Chapter 6

Impact of Interventions on Health and Development during Childhood and Adolescence: A Conceptual Framework

Donald A. P. Bundy and Susan Horton

This chapter provides a conceptual framework for exploring the processes and inputs that determine the physical, cognitive, and intellectual growth of human beings from birth to adulthood. This task is made particularly difficult by the absence of a holistic academic discipline that provides an overview of this critical phase in the human life course. It is also complicated by the curiously partial approach to studies in this area; much of the literature on child health ends when a child reaches age two years, while much of the literature on child education does not begin until a child reaches age five years. This significant mismatch in the literature reflects a similar lack of connection between the scale of public investment in primary education—one of the few public goods that attracts near-universal support—and the scale of investments in health and nutrition during middle childhood and adolescence.

Development during adolescence (ages 10–19 years) has received greater attention than the middle childhood years (ages 5–9 years; see, for example, Patton and others 2016). The unfortunate tendency to treat adolescence as separate from childhood has impeded efforts to enhance the understanding of the interrelationships between adolescence and earlier development and of the contribution of health and nutrition to the development of the next generation. Definitions of age groupings and age-specific terminology used in this volume can be found in chapter 1 (Bundy and others 2017).

The focus on the first 1,000 days—from the first day of pregnancy until age two years—has caused us to lose sight of the fact that child and adolescent growth and development are complex processes with multiple periods of sensitivity to intervention. Early intervention is undoubtedly critical to human development. However, the emphasis on the proposition that harm experienced in early life is irreversible not only is weakly supported by the evidence, but also has led to an unfortunate lack of emphasis on exploring important and relevant interventions later in childhood. Similarly, the declining rate of return on educational investments posited by Heckmann (2011) may need to be reconsidered following recent neurobiological research on brain development and a broader recognition of the complexity of intellectual skills, which extend well beyond numeracy and literacy.

INTERVENTIONS DURING MIDDLE CHILDHOOD AND ADOLESCENCE

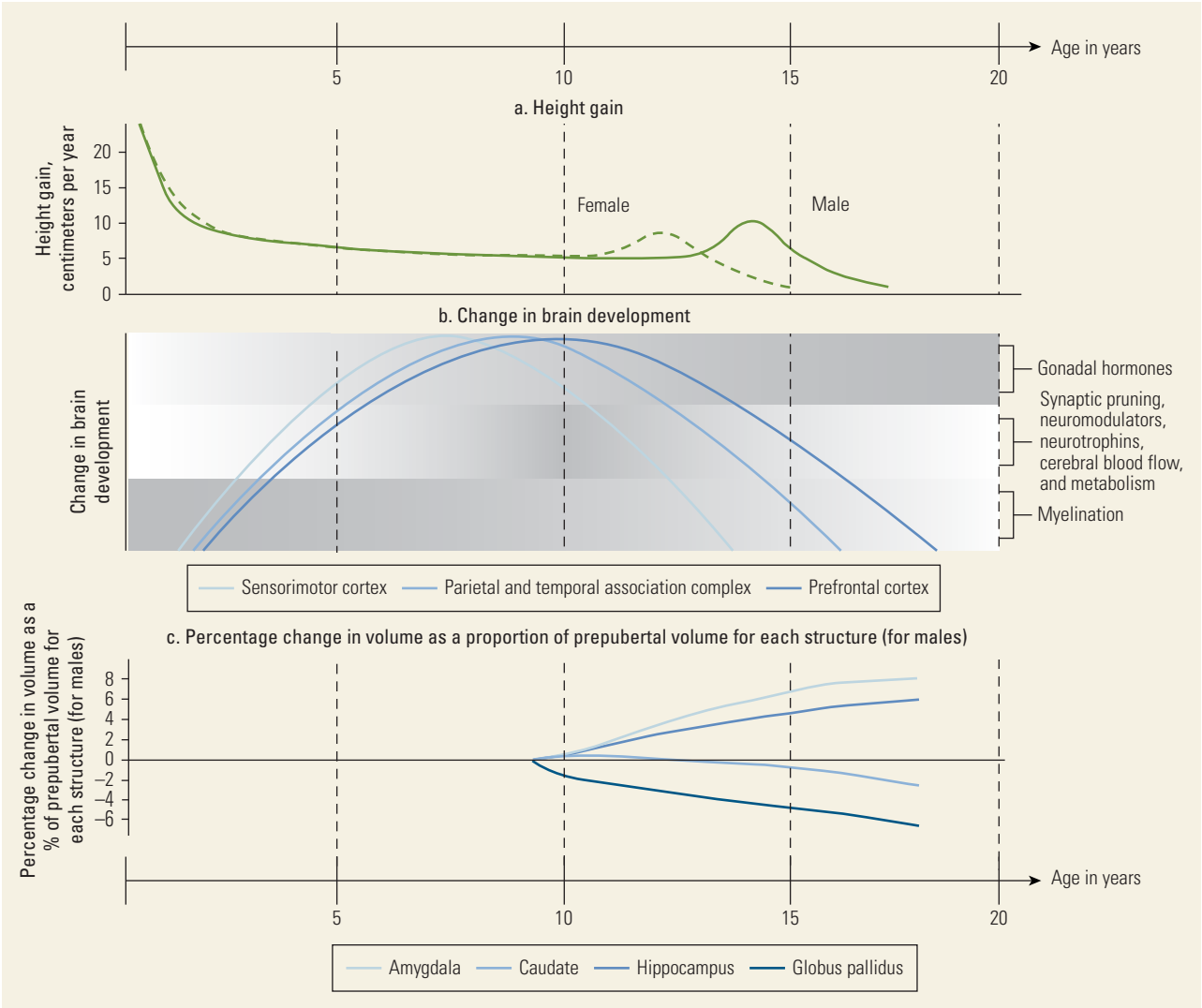
Volume 2 of the third edition of *Disease Control Priorities, Reproductive, Maternal, Newborn, and Child Health* (Black and others 2016), explores evidence of the importance of maternal and young child health for subsequent child development. This chapter complements those findings by exploring evidence of the consequences of intervention at later points throughout the life course. This chapter places

