identified two packages of interventions (overview provided in

table 2) aimed at school-age children (5–14 years; table 3); and late adolescence (15–19 years; table 4), and the economic implications (table 5). In practice, both packages are required to cover the needs of adolescents from 10 to 19 years. The scale of relevance of the package is illustrated by figures 4 and 5 for school-age children and adolescents, showing that the two age groups combined constitute a substantial proportion of the overall population of all countries, with the proportion greatest in the poorest countries: 17% of high-income countries, rising to 37% of low-income countries.

Essential package of interventions for school-age children

Health programmes targeted at schools are among the most ubiquitous forms of health services for school-age children in LLMICs. Since the inclusion of school health programmes in the launch of Education for All in 2000, almost all countries provide school health services at some level, although the coverage is often uneven.[27] The World Food Programme estimates that more than 360 million schoolchildren receive school meals every day,[28] many in LLMICs, and WHO estimates that over 450 million schoolchildren (more than half of the target population) are dewormed annually,[29] nearly all of whom are in LLMICs. These largely public efforts are variable in quality and coverage, but the large scale of existing programmes indicates a willingness by governments to invest in health and education in this age group.

The school system represents an exceptionally cost-effective platform to deliver an essential package of health services to this age group, which has been well documented for high-income countries.[30] Provision of health services in schools is also increasingly equitable, especially since increases in primary enrolment and attendance rates and narrowing of gender gaps are among the greatest achievements of the Millennium Development Goals.[31] In LLMICs with underdeveloped health systems with limited geographical reach, the education system is particularly well situated to promote health among school-going children and adolescents who might not be reached by health services. Typically, more schools exist than health facilities in all income settings, and rural and poor areas are more likely to have schools than health centres.

In the remainder of this section, we examine the investment case for the provision of an integrated package of essential health services for children attending school in LLMICs (table 3; figure 1).

Middle childhood growth and consolidation phase

An important economic rationale for targeting the health and development of school-age children is promotion of learning at an age when they have, what is often their only opportunity, to attend school. Ill health can be a catalyst for absenteeism or dropping out of school: for example, malaria and worm infections can reduce attendance, and anaemia due to malaria or worm infections can impair cognition, attention span, and learning.[28,29,32–35] Estimates suggest that, in areas where malaria and worm infections are prevalent, students who are poor could gain the equivalent of 0·5 to 2·5 extra years of schooling if given appropriate health inter-

***Panel:* Research and development priorities for child and adolescent health and development**

Collect high-quality data on health and development needs of individuals aged 5–19 years

- As shown in table 1, research has focused strongly on the health and development of children under 5 years and a concomitant relative absence of research on the needs of middle childhood and adolescence. Information on children aged 5–9 years is particularly scarce.

Pilot and evaluate packages of interventions for middle childhood and adolescence

- The packages proposed in volume 8 are based on published literature for individual interventions. In many cases, evidence is partly and overly reliant on outcomes in high-income countries. This reliance suggests a need to carefully pilot and evaluate the packages under local circumstances before scale-up.

Do more long-term longitudinal studies

- Most of the available analyses are too short-term (typically <1 year) to provide useful guidance on development, which is a long-term issue. To be useful, studies need to track outcomes over many years. A key question concerns the relative importance to development outcomes of intervention at different phases.

Measure multiple outcomes of interventions

- Studies generally assess single or a few outcomes, whereas the focus of development is multisectoral and multifactorial. More studies are needed that assess physical growth and cognitive development to understand the mutual benefits for health and education outcomes.

Track mortality after 5 years of age

- Evidence that mortality is substantially higher than previously recognised in children aged 5–14 years indicates a need for appropriate survival interventions for this age group. A starting point would be to assess the applicability of interventions that have proven successful in reducing the mortality of children under 5 years; however, the causes of death are likely to be quite different for adolescents over 14 years.

Examine the social dimensions of intervention in childhood and adolescence

- The social ecology of children's lives is poorly understood in low-income and lower-middle-income countries (LLMICs). Locally relevant research is needed on the importance of families, teachers, and the gender context.

Understand biological differences as a development issue

- Growth and development differ between sexes. For example, timing of the growth spurt and accompanying physiological changes occur on a different timeline and scale during pubertal development. Large differences are also apparent in brain development; however, little is known about the implications for behavioural intervention.

