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

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Total word count (inclusive): 4964 words

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Abstract

The realization of human potential for development requires age-specific investment throughout the 8000 days of middle childhood and adolescence. Focus on the first 1,000 days is an essential but insufficient investment, and intervention also is 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 recognized; *the Adolescent Growth Spurt* (10-14), when dramatic changes place commensurate demands on good diet and health; and t*he Adolescent Phase of Growth and Consolidation* (15 to early 20s), when new responses are needed to support challenges around brain maturation, more intense social engagement, and emotional control. Two cost-efficient packages, one delivered through schools, 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 earlier growth failure, and leveraging better learning from concomitant education investments.

INTRODUCTION

It seems that society and the common legal definition have got it about right: it takes some 21 years for a human being to reach adulthood. The evidence shows a particular need to invest in the crucial development period from conception to age two (the first 1,000 days) and also during critical phases over the next 7000 days. Just as babies are not merely small people, they need special and different types of care from the rest of us, so growing children and adolescents are not merely short adults, they too have critical phases of development that need specific interventions. Ensuring that life's journey begins right is essential, but it is now clear that we also need support to guide our development up to our 21st birthday if everyone is to have the opportunity to realize their potential. Our thesis is that research and action on child health and development should evolve from a narrow emphasis on the first 1,000 days to holistic concern over the first 8,000 days; from an age-siloed approach to an approach that embraces the needs across the life cycle.

Here we present an overview of the analyses from the upcoming Volume 8 of Disease Control Priorities (third edition), published by the World Bank, entitled *Child and Adolescent Health and Development.* This Volume identifies cost-effective, scalable health interventions during middle childhood and adolescence that can promote physical, cognitive and intellectual development during middle childhood and adolescence. In 30 chapters, the volume explores the health and development needs of the five to 21 year age-group and presents evidence for a package of investments to address priority health needs, expanding on other recent 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 the maximum benefit from investments in schooling for this age-group, such as those proposed by the recent International Commission on Financing Global Education Opportunity.[3] Volume 8 shares contributors to both Commissions, and complements an earlier volume in the DCP3 series, Volume 2 entitled *Reproductive, Maternal, Newborn and Child Health*,[4] which focuses on health in the under-five age group.

Figure 1 sets out the sequential phases of development, and proposes a standardized age nomenclature, the current absence of which serves to emphasize the neglect of some age-groups.

<<figure 1 about here>>

This review summarizes the main conclusions of Volume 8, and is intended as a road map to the evidence and analyses published in detail in the 30 chapters of the volume. The analysis uses four key tools—cost-effectiveness, extended cost-effectiveness, benefit-cost analysis, and returns on investment—to identify and prioritize 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 current public investment in health lag far behind the potential because of the declining levels of investment after 5 years of age.

This bias in investments is paralleled by a similar bias in research interest. Approximately 99 percent of publications in Google Scholar and 95 percent in PubMed which specify age during the first 20 years of life focus on children under age five (Table 1). This strong bias towards early childhood in the health literature may have been helpful in the successful Millennium Development Goal (MDG) drive to reduce under five mortality, but may also have caused us to lose sight of the fact that the subsequent decades of growth and development in the transition to adulthood also involve complex processes and critical periods that are sensitive to intervention.

<<table 1 about here>>

The focus in this volume is on the scientific evidence, but local contexts too are important for developing practical policies, including culture, beliefs, lifestyles, and health systems, as well as other key determinants such as gender, race, ethnicity, sexuality, geography, socioeconomic status, and disability.[9] Some groups that tend to be marginalized and overlooked when planning intervention strategies, such as ethnic minorities, LGBT (lesbian, gay, bisexual or transgendered) youth, 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 develop a conceptual framework for exploring the processes and inputs that determine physical and cognitive growth from birth to adulthood (figure 2). The framework emphasizes that there are several key development phases following the first 1,000 days when age-specific intervention is necessary.

<<figure 2 about here>>

Figure 3 was developed by the World Bank to guide human development strategy and policy,[16] and illustrates how key health and educational interventions might be timed according to the different sensitivities at different ages. The figure also indicates current levels of school participation at different ages for low- and middle-income populations, showing why schools and the education sector can be important delivery platforms for reaching children in middle childhood and adolescence.

<<figure 3 about here>>

Early intervention is critical for setting 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 an unfortunate lack of emphasis on exploring interventions later in childhood.[18] Similarly, the widely cited conceptual framework of continuously declining rates of return with age is at variance with what is now known about the plasticity of brain development,[19,20] and of physical growth during much of middle childhood[12], and also fails to take into account the intergenerational benefits of actions in later childhood and adolescence. As we show in this overview, and in much more detail in the volume itself, current evidence suggests that there is the potential 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 does not mean that mortality is unimportant in older children. A new analysis of mortality using Demographic and Health Surveys to estimate death rates for 5-19 year olds in the same way that the data have been used to estimate rates for children under five,[8] was conducted for this volume.

The estimates for 2010 suggest that total annual mortality in Low and Lower Middle Income Countries (LMICs) in the age group 5-19 is around 2·3 million. Deaths in ages 5-9 are estimated

at about 935,000, higher than the estimates of the United Nations Population Division and the Institute for Health Metrics and Evaluation (IHME) for this age group. Congruence of the new estimates with the UN and IHME data is closer in the age group 10-14 and closer yet for 15-19 year olds.

These results suggest that we need to do more to understand mortality in older children. A natural conclusion for policy would be to extend major national and international programmatic efforts that assess levels and causes of mortality in children under-five to include the entire age range from birth through to 19 years. The United Nations Inter-agency Group for Child Mortality Estimation (IGME), which provides estimates through the Child Mortality Estimation (CME) database, and the Child Health Epidemiology Reference Group have historically focused on children under five. IGME now plans to expand its analysis to include 5-19 years olds beginning in 2017.[21]

Morbidity is even more poorly documented than mortality over five years of age. 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 geographic variation in all four development outcomes,[22-24] but there is no systematic collection of morbidity data for this age-group, especially in LMICs. In exploring morbidity we begin to see that health and education are strongly linked in this age-group; the education analysis shows that individual differences in health between students contribute to differences between educational outcomes, and that differences in health are amenable to intervention in the short term.

Essential Package of Interventions for School-Age Children and Adolescents

Volume 2 of DCP3, entitled *Reproductive, Maternal, Newborn and Child Health*,[4] focuses on three essential health packages: under 5 child health; reproductive health; and maternal and newborn health. Here, we identify two packages of interventions aimed at school-age children (table 3), and at later adolescence (table 4), and the economic implications (table 5). In practice, both are required to cover the needs of adolescents from ten to 19 years. The scale of relevance of the package is illustrated by maps 1 and 2 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: 17.2 percent of high-income countries, rising to 37.2 percent of low-income countries.