Corresponding author: Donald A. P. Bundy, Bill & Melinda Gates Foundation, Seattle, Washington, United States; Donald.bundy@gatesfoundation.org.

particular emphasis on giving equivalent weight to the understanding of the role of interventions at all stages, from early childhood through middle years and adolescence. To provide a conceptual scaffolding, we developed figure 6.1 to assemble evidence of effects along the same age-specified life course.

Figure 6.1 illustrates the value of a perspective that extends beyond the first 1,000 days. Rates of physical growth are indeed the highest at younger than age two years, when nutrition is critical. However, the rates at the peak of the adolescent growth spurt for girls are similar to—and for boys exceed—the rates at age two years (figure 6.1, panel a). It has long been recognized that stunting before age three years can be partially reversed by delayed maturation and a longer period of catch-up (Martorell, Khan, and Schroeder 1994), given the right circumstances. A review in chapter 8 in this volume (Watkins and others 2017) presents evidence for smaller, but potentially important, amounts of catch-up growth in older children before the onset of puberty. These data may mean that we need to be more careful about assuming that early insults are irreversible and pay more attention to what can be done for children in middle childhood. The scarcity of studies in this age group also may show the influence of unintended research bias on policy.

Figure 6.1 Human Development to Age 20 Years



Sources: Panel a adapted from Tanner 1990; panel b adapted from Grigorenko 2017; panel c adapted from Goddings and others 2014.
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). Behavioral attributes are paralleled by hormonal and neurobiological changes that target specific brain regions and cell populations (shown in shaded gray to capture the dynamic influences of hormones, various brain processes, and myelination).

Although the first 1,000 days are clearly a key period for brain development, evidence from neuroscience from the past 15 years has given us greater insight into the complexities of brain development. By age 6 years, the brain has reached approximately 95 percent of its adult volume; the volume of gray matter peaks about age 12 years in boys (figure 6.1, panel c) (Goddings and others 2014). For the brain, however, size is not everything. Connections within the brain are of greater importance to functioning than size. The process of myelination speeds up the processing of signals, and the process of synaptic pruning leads to strengthening of particular pathways. White matter in the brain, which reflects increased myelin, peaks in early adulthood. These processes of brain development also depend on individuals' interactions with their environments, which in turn stimulate their learning.