Estimate the scale of the contribution of disability to development

- Children with disabilities are less able to benefit from prosperity. Disability remains a largely hidden topic, which is particularly true for mental health challenges in LLMICs, and even more so in behavioural and social challenges, including autism. Estimates of the Institute for Health Metrics and Evaluation suggest that one-in-six children aged 5–19 years is severely or very severely disabled.

	Low-income countries	Lower-middle-income countries	Total for LLMICs
Basic education*	19	190	210
First 1000 days†	4·4	24	29
Maternal and newborn health	1·3	8·1	9·4
Child health	3·1	16	19
School-age children package (excluding school feeding)	0·13	0·38	0·51
School-age children package (including school feeding)‡	0·47	2·8	3·3
Adolescent package‡	0·88	2·7	3·6

LLMICs=low-income and lower-middle-income countries. *Estimates from the Learning Generation (International Commission on Financing Global Education Opportunity 2016)[3] who estimate public sector spending on pre-primary, primary, and secondary education in LLMICs. The report calls for an increase to US$72 billion and US$508 billion, respectively, by 2030. †Estimates are based on interventions in volume 2 and are for the cost of two packages: maternal and newborn health, and health of children under 5 years. These interventions estimate spending in LLMICs. Based on current prices, an estimated incremental annual investment of US$5.3 billion and $22 billion, respectively, is needed to achieve 80% coverage.[4] ‡Estimates are summarised in table 5 and are the estimated total cost of implementation of the school-age and adolescent packages in LLMICs. No formal estimates of current coverage exist, and we estimate current services reach between 20–50% of the target.

Table 2: **Estimates of public sector investment in human development in LLMICs (US$ billion per year)**

	Primary health centre	School	Benefit of intervention delivery in schools
Physical health			
Deworming	Deworming	Deworming	In endemic areas, regular deworming (following WHO guidelines) can be done inexpensively in schools since most deworming drugs are donated; benefits in school attendance has been reported as a result
Insecticide-treated net promotion	Insecticide-treated net promotion	Insecticide-treated net promotion	Education about the use of insecticide-treated nets in endemic areas is important because schoolchildren tend to use nets less often than mothers and small children.
Tetanus toxoid and HPV vaccination	Tetanus toxoid and HPV vaccination	Tetanus toxoid and HPV vaccination	Schools can be a good venue for administration of tetanus boosters, which benefit young people and babies born to those young women.
Oral health promotion	Oral health promotion and treatment	Oral health promotion	Education on oral health is important; poor households generally cannot afford dental treatment.
Correcting refractive error	Vision screening and provision of glasses	Vision screening and provision of glasses	Vision screening and provision of inexpensive ready-made glasses boost school performance
Diet			
Micronutrient supplementation	..	Micronutrient supplementation	Supports learning
Multifortified foods	..	Multifortified foods	Supports learning
Food provision	..	School feeding	School meals promote attendance and education outcomes

HPV=human papillomavirus. School-age children do not regularly contact the health system unless they seek treatment. With the remarkable success of the Millennium Development Goals in increasing enrolment and participation and the continuing focus on universal education with the Sustainable Development Goals, it makes sense to use schools to promote health in this age group and to deliver preventive and curative health interventions. These interventions are affordable and the highest priority because of their health and educational benefits. Table 5 presents the cost of components of the essential package of investments for school-age children. Data are from Fernandes and Aurino.[24]

Table 3: **Essential package of interventions for school-age children (ages 5–14 years)**

ventions. Furthermore, sustaining of benefits across multiple years of schooling could improve cognitive abilities by 0·25 SD, on average. Extrapolation of the benefits of improved accumulation of human capital could translate to around a 5% increase in earning capacity over the life course.[36]

Some of these interventions in middle childhood also have important roles in the maintenance and sustaining of the gains of previous investments, and children who slip through the early safety net can still achieve some catch-up growth with interventions in middle childhood.[12] Furthermore, new mortality analyses[9] show that survival of children aged 5–9 years continues to be a substantial challenge, largely due to the persistent high prevalence of infectious diseases including pneumonia, diarrhoea, and malaria. The control of infectious disease therefore remains an important intervention in this age group.