<<maps 1 and 2 about here>>

a. Essential Package of Interventions for School-Age Children

Health programs targeted through schools are among the most ubiquitous for school-age children in LMICs. Since the inclusion of school health programs in the launch of Education for All in 2000, it is difficult to find a country that is not attempting to provide school health services at some level, although the coverage is often limited.[26] The World Food Programme estimates that more than 360 million school children receive school meals every day,[27] many in LMICs, and the World Health Organization (WHO) estimates that over 450 million school children, more than half of the target population, are dewormed annually,[28] nearly all in LMICs. These largely public efforts are variable in quality and coverage, but the large scale of existing programs indicates a willingness by governments to invest in health as well as education in this age group.

The school system represents an exceptionally cost-effective platform through which to deliver an essential package of health services to this age group, as has been well documented for HICs.[29] It is also increasingly equitable, especially since increases in primary enrollment and attendance rates, and narrowing of gender gaps, are among the greatest achievements of the MDGs.[30] In LMICs with weak health systems, the education system is particularly well-situated to promote health among school-going children and adolescents, who may not be reached by health services. There are typically more schools than health facilities in all income settings, and rural and poor areas are more likely to have schools than to have health centers.

In this section, we examine the investment case for providing an integrated package of essential health services for children attending school in low- and lower-middle income countries (table 3). "School-age" includes both middle childhood and early adolescence (figure 1).

<<table 3 about here>>

Middle Childhood Growth and Consolidation Phase: An important economic rationale for targeting the health and development of school-age children is to promote learning at an age when they have what may be 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 resulting from malaria or worm infections can impair cognition, attention span, and learning.[27,28,31-34] Estimates suggest that, in areas where malaria and worm infections are prevalent, poor students could gain the equivalent of 0·5 to 2·5 extra years of schooling if given appropriate health interventions, while sustaining benefits across multiple years of schooling could improve cognitive abilities by 0·25 standard deviation, on average. Extrapolating the benefits of improved accumulation of human capital could translate to roughly a five percent increase in earning capacity over the life course.[35]

Some of these interventions in middle childhood also have important roles to play in maintaining and sustaining the gains of earlier investments, and children who slip through the early safety net can still achieve some catch-up growth with interventions in middle childhood.[12] Furthermore, the new mortality analyses show that,[8] for ages five to nine, survival continues to be a significant challenge, largely due to the persistent high prevalence of infectious diseases, including pneumonia, diarrhea, and malaria. The control of infectious disease therefore remains a critical element of interventions in this age group.

In many malaria-endemic areas, successful control programs have reduced the level of transmission substantially,[36-38] but since the age pattern of clinical malaria is determined by the level of transmission and the consequent level of acquired immunity,[39,40] clinical attacks of malaria are becoming more common in older children. In The Gambia, the peak age of hospital admission for severe malaria increased from 3·9 years in 1999–2003 to 5·6 years in 2005–07;[41] similar changes have been seen in Kenya.[37] This has created a new challenge for intervention since none of the population based presumptive treatment approaches is recommended for the school-age group, and the current policy of testing and treating with Artemisinin-based combination therapy for falciparum malaria does not appear cost-effective in this age-group.[32,42]

Similarly, intestinal worm burdens are often greatest in school-age children, and while there is broad consensus on the benefits of treating infected children, there is controversy regarding the most commonly used approach to school-based treatment – that is, treatment of all children at risk, without individual screening.[28] In 2015, more than 450 million school-age children were treated, and in 2016 India alone reported treating 340 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 for girls and that can be modified by external factors, including diet. This phase may provide the best opportunity for catch-up growth, with growth velocities reaching equivalence to those of children at age two.

The growth spurt brings rapidly increasing muscle, bone and organ mass, and of high dietary demand. One way of responding to this, providing meals in schools, is arguably the most prevalent publicly-funded resource transfer program world-wide, with some 360 million children being fed every school day. A narrow focus on health outcomes underestimates the benefits of multiple cross-sectoral outcomes, including: promoting school participation, especially for girls, providing a productive social safety net in hard-to-reach communities, and stimulating rural economies through the procurement of local produce.[27] School feeding should be viewed as an option among other transfer programs with multiple outcomes.[43] From a social perspective (often taken in economic evaluation) the net cost of a transfer is often close to the ten to 15 percent of the cost that is required for delivery. School meal programs can thus be viewed as

conditional (because school attendance triggers the transfer) non-cash transfer programs and evaluations suggest that school feeding typically increases attendance rates by 8 percent and,[27] from this effect alone, benefit-cost ratios of 2 or more can be inferred.

School-based delivery of vaccination is particularly effective at this age, especially for girls. Tetanus toxoid lowers the risk of contracting tetanus both for recipients and for the children of adolescent girls, thus providing an intergenerational benefit, while 70 percent coverage of human papillomavirus (HPV) 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.[33] There is evidence that school-based vaccination programs can achieve effective covereage.[29]

Early adolescence is the age when the most common vision problems – refractive errors – first emerge, and school-based screening of children in select grades 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 risking life-long impairment.[44] Early adolescence is also a key phase for promoting life-long healthy behaviors,[7] including oral hygiene and good dietary practices. This phase may be particularly sensitive to diet, as it is associated with the emergence of micronutrient deficiency diseases, such as anaemia and iodine deficiency.

b. Essential Package of Interventions for later Adolescence

A phase of Adolescent Growth and Consolidation following the pubertal growth spurt begins around 15 years of age, and continues into the 20s, and requires a package of age-specific interventions (table 4). This period has traditionally been viewed as socially important but has lacked concerted attention as a critical period for health and development. This is an age when self-agency becomes increasingly important, and although the concept of Adolescent-Friendly Health Services has been widely adopted, in reality the quality and coverage rarely respond to the need, in particular ensuring 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 and encompass changes to the curriculum and the wider social environment, as well as engagement with families and the community, are more likely to improve sexual health, reduce violence, and decrease substance use.[29,45] In the broader population, intersectoral action has been central to public health gains in many countries, including transport sector actions to reduce road traffic injuries and taxes to achieve tobacco control.[46,47]

<<table 4 about here>>

With the exception of sexual and reproductive health, available evidence on preventive interventions derives largely from High Income Countries, and the United States 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.[49] 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 local government, families, youth-focused and religious organizations, and schools.

Universal health coverage for adolescents requires training healthcare providers not only to respond to health problems beyond a focus on sexual and reproductive health, but also to adopt non-judgemental attitudes, to maintain confidentiality and to engage with adolescents, while maintaining lines of communication with families. There needs to be a focus on addressing the financial barriers that are especially important for adolescents, such as out-of-pocket payments, as well as the need to develop accessible platforms for health delivery that work for this age group. There is growing recognition of the importance of agency for this age group, and of identifying approaches to health that enhance decision-making and engagement of adolescents around their health and health care. Lack of adolescent agency is particularly common in LMICs.