Different areas of the brain have different functions and develop at different rates. Peak development of the sensorimotor cortex, which is associated with vision, hearing, and motor control, occurs relatively early, and development is limited after puberty. The parietal and temporal association complex, responsible for language skills and numeracy, develops the fastest a little later; hence, the observation that by about age 14 years, although it is possible to learn new languages, it is more difficult to speak a new language in the same way as a native speaker (Dahl 2004). The prefrontal cortex develops later still; this is the area associated with higher brain functions, such as executive control (figure 6.1, panel b) (Grigorenko 2017).

It is possible to see some of these differential growth rates in brain capabilities in the relationship between the size of subcortical regions in figure 6.1, panel c. The figure plots size as a function of stage of puberty using Tanner's well-known five stages, which can be categorized as pre-, early, mid-, late, and postpuberty. The panel shows the pattern for adolescent boys; the patterns are similar for girls but occur at earlier ages because of different patterns of puberty. The panel shows that the size of those regions associated with movement (such as the caudate and globus pallidus) is shrinking during early adolescence because these functions are more mature. In contrast, regions associated with memory, decision making, and emotional reactions (amygdala and hippocampus) are still growing in adolescence.

The development of behaviors and social skills has long been recognized as age dependent, and it is now recognized that this development is closely related to neurological development. The subcortical regions are not fully developed at the point at which they reach maximum size; they require additional time to establish rapid processing and transmission of signals to other parts of the brain. The prefrontal cortex develops later still with maturation continuing into the third decade. This prolonged process helps explain why adolescence is a time of strong passions (Dahl 2004), impulsiveness (Casey, Jones, and Hare 2008), and risk taking (Casey, Jones, and Hare 2008; Steinberg 2007). The earlier development of brain regions associated with these behaviors outstrips the slower development of brain areas associated with control of impulses, delay of gratification, and regulation of emotions (Steinberg 2007). Accordingly, a focus on readily measurable cognitive function, as in much of the educational literature, ignores the more complex and later-developing brain functions that have important consequences for creativity, social functioning, and strategic thinking.

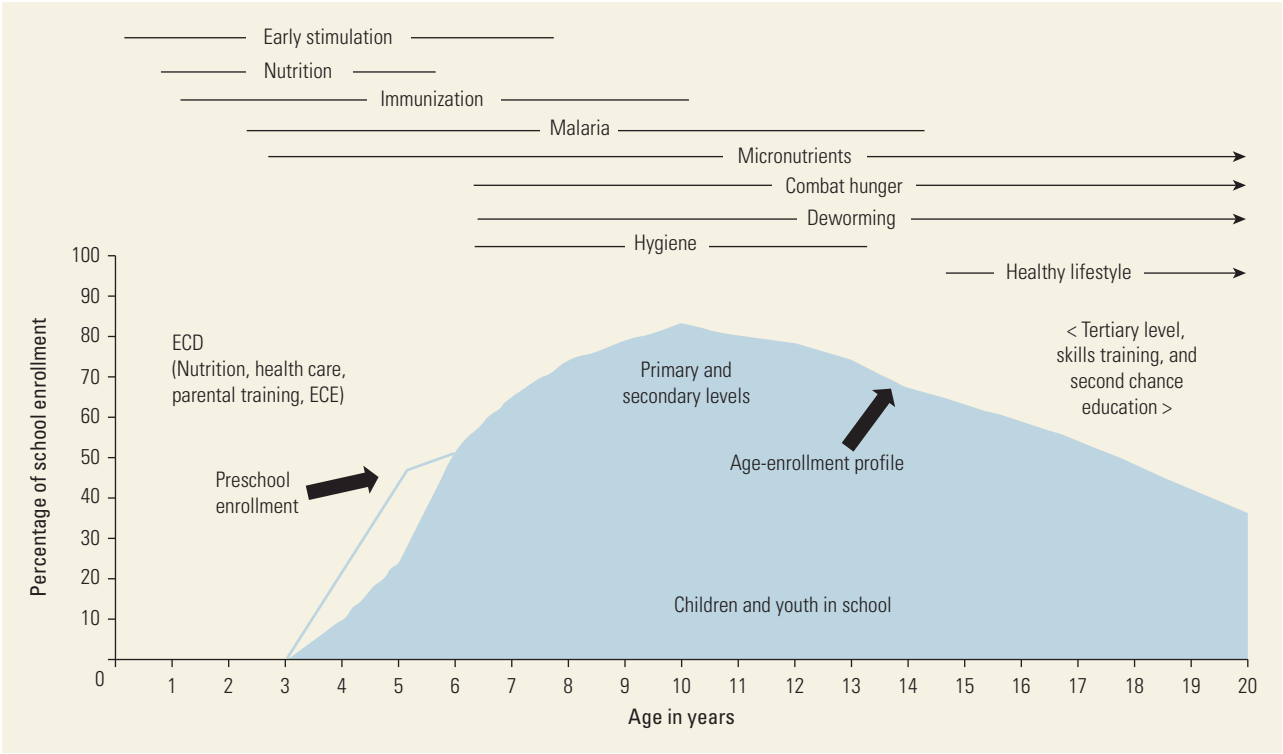
Figure 6.2 was developed to guide human development strategic policy and suggests how key health, nutritional, and educational interventions might be timed according to the different sensitivities at different ages. The figure also indicates the likely levels of school participation at different ages for low- and middle-income populations, showing how important the education sector can be for reaching children in middle childhood and adolescence, and presaging the discussion of delivery platforms in section 4 of this volume, which in turn underpins the discussion of various age- and stage-specific intervention packages discussed in section 5 of this volume.