In many malaria-endemic areas, successful control programmes have reduced transmission rates substantially,[37–39] but since the rate of transmission and consequent level of acquired immunity establishes the age pattern of clinical malaria,[40,41] clinical attacks in older children aged 5–9 years are increasing. In The Gambia, peak age of hospital admission for severe malaria increased from 3·9 years in 1999–2003 to 5·6 years in 2005–07;[42] similar changes have been seen in Kenya.[38] These changes have created a new challenge for intervention because no population-based presumptive treatment approaches are recommended for school-age children, and the policy of testing and treatment with Artemisinin-based combination therapy for falciparum malaria does not appear cost-effective in this age-group.[33,43]

Similarly, burdens of intestinal worms are often greatest in school-age children. Although there is broad consensus on the benefits of treatment of children who are infected, there has been controversy about the measurement of benefits and the programmatic approach.[29] The new WHO guideline (published September, 2017) unambiguously recommends deworming without screening of this age group, when prevalence exceeds 20%.[44] Hopefully this will clarify policy in this area and sustain coverage.

In 2015, more than 450 million school-age children were treated globally and in 2016 India alone reported the treatment of more than 300 million children.

Adolescent growth spurt phase

The pubertal growth spurt is a watershed in the transition from childhood to adolescence; a process that occurs earlier in girls than boys and can be modified by external factors including diet. This phase might provide the best opportunity for catch-up growth, with growth velocities reaching the equivalent to those of children at 2 years.

The growth spurt rapidly increases muscle, bone, and organ mass and dietary demand. One response to this demand, the provision of school meals, is arguably

	Population	Community	Primary health centre	School	Benefit of intervention delivery in schools
Physical health	Healthy lifestyle messages: tobacco, alcohol, injury, and accident avoidance and safety	Adolescent-friendly health services	Adolescent-friendly health services: provision of condoms to prevent STIs; provision of reversible contraception; treatment of injury and abuse; and screening and treatment of STIs	Healthy lifestyle education including accident avoidance and safety	National media messages on healthy life choices designed to appeal to adolescents, combined with national policy efforts to support healthy choices (ie, limit adolescent access to products most harmful to their health)
	Sexual health messages	..	..	Sexual health education	Additional health education in schools aimed at issues relevant to older ages (15–19 years) in countries with higher levels of secondary completion, intended to supplement earlier messages for children aged 10–14 years in the school-age package
		..	..	Adolescent-friendly health services	Provision of adolescent-friendly health services within schools or health-care facilities that respect adolescent needs
Nutrition	Nutrition education messages	..	..	Nutrition education	..
Mental health	Mental health messages	..	Mental health treatment	Mental health education and counselling	..

STI=sexually transmitted infection. Adolescents are the hardest group to reach since many are no longer in school and feel uncomfortable accessing health services predominantly designed for adults. They might fear inadequate confidentiality, and in some cases (such as teen pregnancies) might be stigmatised by health-care workers. The total costs of the school-age package are about US$10 per child aged 5–14 years and $9 per adolescent aged 10–19 years. Table 5 presents the cost of components of the essential package of investments for adolescents. Data are from Horton and colleagues.[25]

Table 4: **Essential package of investments for adolescents (around 10–19 years)**

the most prevalent publicly-funded resource-transfer programme worldwide, with 360 million children being fed every school day. A narrow focus on health outcomes underestimates the benefits of multiple cross-sectoral outcomes including: promotion of school participation (especially for girls), provision of a productive social safety net in hard-to-reach communities, and stimulation of rural economies through the procurement of local produce.[28] School feeding should be viewed as an option among other transfer programmes with multiple outcomes.[45] From a social perspective (often taken in economic evaluation), the net cost of a transfer is often close to 10–15% of the delivery cost. School meal programmes can thus be viewed as conditional (because school attendance triggers the transfer) non-cash transfer programmes. Evaluations suggest that school feeding typically increases attendance rates by 8% and,[28] from this effect alone, benefit-cost ratios of two or more can be inferred.