The expansion of access to secondary education, particularly for girls, is one of the Sustainable Development Goals (SDGs) targeted for 2030, and offers particular opportunities to improve adolescent health and wellbeing. Secondary education is effective in increasing the age at marriage and first pregnancy.[50] Participation in quality secondary education enhances cognitive abilities, improves mental and sexual and reproductive health, lowers risks for later-life NCDs, and offers significant intergenerational benefits.[51] 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 maintain lifestyles that minimize health risks. Equally, achieving the educational and economic benefits that secondary schools offer requires the avoidance of early pregnancy, infectious diseases, mental disorders, injury-related disability, and undernutrition.

Media messages have particular salience during the adolescent years and provide an essential platform for health action, and have proven effective in HICs.[29,52-54] Adolescents are biologically, emotionally, and developmentally primed for engagement beyond their families, and the media, particularly social media, offer that opportunity. Social media may also bring hazards, among the most conspicuous being online grooming, cyber-bullying, and a growing preoccupation with body image, and so any intervention has to take these negatives into account.

c. Economic Analysis of the Essential Packages

Table 2 summarizes current levels of public investment in three important areas for child and adolescent health and development in low and lower middle-income countries: basic education

(pre-primary, primary and secondary); health in the first 1,000 days, and the two intervention packages for ages five to 19 years.

<<table 2 about here>>

Of the three areas, education attracts the largest investment at US$206 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 low and lower-middle income countries by 2030,[3] requiring an increase from four to 5·8 percent of gross domestic product (GDP), equivalent to an annual rate of growth in public education spending of seven percent over a fifteen year period. In addition to education interventions, the Commission identifies 13 non-teaching interventions as "highly effective practices to increase access and learning outcomes", including three health interventions: school feeding, malaria prevention and micronutrient intervention. The achievement of universal secondary education by 2030 is a specific SDG 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 very large public expenditures for education, the current annual investment in health for children under five in LMICs is an estimated $28.6 billion (table 2),[56] which includes investments in maternal and new-born health, as well as child health for children under five years. It is estimated, based on current prices, that the cost of increasing coverage to 80% would be an additional $27.3 billion annually.

For interventions in the health and development of children in the age range five to 19 in low- and lower-middle income countries, we have no direct estimate of current expenditure.[57] We present here the estimated total and incremental costs of providing a school-age package and an adolescent package to 80% of this age group (Table 2 and Table 5). We estimate the total cost as US$6·9 billion, comprised of US$1·4 billion and US$5·5 billion in low- and lower-middle income countries, respectively (not including HPV vaccination). Assuming that current provision is of the order of 20 to 50 percent of need, this implies an incremental need of between US$3·4 billion and US$5·4 billion annually, representing between 0·03 percent and 0·07 percent of GDP, dramatically less than the increments sought for education or for the health programs for children under five years of age.

<<table 5 about here>>

The single most-costly component is school meals, which account for almost half of the additional investment required. We have argued earlier that this is a special case, and is neither paid for by

the Ministry of Health, nor primarily aimed at improving health. It is standard in DCP3 to distinguish interventions within the health sector from those delivered and financed outside the sector. School meals, while part of the essential health package are intersectoral in origin. Table 2 shows the costs with and without school meals.[59]

Taken together, these analyses suggest important conclusions for investing in health in the five to 19 age group. It is apparent that education investments dominate all other public investments in human development during the first two decades of life. Using our estimates of current expenditure, the current costs of providing access in low and lower middle income countries to basic education, and a package of health services for under-fives (including maternal and newborn health), are US$206 billion and US$28.6 billion, respectively. The cost of the additional essential health and development packages for five to 19 years olds are between US$1·4 billion and US$3·4 billion, respectively (excluding school meals). Given that the latter two health and development investments underpin those in education it seems difficult to justify investing in education without making the complementary investments in health and human development for this age group, especially given the comparatively low additional cost of the health and development packages. The modest cost of the two packages suggests that scaling up the health packages for ages five to 19 is therefore a high return and low-cost investment which 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 common sense view that growing children need both health and education – *mens sana in corpore sano* – is supported by the evidence for linkages between health and educational attainment,[30,60] and between educational attainment and health outcomes.[61]

Drought and social shocks, can adversely affect height in adolescence, which in turn, adversely affect schooling.[62] Effect sizes can be large, for example in a Zimbabwe study of drought if individuals had reached median height for age, they would have been 3·4 centimeters taller, started school six months earlier, and achieved 0·85 more grade of schooling. The evidence of impact of health interventions on education outcomes in high income countries, especially the US, is well documented.[29,52-54] There are also some trials in low and middle-income countries that indicate impact: for example, young children with better diets in the Philippines did better in school[63], and micronutrient deficiencies, particularly of iodine and iron, both known to affect cognition, have adverse effects on grade repetition and scores on cognitive tests.[64] But a recent

systematic review largely in LMICs provides a more ambiguous picture[65] A key conclusion is that developmental outcomes are crucially dependent upon the age-specific timing of intervention, and upon the duration of follow-up, and that this is an area of study where longitudinal trials are particularly important, but are currently rare.

An extensive literature documents the correlation between higher levels of education and lower levels of mortality, illness and health risk. In a new study in this volume, strong controls for country-specific effects in both the level and rate of change of adult mortality resulted in education effects that are quantitatively and statistically highly significant.[61] Education effects on adult mortality rates were found to be about the same as the effects on child mortality: around 2-3 percent reduction per additional year of education and per 1 standard deviation improvement in test scores. If rates of return to educational investments are recalculated to take into account reasonable estimates of the value 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 one additional year of education increases from 7 to 9·3 percent if the effect of education on mortality is included.

Conclusions

The main conclusion is that the current investment focus on the first 1,000 days of human development is necessary, but not enough. The narrow focus on investing in health in the earliest years underserves our children and adolescents by failing to support their development at other critical phases during the first two decades of life, and by failing to secure the early gains. This unbalanced approach has not only resulted in a neglect of health service provision after the first 1,000 days, but has also deflected research away from middle childhood and adolescence.

The issue is not that the first 1,000 days are less important than previously thought, but rather that the subsequent 7,000 days to 21 years of age have much greater importance than has been recognized. Based largely on cost-effectiveness and benefit-cost analyses, we have identified two essential packages of interventions that together can help 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 adolescence package, built both around the school and around access to non-stigmatizing, affordable and confidential health care, can help further address the needs during the adolescent growth spurt and the very particular needs of later adolescence. The purposes of the two packages overlap, as do the age ranges of the target populations, and so both packages are required to support development through middle childhood and adolescence.

There are powerful opportunities for synergy between health and education that are currently underexploited. The school, and the education sector, should be recognized as key participants in promoting health, both by providing an infrastructure for delivery and, just as importantly, by providing the learning, understanding and life skills that, for example, have contributed about 30 percent of the observed decline in maternal mortality since 1990. On the other hand, the health of school-age children and adolescents, especially in low and lower middle income countries, is an important determinant of education outcomes, having consequences for both education access and learning. The analyses presented here for the first 8000 days, indicate that investments in health leverage education outcomes, and investments in education leverage health.