IMPLICATIONS FOR PHASES OF DEVELOPMENT

Our current understanding of human development during the first two decades of life suggests that there is a series of phases, each of which is critical to development and each of which requires a different set of interventions to support development and sustain the gains of the previous phases. Table 6.1 attempts to represent this process by dividing the first 20 years of life into five phases of physical, behavioral, and emotional development.

The age ranges selected are indicative and simplified; at the population level the phases will each cover a broader range and they will overlap. Middle childhood arguably begins before age five years, but beginning at age five years helps alignment with formal education practice. Middle childhood is also not entirely separable from adolescence, and for many children incorporates an initial period of juvenility followed by the early beginnings of pubertal processes. Similarly, many of the health risks of middle childhood—especially around infectious disease—persist into early adolescence, so that during the adolescent growth spurt phase the school age and the adolescent packages are both relevant. Finally, the end point at age 20 years is a widely accepted marker of the transition from adolescence to adulthood, hence the social and legal importance of the

Figure 6.2 Indicative Rate of School Enrollment in Low- and Middle-Income Countries



Source: Adapted from World Bank 2011.
Note: ECD = early childhood development; ECE = early childhood education.

Table 6.1 Key Phases of Child and Adolescent Health and Development

Phase	Period	Developmental importance	Examples of interventions	Packages
The First 1,000 Days	Ages 9 months to 2 years	The most rapid growth of body and brain; underpins all subsequent development; highest risk of mortality	Maternal, reproductive, newborn, child health (see volume 2); responsive stimulation	RMNCH (volume 2): Packages on maternal and newborn health and on child health
Middle Childhood Growth and Consolidation	Ages 5 to 9 years	Steady physical growth of body while sensorimotor brain function develops; nontrivial risk of death; some catch-up growth possible	Infection control, diet quality, and promotion of healthy behaviors and well-being	The school-age package
Adolescent Growth Spurt	Ages 10 to 14 years	Rapid physical growth, attaining growth velocities not seen since age 2 years, and rapid growth of centers for emotional development; main phase for remedial catch-up growth	Age-appropriate variants on above, plus vaccination, structured physical exercise, and promotion of healthy emotional development	The school-age and adolescent packages
Adolescent Growth and Consolidation	Ages 15 to 19 years	Consolidation of physical growth and especially of links in the brain; risk-taking behavior associated with socioemotional development; last chance for remedial growth in height	More focus on reproductive health, incentives to stay in school, protection from excessive risk taking, and early identification of mental health issues	The adolescent package

Note: RMNCH = Reproductive, Maternal, Newborn, and Child Health.

twenty-first birthday, but it is now recognized that significant late-stage adolescent changes continue through to the mid-twenties.

Table 6.1 also indicates the packages of interventions that can be developed to respond to the specific needs of each phase of development.