School-based delivery of vaccination is particularly cost-effective for school-age children (5–14 years), especially for girls. Tetanus toxoid lowers the risk of tetanus contraction for recipients and the children of adolescent girls, thus providing an intergenerational benefit. A 70% coverage of human papillomavirus vaccine that is effective over a lifetime could avert more than 670 000 cases of cervical cancer in sub-Saharan Africa over consecutive birth cohorts of girls vaccinated as young adolescents.[34] Furthermore, evidence exists that school-based vaccination programmes can achieve effective coverage.[30]

Early adolescence is the age when the most common vision problems (ie, refractive errors) first emerge. School-based screening of children around 10–14 years of age is a cost-effective way to detect and correct refractive errors of vision that could otherwise increase the probability of dropping out of school and the risk of life-long visual impairment.[46] Early adolescence is also a key phase for the promotion of life-long healthy behaviours,[8] including oral hygiene and good dietary practices. This phase might be particularly sensitive to diet because of its association with the emergence of diseases of micronutrient deficiency, such as anaemia and iodine deficiency.

Essential package of interventions for later adolescence

Adolescent growth and consolidation following the pubertal growth spurt begins around 15 years and continues to 20 years. This phase requires a package of age-specific interventions (table 4) and has traditionally been viewed as socially important but has had insufficient concerted attention as a crucial period for health and development. 15–20 years of age is when self-agency becomes increasingly important, and although the concept of adolescent-friendly health services has been widely adopted, quality and coverage rarely respond to the need, often failing to ensure that adolescents are able to make their own decisions about their health. School-based interventions that go beyond the teaching of health education in classrooms, encompass changes to the curriculum and wide social environment, and engage with families and the community are more likely to improve sexual health and reduce violence and substance use.[30,47] In the broad population, intersectoral action has been essential to public health gains in many countries, including actions by the transport sector to reduce road traffic injuries and taxes to achieve tobacco control.[48,49]

	Mode of delivery	Approximate cost per child who benefits (US$) in LLMICs	Approximate cost per child (US$) in relevant age group	Aggregate cost in low-income countries (US$, millions, per year)	Aggregate cost in lower-middle-income countries (US$, millions, per year)
School-age children					
School feeding	Meals (fortified with micronutrients) provided at school	41 (targeted to 20% of population in most food-insecure or poor areas)	8·20 per child aged 6–12 years	340	2400
Health education (oral health, reproductive health, and ITN use)	ITN education delivered only in endemic areas	0·50 per educational message (ITN message delivered only in endemic areas; assumed 50% of children in LLMICs)	0·75 per child aged 6–12 years	31	110
Vision screening	Pre-screening by teachers and vision tests and provision of ready-made glasses on-site by eye specialists	3·60 per child to screen and provide glasses to the fraction of the age group needing glasses	0·60 per child aged 6–12 years	25	90
Deworming	Medication for soil-transmitted helminths or schistosomiasis delivered by teachers once a year in endemic areas	0·70 per child in endemic areas; 50% of areas endemic	0·35 per child aged 6–12 years	14	52
Tetanus toxoid booster	Single-dose booster administered to all children in one grade by nurse or similar	2·40 per child	0·40 per child aged 6–12 years	16	59
HPV vaccine	Part of the cancer essential package	10 per fully vaccinated girl (Gavi-eligible countries)	0·83 per child aged 6-12 years	43	74
Aggregate costs without HPV vaccine	..	48	10	430	2700
Aggregate costs without school feeding and HPV vaccine	..	17	2	130	390
Adolescents					
Media messages or national policy regarding health	Messages concerning use of tobacco, alcohol, and illicit drugs; sexual and reproductive health; mental health; healthy eating or physical activity	1 per adolescent	1 per adolescent aged 10–19 years	..	..
Health education in schools	Education for targeted age group	9 per year per adolescent aged 14–16 years	3 per adolescent aged 10–19 years	90	450
Adolescent-friendly health services	Health services offering respectful and confidential access for adolescents	5 per adolescent	5 per adolescent aged 10–19 years	790	2300
Aggregate costs	..	15 per adolescent aged 10–19 years	9 per adolescent aged 10–19 years	880	2700

LLMICs=low-income and lower-middle-income countries. ITN=insecticide-treated net. HPV=human papillomavirus. The total cost of the school-age package is about US$10 per child in the age group of 5–14 years and about $9 per adolescent in the age group of 10–19 years. Compared with per capita public expenditures on health in 2013 of around US$31, this cost does not seem unreasonable, but it is high for low-income countries, which spent only $14 per capita on health in 2013. Data are from Fernandes and Aurino 2017[24] and Horton and others 2017.[25]