The current world view is that education is a high priority, and the MDGs have helped ensure near-universal access to primary education free at the point of delivery. It is a SDG goal to achieve the same for secondary education by 2030. There is also increasing recognition that the RMNCH demands of the 1,000 days should be viewed as a high priority. Here 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 proposed here are a practicable and affordable investment, even for LMICs. Based on current expenditures world-wide in LMICs, the annual cost of providing access to health care for children under five is US$28.6 billion, and the cost of providing basic education is US$206 billion. For the same countries, the estimated incremental cost of the essential health and development packages for ages five to 19 would add between US$1·4 billion and US$3·4 billion. This is a small increment to leverage the existing investments in early childhood and education, and to secure the health and development of the next generation. Given the current levels of development assistance, and of domestic investment, in both the first 1,000 days and in education, there would seem to be a strong economic case for leveraging these investments with critical, but more modest, health investments during the next 7,000 days, with benefits for equity, for realizing individual potential, and for maximizing the opportunities for the next generation.

The implication is that public policy needs to align with parental commitments, and to commit to addressing health, development and education through the first two decades of life. Many countries already emphasize the social and legal importance of the 21st birthday, and our analyses suggest that it is necessary and affordable for all countries to mirror that commitment with practical investment in middle childhood and adolescence.

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Panel 1 Key Messages from Volume 8

1. It takes 21 years (or 8000 days) for a child to develop into an adult. Throughout this period there are sensitive phases that shape development. Age-appropriate and condition-specific support is required throughout the 8000 days if a child is to achieve full potential as an adult.

2. Investment in health during the first 1000 days is widely recognized as a high priority, but there is historical neglect of investments in the next 7000 days of middle childhood and adolescence. This neglect is also reflected in investment in research into these older age-groups.

3. There are at least three phases which are critical 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 much higher than previously realized.
- Adolescent Growth Spurt (10-14 years) when there is a major increase in body mass, and significant physiological and behavioral changes associated with the puberty.
- Adolescent Growth and Consolidation Phase (15 to early 20s) bring further brain restructuring, linked with exploration and experimentation, and initiation of behaviors that are life-long determinants of health.

4. Broadening investment in human development to include scalable interventions during the next 7000 days can be achieved cost-effectively at modest cost. Two essential packages were identified: the first addresses needs in middle childhood and early adolescence through a school-based approach; the second focusses on older adolescents through a mixed community/media/health systems approach. Both offer high cost-effectiveness and benefit-cost ratios.

5. Well-designed health interventions in middle childhood and adolescence can leverage the already substantial investment in education, and better design of educational programs can bring better health. The potential synergy between health and education is currently undervalued, and the returns on co-investment rarely optimized.

Panel 2. Research and Development Priorities for Child and Adolescent Health and Development

1. *Collect better data on health and development needs in the age-range five to 21 years.* As shown in table 1, there has been a strong research focus on the health and development of children under five, and a concomitant relative absence of research on the needs of middle childhood and adolescence. There is a particular lack of information on children five to nine years of age.
2. *Pilot and evaluate packages of interventions for middle childhood and adolescence.* The packages proposed in this volume are based on the published literature for the individual interventions. In many cases, the evidence is partial and overly reliant on experiences in HICs. This suggests a need to carefully pilot and evaluate the packages under local circumstances before going to scale.
3. *Conduct more long-term longitudinal studies.* Most of the available analyses are too short-term (typically less than a year) to provide useful guidance on development, which is inherently a long-term issue. To be useful, studies need to track outcomes over multiple years. A key question concerns the relative importance to development outcomes of intervention at different phases.
4. *Measure multiple outcomes of interventions.* Studies generally assess single or a few outcomes, whereas the focus of development is inherently multisectoral and multifactorial. In particular, more studies are needed that assess simultaneously both physical growth and cognitive development, in order to assess the mutual benefits for health and education outcomes.
5. *Track mortality beyond age five.* The new evidence that mortality is substantially higher than recognized in ages five to 14 indicates a need for more clarity about 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 five; however, the causes of death are likely to be quite different for older adolescents, in particular.
6. *Examine the social dimensions of intervention in childhood and adolescence.* The social ecology of children's lives is poorly understood in LMICs. There is a particular need for locally relevant research on the importance of families and teachers, and of the gender context.
7. *Understand biological differences as a development issue*. There are sex differences in growth and development. For example, pubertal development differs by sex, so the timing of the growth spurt and the accompanying physiological changes also happen on a different timeline and scale. We now know that large differences are also apparent in brain development, yet know little of the implications for behavioral intervention.
8. *Estimate the scale of the contribution of disability to development.* Children with disabilities are less able to benefit from prosperity, and disability remains a largely hidden

topic. This is particularly true of mental health challenges in LICs/LMICs, and even more so of behavioral and social challenges, including autism. IHME estimates suggest that one-in-six children five to 19 is severely or very severely disabled.

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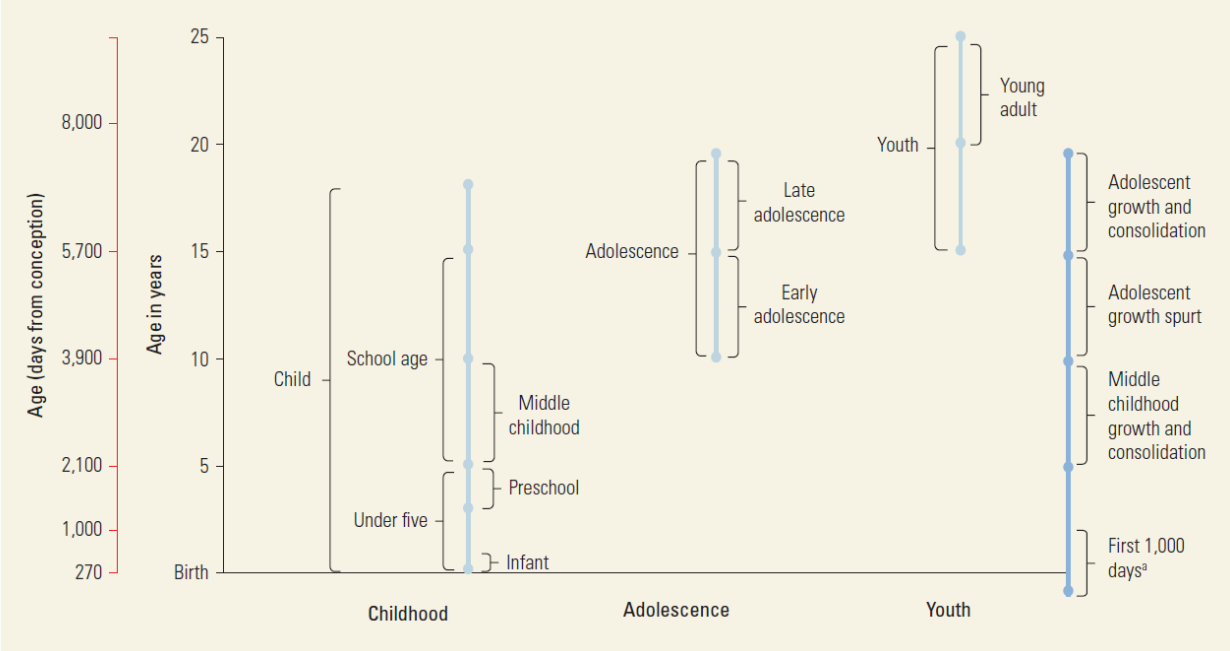
Figure 1 Nomenclature Concerning Age and Four Key Phases of Child and Adolescent Development

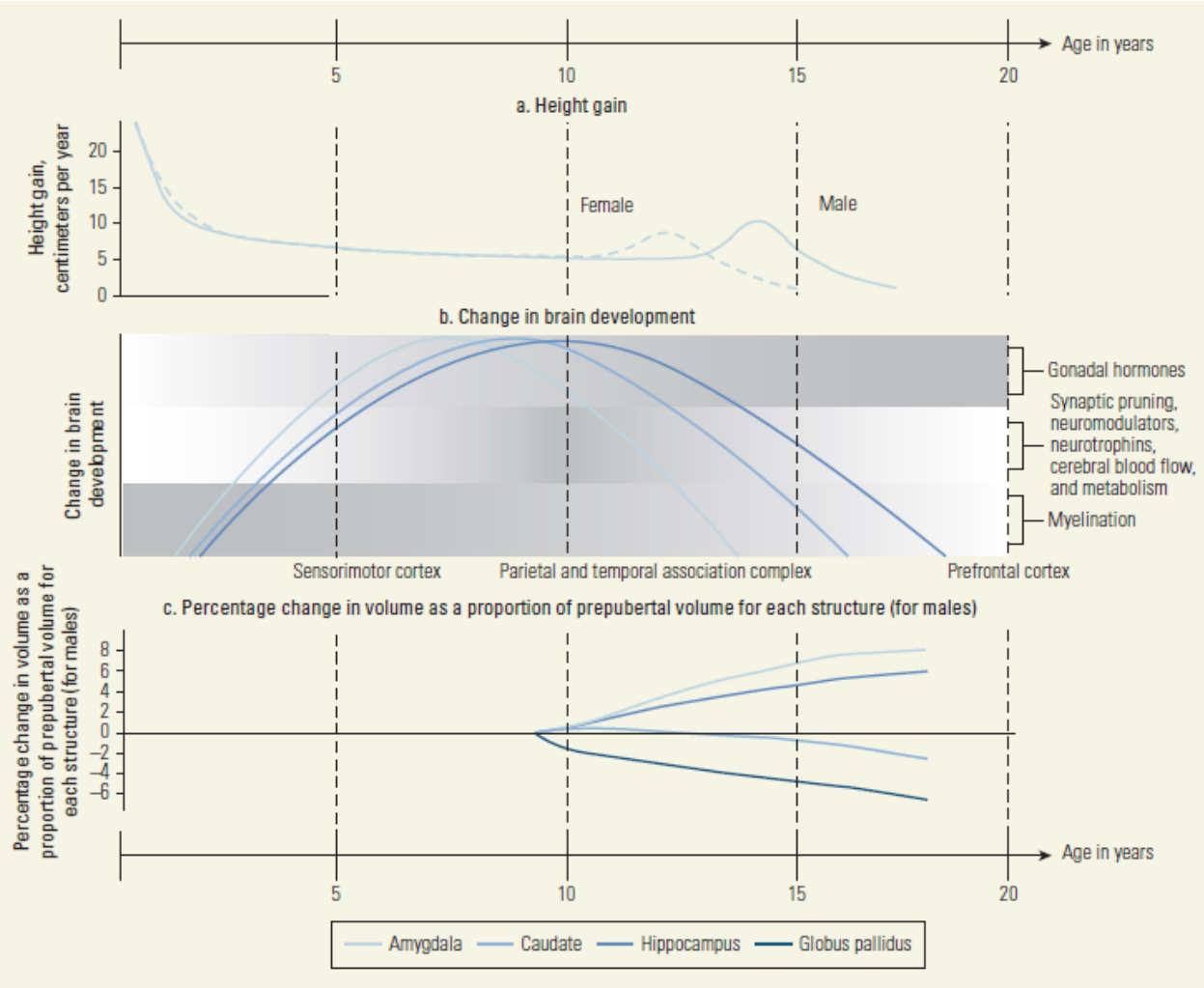


Source: Bundy et al 2017[5]

Note: a. The first 1,000 days is typically measured from the time of conception, as is the first 8,000 days that we discuss as the overall child and adolescent development period; the other age ranges here are presented here are measured from birth.

The figure shows the alignment between age groups and four key phases critical to development. These key phases are used as an organizing principle for intervention throughout this volume. There is a surprising lack of consistency 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 five to nine in particular is reflected in the absence of a commonly-accepted name for this age-group. Figure 1 illustrates the nomenclature used in this review, which we have sought to align with the definitions and use outlined in the 2016 Lancet Commission on Adolescent Health and Wellbeing, in particular using "middle childhood" to reflect the age range between five to nine years. We also refer to children and adolescents between five to 14 years as "school-age", since in low and lower-middle income countries these are the majority of children in primary school, due to high levels of grade-repetition, late entry to school, and drop-out. As income levels rise and secondary schooling enrollment increases, children attending school will typically include those older than age 14. Note that where possible we have extended our analyses up to age 21, but standard reporting of age data is in quintiles, so for convenience we often have to report the upper range as 15-19 years.