Table 5: **Cost of components of essential packages to promote health of school-age children and adolescents in LLMICs**

Apart from sexual and reproductive health, available evidence on preventive interventions derives largely from high-income countries and the USA in particular. The social and environmental determinants of adolescent health and wellbeing act at different levels and across different sectors. The most effective responses are likely to operate at multiple levels of particular settings.[50] The lives of young people are affected by community behaviour and norms as well as the values of adults and other adolescents. Community interventions have commonly involved the local government, families, youth-focused and religious organisations, and schools.

Universal health coverage for adolescents requires training of health-care providers not only to respond to health problems beyond a focus on sexual and reproductive health, but also to adopt non-judgmental attitudes, maintain confidentiality, and engage with adolescents, while maintaining communication with families. Addressing the financial barriers that are especially important for adolescents, such as out-of-pocket payments, contributes to the need to develop accessible platforms for health delivery that are effective for this age group. Recognition is growing of the importance of agency for adolescents and identification of approaches to health that enhance decision making and engagement of adolescents in their health and health care. Adolescent agency is particularly underdeveloped and undersupported in LLMICs.

The expansion of access to secondary education, particularly for girls, is one of the Sustainable Development Goals targeted for 2030 and offers opportunities to improve adolescent health and wellbeing. Secondary education effectively increases the age at marriage and first pregnancy.[51] Participation in quality secondary education enhances cognitive abilities, improves mental, sexual, and reproductive health, lowers risks for later-life non-communicable diseases, and offers substantial

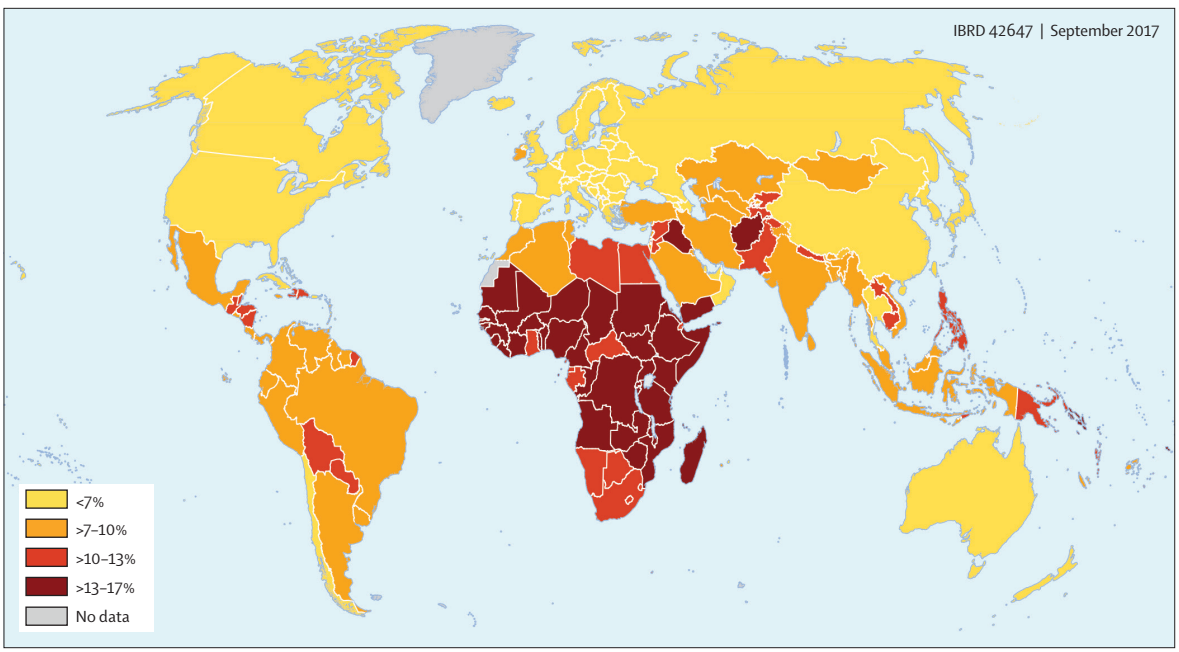

Figure 4: **Proportion of country population comprised of children in middle childhood (5–9 years)[26]**

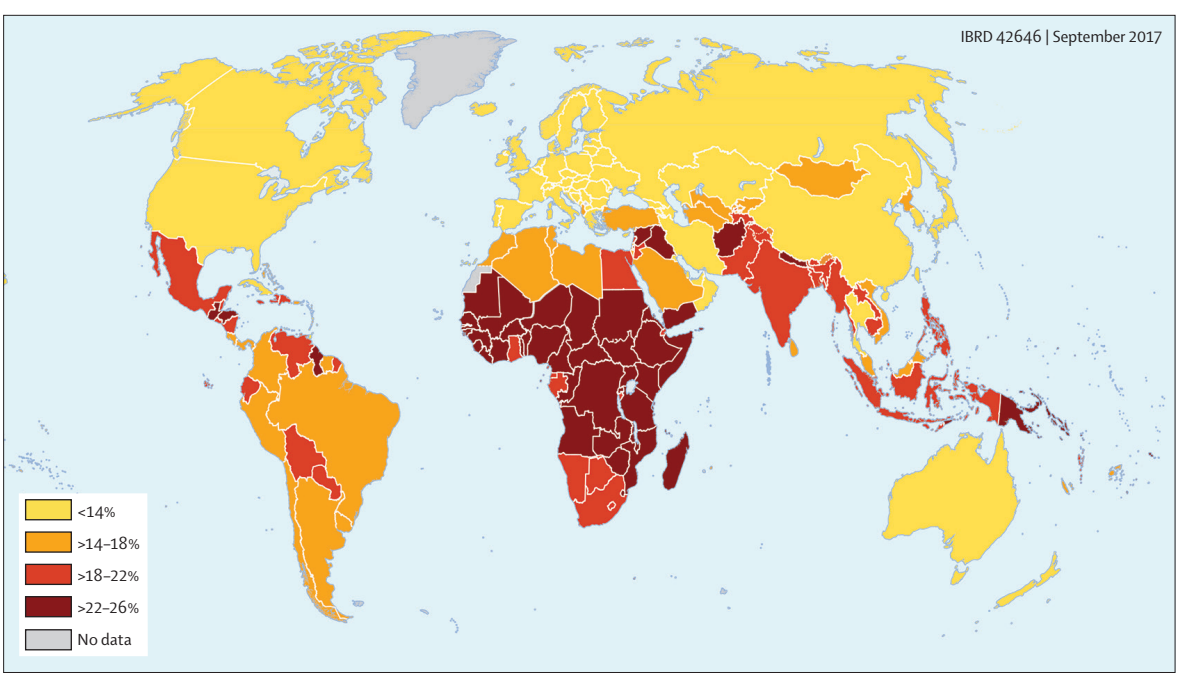

Figure 5: **Proportion of country population comprised of adolescents (10–19 years)[26]**

intergenerational benefits.[52] Secondary schools also provide a platform for health promotion that can strengthen self-agency around health, provide essential health knowledge including comprehensive sexuality education, and help to maintain lifestyles that minimise health risks. Achievement of the educational and economic benefits that secondary schools offer requires avoidance of early pregnancy, infectious diseases, mental disorders, injury-related disability, and undernutrition.

Media messages have salience during adolescence, provide an essential platform for health action, and have proven effective in high-income countries.[30,53–55] Adolescents are biologically, emotionally, and developmentally primed for engagement beyond their families, and the media, particularly social media, offers that opportunity. Social media might also bring hazards,

among the most conspicuous being online grooming, cyberbullying, and a growing preoccupation with body image; therefore, any intervention should take these negatives into account.

Economic analysis of the essential packages

Table 2 summarises existing annual levels of public investment in three important areas for child and adolescent health and development in LLMICs: basic education (pre-primary, primary, and secondary), health in the first 1000 days, and the two essential packages proposed for ages 5–19 years (school-age and adolescence).