Figure 2. Human Development to Age 20

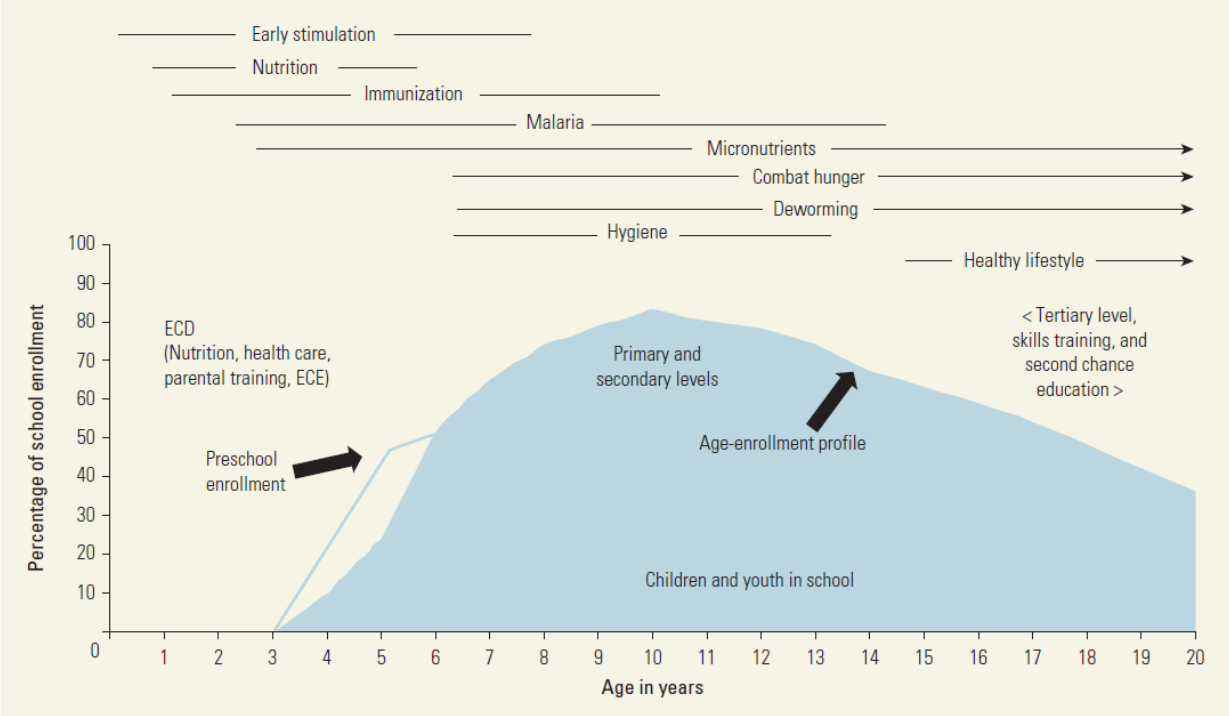


Sources: Panel a adapted from Tanner 1990[9]; panel b adapted from Grigorenko 2017[10]; panel c adapted from Goddings et al. 2014.[11]

Note: Figure 2 (panel a) shows that rates of physical growth are at their highest below age two, emphasizing the importance of the first 1,000 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 age two years and also happens in quite different ways.[11] Evidence presented in Volume 8 shows that human growth remains relatively plastic throughout much of childhood, with potentially important amounts of catch-up growth.[11] Figure 2 (panel b) uses evidence from neuroscience over the past 15 years to show that critical phases of brain development occur beyond the first 1,000 days, in some cases long after. By age six, the brain has reached approximately 95 percent of its adult volume, and it is thereafter not the size of the brain but the connections within it that are of growing importance,[12] with different areas of the brain with different functions developing at different rates. For example, the peak development of the sensorimotor cortex, which is associated with vision, hearing, and motor control, occurs relatively early, and little development occurs after puberty. The parietal and temporal association complex, responsible for language skills and numeracy, develops a little later; hence, the observation that although it is possible to learn new languages after about 14 years of age, it is more difficult to speak a new language with the fluency of a native speaker.[13] The prefrontal cortex develops later still; this is the area associated with higher brain functions, such as executive

control.[11] Figure 2 (panel c) illustrates that there is a sequence of brain development, and the kind of growth in middle childhood and adolescence differs from that in early life.[14] The panel shows the relationship between the size of subcortical regions for adolescent boys; the patterns are similar for girls but occur at earlier ages because of different patterns of puberty. The regions associated with movement (such as the caudate and globus pallidus) shrink in size during early adolescence because these structures are becoming more efficient as the functions become more mature. In contrast, regions associated with memory, decision making, and emotional reactions (amygdala and hippocampus) are still developing and growing in size during adolescence. With the onset of the hormonal changes of puberty in middle childhood, a new phase of brain development commences in which the individual's interaction with the social, cultural, and educational environment shapes the processes of myelination and synaptic pruning of centers involved in emotional processing and higher executive functioning.[15]
Note: The vertical axis in panel b shows relative rate of growth of three brain areas from 0 to highest. The progressive shading indicates when the indicated activity is at its most intense (darkest shading).

Figure 3 Indicative Rate of School Enrollment in Low- and Middle-Income Countries



Source: Adapted from World Bank 2011[17]

Note: ECD = early childhood development. ECE = early childhood education. Note that this figure was developed and published originally by the World Bank to assist countries in taking a cross-sectoral and life-cycle approach to promoting human development, especially education and health outcomes. The age-related positions and lengths of the lines is intended to be illustrative of the approach, and are not intended to be precise.

Table 1. Analysis of Published Literature Describing Health and Mortality, Ages 0–19

	Google Scholar						*PubMed*					
	Mortality		*Cause of death*		*Health*		*Mortality*		*Cause of death*		*Health*	
Age group	*Number*	*%*	*Number*	*%*	*Number*	*%*	*Number*	*%*	*Number*	*%*	*Number*	*%*
Under 5[a]	939,400	98·81	55,900	94·62	2,705,100	99·17	59,836	93·95	8,374	94·29	129,332	95·33
5–9	1,520	0·16	405	0·69	3,240	0·12	3,262	5·12	383	4·31	4,751	3·50
10–14	2,760	0·29	784	1·33	6,120	0·22	333	0·52	65	0·73	750	0·55
15–19	7,050	0·74	1,990	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	8,881	100	135,741	100

a. Includes infant and neonatal.

Note: Table 1 provides 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 may reflect a lack of interest or a lack of research funding and attention to health in middle childhood and adolescence, resulting in a lack of data. The analyses for the Global Burden of Disease 2013 came to a similar conclusion, pointing out that most of the unique data sources for risk factors at ages 15–19 were from school-based surveys, that children younger than five years had the most data available of any age group, and that adolescents aged 10–14 years had the fewest data sources.[6] The 2007 World Development Report Development and the Next Generation similarly found severe data shortcomings around these age groups[7], while Hill et al. found no empirical studies of mortality rates in the age group 5-14 in countries without vital statistics, which is the majority of LMICs.[8]

Note: We would like to acknowledge Jinyuan Qi from the editorial team for undertaking this literature search in Google Scholar and PubMed, which was for publications since 2005 and was undertaken on September 29 2016. The search terms included (i) mortality; (ii) cause of death; and (iii) health for the following age groupings: neonatal, aged 0-4, 5-19, 5-9, 5-10, 10-14, 15-19, 10-19.