Of the three areas, education attracts the largest investment at US$210 billion per year in 2015, much of which is from the public sector and is intended to provide pre-primary, primary, and secondary education, free at the point of delivery. The International Commission on Financing Global Education Opportunity calls for governments to increase domestic public expenditures to support universal provision of primary education in LLMICs by 2030,[3] which requires an increase from 4% to 5·8% of gross domestic product and is equivalent to an annual rate of growth in public education spending of 7% over a 15 year period. In addition to education interventions, the Commission identifies 13 non-teaching interventions as "highly effective practices to increase access and learning outcomes",[3] including three health interventions: school feeding, malaria prevention, and micronutrient intervention. The achievement of universal secondary education by 2030 is a Sustainable Development Goal, and is also cited in the report of the *Lancet* Commission on adolescent health and wellbeing as key to the phase of adolescent growth and development.

In contrast to these large public expenditures for education, the annual investment in health for children under 5 years in LLMICs is estimated to be $29 billion (table 2),[56,57] which includes investments in maternal and newborn health, as well as child health for children under 5 years. Based on existing prices, increasing coverage to 80% is estimated to require an additional $27 billion annually.[57]

The last of the three areas for investment is for interventions in the health and development of children aged 5–19 years in LLMICs, for which no direct estimate of current expenditure exists.[58] The estimated total and incremental costs of the provision of a school-age package and an adolescent package to 80% of this age group is shown in table 2 and table 5. We estimate the total cost as $6·9 billion, comprised of $1·4 billion and $5·5 billion in low-income and lower-middle-income countries respectively. We estimate that current service provision is between 20% and 50% of the coverage required, suggesting an incremental need of between $3·4 billion and $5·5 billion annually, representing between 0·03% and 0·07% of gross domestic product. This is substantially less than the increments sought for education and for health programmes for children under 5 years.

The single most costly component to the public sector is school meals, which account for almost half of the additional investment required. Since school meals constitute a transfer programme, the value of school meals to households balances the cost to government resulting in a net cost of close to zero. We have argued that school meals are a special case, and are neither paid for by the Ministry of Health, nor primarily aimed at health improvement. Distinguishing of interventions within the health sector from those delivered and financed outside the sector is standard in DCP3. School meals, although part of the essential health package, are intersectoral in origin. Table 2 shows the costs with and without school meals.

These analyses suggest important conclusions for the investment in health of children aged 5–19 years. Education investments dominate all other public investments in human development during the first two decades of life. Based on our estimates of existing annual expenditure, the costs of the provision of access to basic education and a package of health services for children under 5 years (including maternal and newborn health) in LLMICs are $210 billion and $29 billion, respectively. The annual cost of additional essential health and development packages for children aged 5–19 years is between $3·4 billion and $5·5 billion, depending on whether the current provision is 50% or 20% of the target. These annual costs become $2·1 billion or $3·4 billion if the costs of school meals are excluded. The annual investments in 5–19 year olds target the same population as the $210 billion invested annually in education, and are synergistic. The modest cost of the two essential packages (school-age and adolescents) suggests that scale-up of the health packages for children aged 5–19 years is a high-return and low-cost investment that addresses the most pressing development needs throughout the first two decades of life.

Health and education are two sides of the same coin

The view that education and health are separate silos in human development reflects an administrative and bureaucratic reality, but does not best serve the needs of the growing child and adolescent. The view that growing children need both health and education—mens sana in corpore sano—is supported by the evidence for linkages between health outcomes and educational attainment,[31,59] and between educational attainment and health outcomes.[60]

Drought and social shocks can adversely affect height in adolescence, which in turn adversely affects schooling. Effect sizes can be large, for example in a study[61] of drought in Zimbabwe, individuals who reached median height for age were 3·4 cm taller, started school 6 months earlier, and achieved 0·85 more grades of schooling than those who did not reach median height for age. The impact of health interventions on education outcomes in high-income countries, especially in the USA, is well

documented.[30,53–55] Some trials in low-income and middle-income countries indicate impact. For example, young children with good diets in the Philippines enter school earlier and have greater learning productivity per year of schooling than do their less advantaged siblings,[62] and micronutrient deficiencies, particularly of iodine and iron that are known to affect cognition, had adverse effects on grade repetition and scores in cognitive tests.[63] However, a 2015 systematic review[64] of mostly LLMICs provides an ambiguous picture. A key conclusion is that developmental outcomes are crucially dependent on the age-specific timing of intervention and duration of follow up; longitudinal trials are particularly important in this area of study, but are rare. The panel on research priorities indicates specific areas where further studies are required.

Literature extensively documents the correlation between high levels of education and low rates of mortality, illness, and health risk. In a new cross-country panel,[3,60] strong controls for country-specific effects in both the level and rate of change of adult mortality revealed statistically significant and quantitatively important education effects. The effects of education on rates of adult mortality were near equivalent to the effects on child mortality: around 2–3% reduction in mortality per additional year of education and per 1 SD improvement in test scores. If rates of return to educational investments are recalculated to consider estimates of mortality reduction, the returns to education increase by about one-third. For example, in lower-middle-income countries the estimated internal rate of return to 1 additional year of education increases from 7% to 9·3% if the effect of education on mortality is included.

Conclusions

Investment focus on the first 1000 days of human development is necessary but insufficient. This narrow focus underserves children and adolescents by inadequately supporting their development at other crucial phases during the first two decades of life and not securing the early gains. This unbalanced approach has not only resulted in neglect of health service provision after the first 1000 days, but has also deflected research away from middle childhood and adolescence.

The issue is not that the first 1000 days are less important than previously thought, but rather that the subsequent 7000 days have much greater importance than has been recognised. On the basis of cost-effectiveness and benefit-cost analyses, we have identified two essential packages of interventions that can help to address these health and development demands in middle childhood and adolescence. A school-age package, largely built around school-based delivery, can address many needs during middle childhood and the adolescent growth spurt. An adolescent package, built around the secondary school and access to non-stigmatising, affordable, and confidential health care, can help to further address the needs during the adolescent growth spurt and very particular needs of later adolescence. The purposes of the two packages and age ranges of the target populations overlap; therefore, both packages are required to support development through middle childhood and adolescence.

There are currently underexploited yet powerful opportunities for synergy between health and education. Schools and the education sector should be recognised as key participants in the promotion of health. Schools can provide an infrastructure for health delivery, and for the learning, understanding, and life skills that, for example, have contributed about 30% of the observed decline in maternal mortality since 1990. Conversely, the health of school-age children and adolescents, especially in LLMICs, is an important determinant of education outcomes, which has consequences for education access and learning. Our analyses of the first 8000 days indicate that investments in health leverage education outcomes, and investments in education leverage health.

The existing world view is that education is a high priority, and the Millennium Development Goals have helped to ensure near-universal access to primary education free at the point of delivery. The same achievement for secondary education by 2030 is a Sustainable Development Goal. Recognition is increasing that the demands of reproductive, maternal, newborn, and child health during the first 1000 days of life should be viewed as a high priority. We argue that, for similar reasons, the incremental costs of addressing health and development needs during middle childhood and adolescence should also be viewed as a high priority.

Our calculations suggest that the essential packages we have proposed are a practicable and affordable investment, even for LLMICs. Based on current expenditures worldwide in LLMICs, the annual cost of the provision of access to health care for children under 5 years is $29 billion, and the cost of provision of basic education is $210 billion. For the same countries, the estimated incremental cost of essential health and development packages for children aged 5–19 years would add $3·4–5·5 billion ($2·1–3·4 billion if school feeding is excluded), dependent on whether current provision of these services is 20% or 50% of need. This is a small increment to leverage the existing investments in early childhood and education and secure the health and development of the next generation. Based on the levels of development assistance and of domestic investment in the first 1000 days and in education, a strong economic case exists for leverage of these investments with crucial, but more modest, health investments during the next 7000 days. This will bring benefits for equity, realisation of individual potential, and maximisation of opportunities for the next generation.

The implication is that public policy needs to align with parental commitments and to address health, development, and education throughout the first two

decades of life. Many countries already emphasise the social and legal importance of the 18th and 21st birthdays, and our analyses suggest that mirroring of that commitment with practical investment in middle childhood and adolescence is high value and affordable for all countries.

Contributors

All authors contributed to the development of the *Disease Control Priorities*, 3rd edition Child and Adolescent Health and Development volume. DAPB wrote the first draft and all authors contributed to its revision. The main messages from this manuscript draw from the analyses across the volume.

Declaration of interests

SH reports a grant from the University of Washington for research assistance. DAPB reports being employed by the Bill & Melinda Gates Foundation, which funds DCP3. All other authors declare no competing interests.

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