Table 2 Estimates of Public Sector Investment in Human Development in Low- and Lower-Middle-Income Countries
US$, billions

	Low-income countries	*Lower-middle-income countries*	*Total for both low- and lower-middle-income countries*
Current Spending			
Basic education[a]	19	187	206
First 1,000 days[b]	4.4	24.2	28.6
Maternal and newborn health	1.3	8.1	9.4
Child health	3.1	16.1	19.2
Proposed New Package			
School-age children package (excluding school feeding and HPV vaccination)	0·13	0·38	0·51
school feeding)[c]	0·47	2· 8	3·3
Adolescent package[c]	0·88	2·7	3·6
Total proposed spending on new packages in middle childhood and adolescence (including school feeding, but excluding HPV)[c]	1·4	5·5	6·9

a. These estimates are from *the Learning Generation* (International Commission on Financing Global Education Opportunity 2016, 37).[3] They estimate current public sector spending on pre-primary, primary and secondary education in low- and lower-middle-income countries. The report calls for an increase to US$72 billion and US$508 billion, respectively, by 2030.

b. These estimates are based on the interventions presented in volume 2 and are for the cost of two packages: (a) maternal and newborn and (b) under-five child health. They estimate current spending in low- and lower-middle-income countries. Based on current prices, an estimated incremental annual investment of US$5.3 billion and US$22billion, respectively, is needed to achieve 80% coverage.[4]

c. These estimates are summarized in table 5. They are the estimated total cost of implementing the school-age and adolescent packages in low- and lower-middle-income countries. There are no formal estimates of current coverage, but it is likely in the range 20–50% of this figure.

Table 3 Essential Package of Interventions for School-Age Children (Ages 5–14 Years)

Health area	*Population*	*Community*	*Primary health center*	*School*	*Benefit of delivering interventions in schools*
Physical health	—	Deworming	Deworming	Deworming	In endemic areas, regular deworming (following WHO guidelines) can be done inexpensively in schools now that the majority of deworming drugs are donated; there are reported benefits in school attendance as a result.
		Insecticide-treated net promotion	Insecticide-treated net promotion	Insecticide-treated net promotion	Education concerning the use of insecticide-treated nets in endemic areas is important, as 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 administering tetanus boosters, which benefit not only the young people themselves, but also the 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.
			Vision screening and provision of glasses	Vision screening and treatment	Vision screening and provision of inexpensive ready-made glasses boost school performance.
Nutrition	—	Micronutrient supplementation	—	Micronutrient supplementation	—
		Multifortified foods	—	Multifortified foods	—
				School feeding	School meals promote attendance and education outcomes.

Source: Fernandes and Aurino 2017[58]

Note: — = not available; WHO = World Health Organization; HPV = human papilloma virus. 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 enrollment 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 given their health and educational benefits. Table 5 presents the cost of components of the essential package of investments for school-age children

Table 4. Essential Package of Investments for Adolescents (Ages 10–19 Years, Approximately)

Health area	*Population*	*Community*	*Primary health centers*	*Schools*	*Benefit of targeting interventions to adolescents*
Physical health	Healthy lifestyle messages: tobacco, alcohol, injury, accident avoidance/safety	Adolescent-friendly health services	Adolescent-friendly health services: provision of condoms to prevent STIs; provision of reversible contraception; treatment of injury in general and abuse in particular; screening and treatment of STIs	Healthy lifestyle education; including accident avoidance and safety	National media messages on healthy life choices, in a format designed to appeal to adolescents, combined with national policy efforts to support healthy choices (limiting access of adolescents 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, intended to supplement messages for younger children in the school-age package
				Adolescent-friendly health services	Provision of adolescent-friendly health services within schools or within health care facilities in ways that respect adolescent needs
Nutrition	Nutrition education messages	—	—	Nutrition education	—
Mental health	Mental health messages	—	Mental health treatment	Mental health education and counseling	—

Source: Horton and others 2017[48]

Note: — = not available; 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 may fear lack of confidentiality, and in some cases (such as teen pregnancies) may be stigmatized by health care workers. The total costs of the school-age package are about US$10 per child in the 5–14 age group and US$9 per adolescent in the 10–19 age group. Table 4 presents the cost of components of the essential package of investments for adolescents.

Table 5. Cost of Components of Essential Packages to Promote Health of School-Age Children and Adolescents in Low- and Lower-Middle-Income Countries

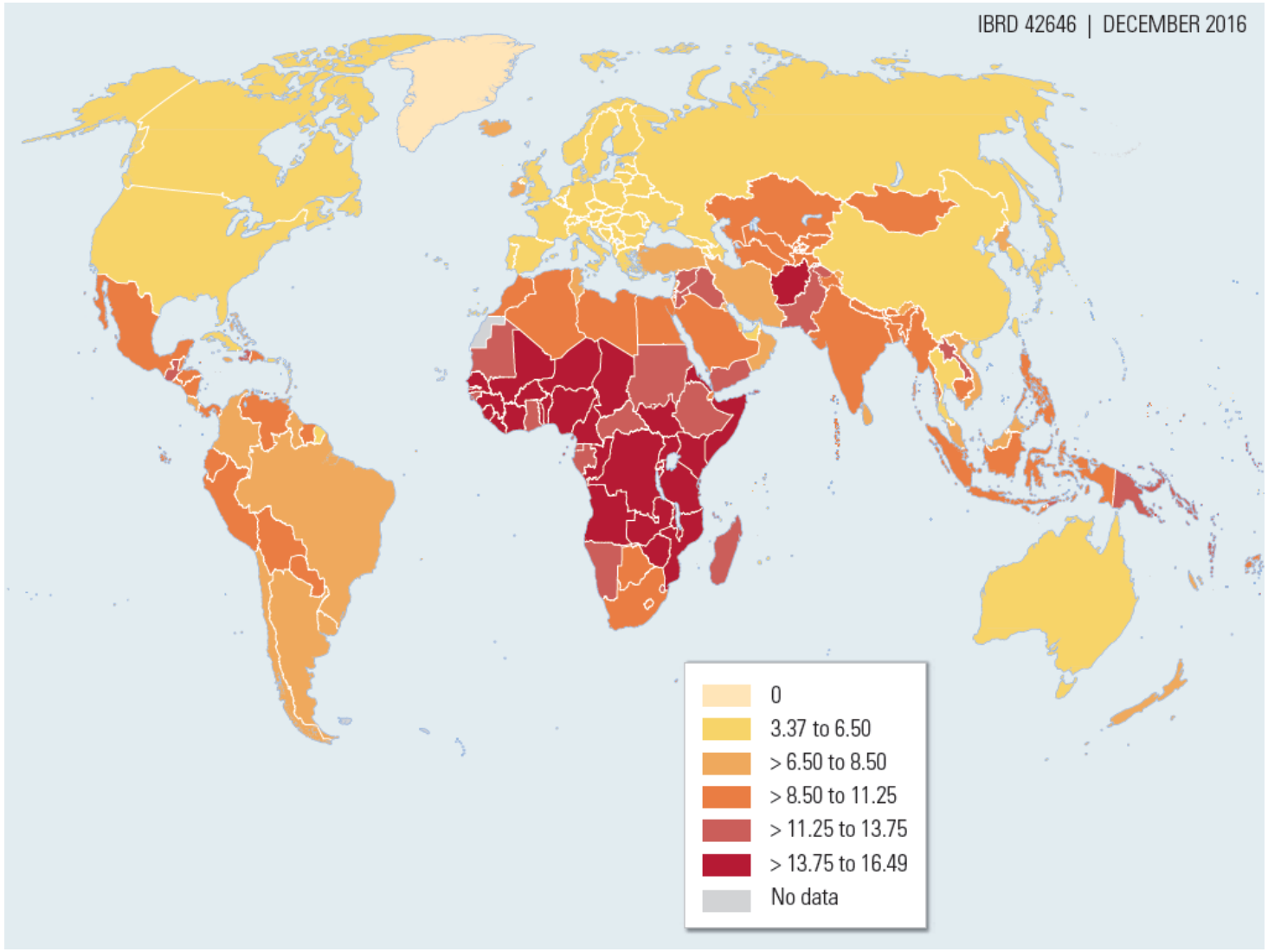
Intervention	*Mode of delivery*	*Approximate cost per child who benefits (US$) in low- and lower-middle income countries*	*Approximate cost per child (US$) in relevant age group*	*Aggregate cost in low-income countries (US$, millions, per year)*	*Aggregate costs in lower-middle income countries (US$, 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 age 6–12	340	2,400
Health education (oral health, 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 low- and lower-middle income countries)	0·75 per child age 6–12	31	110
Vision screening	Prescreening by teachers; 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 age 6–12	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 age 6–12	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 age 6–12	16	59
HPV vaccine	Part of the cancer essential package	10 per fully vaccinated girl (Gavi-eligible countries)	0·83 per child age 6-12	43	74
Aggregate costs Without HPV vaccine		48	10	430	2,700

Intervention	*Mode of delivery*	*Approximate cost per child who benefits (US$) in low- and lower-middle income countries*	*Approximate cost per child (US$) in relevant age group*	*Aggregate cost in low-income countries (US$, millions, per year)*	*Aggregate costs in lower-middle income countries (US$, millions, per year)*
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 age 10–19	—	—
Health education in schools	Education for targeted age group	9 per year per adolescent age 14–16	3 per adolescent age 10–19	90	450
Adolescent-friendly health services	Health services offering respectful and confidential access for adolescents	5 per adolescent	5 per adolescent age 10–19	790	2,300
Aggregate costs		15 per adolescent age 10–19	9 per adolescent age 10–19	880	2,700

Source: Fernandes and Aurino 2017[58]; Horton and others 2017.[48]

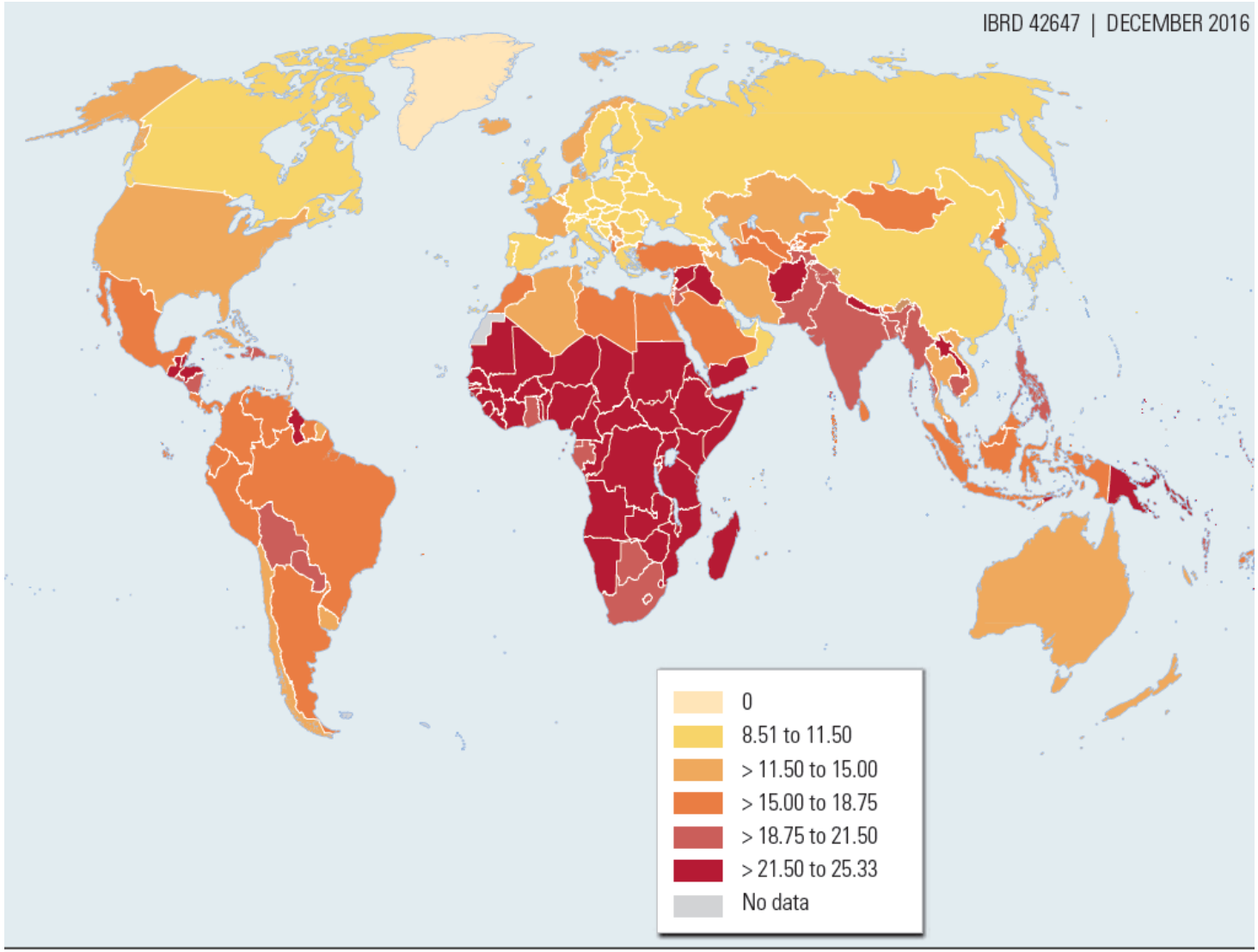
Note: — = not available. ITN = insecticide-treated net; HPV = human papilloma virus. The total cost of the school-age package is about US$10 per child in the 5–14 age group and about US$9 per adolescent in the 10–19 age group. Compared to per capita public expenditures on health in 2013 of around US$31, this does not seem unreasonable, but it is high for low-income countries, which spent only US$14 per capita on health in 2013.

Map 1. Proportion of country population that is comprised of children in middle childhood (between ages 5-9)



Source: United Nations, World Population Prospects: the 2015 Revision, July 2015[25]

Map 2. Proportion of country population that is comprised of adolescents (between ages 10-19)



Source: United Nations, World Population Prospects: the 2015 Revision, July 2015[25]