OVERVIEW OF SECTION 2 OF THIS VOLUME

The following chapters in this section expand on the this discussion of intervention and the life course and are based on the conceptual framework illustrated in figure 6.1.

- Chapter 7 in this volume (Alderman and others 2017) examines in more detail the timing of investments and provides equity arguments for investment in those children who were disadvantaged in the investments received before age five years.
- Chapter 8 in this volume (Watkins and others 2017) explores the issue of the irreversibility of early insult by asking whether catch-up is possible for children whose physical or cognitive growth has been limited in the first 1,000 days.
- Chapter 9 in this volume (Viner, Allen, and Patton 2017) explores age-specific adolescent development.
- Chapter 10 in this volume (Grigorenko 2017) provides a more detailed explication regarding brain development.

REFERENCES

Alderman, H., J. R. Behrman, P. Glewwe, L. Fernald, and S. Walker. 2017. "Evidence of Impact of Interventions on Growth and Development during Early and Middle Childhood." In *Disease Control Priorities* (third edition): Volume 8, *Child and Adolescent Health and Development*, edited by D. A. P. Bundy, N. de Silva, S. Horton, D. T. Jamison, and G. C. Patton. Washington, DC: World Bank.

Black, R., R. Laxminarayan, M. Temmerman, and N. Walker. 2016. *Reproductive, Maternal, Newborn, and Child Health*, volume 2 in *Disease Control Priorities* (third edition), edited by D. T. Jamison, R. Nugent, H. Gelband, S. Horton, P. Jha, R. Laxminarayan, and C. N. Mock. Washington, DC: World Bank.

Bundy, D. A. P., N. de Silva, S. Horton, G. C. Patton, L. Schultz, and D. T. Jamison. 2017. "Child and Adolescent Health and Development: Realizing Neglected Potential." In *Disease Control Priorities* (third edition): Volume 8, *Child and Adolescent Health and Development,* edited by D. A. P. Bundy, N. de Silva, S. Horton, D. T. Jamison, and G. C. Patton. Washington, DC: World Bank.

Casey, B. J., R. M. Jones, and T. A. Hare. 2008. "The Adolescent Brain." *Annals of the New York Academy of Sciences* 1124: 111–26.

Dahl, R. E. 2004. "Adolescent Brain Development: A Period of Vulnerabilities and Opportunities." Keynote Address. *Annals of the New York Academy of Sciences* 1021: 1–22.

Goddings, A.-L., K. L. Mills, L. S. Clasen, J. N. Giedd, R. M. Viner, and others. 2014. "The Influence of Puberty on Subcortical Brain Development." *NeuroImage* 88: 242–51.

Grigorenko, E. L. 2017. "Evidence on Brain Development and Interventions." In *Disease Control Priorities* (third edition): Volume 8, *Child and Adolescent Health and Development*, edited by D. A. P. Bundy, N. de Silva, S. Horton, D. T. Jamison, and G. C. Patton. Washington, DC: World Bank.

Heckmann, J. J. 2011. "Effective Child Development Strategies." In *The Pre-K Debates: Current Controversies and Issues*, edited by E. Zigler, W. S. Gilliam, and W. S. Barnett. Baltimore, MD: Paul H. Brookes Publishing.

Martorell, R., L. K. Khan, and D. G. Schroeder. 1994. "Reversibility of Stunting: Epidemiological Findings in Children from Developing Countries." *European Journal of Clinical Nutrition* 48: S45–57.

Patton, G. C., S. M. Sawyer, J. S. Santelli, D. A. Ross, R. Afifi, and others. 2016. "Our Future: A *Lancet* Commission on Adolescent Health and Well Being." *The Lancet* 387 (10036): 2423–78.

Steinberg, L. 2007. "Risk Taking in Adolescence: New Perspective from Brain and Behavioral Science." *Current Directions in Psychological Science* 16: 55–59.

Tanner, J. L. 1990. *Fetus into Man: Physical Growth from Conception to Maturity*. Cambridge, MA: Harvard University Press.

Viner, R. M., N. B. Allen, and G. C. Patton. 2017. "Puberty, Developmental Processes, and Health Interventions." In *Disease Control Priorities* (third edition): Volume 8, *Child and Adolescent Health and Development*, edited by D. A. P. Bundy, N. de Silva, S. Horton, D. T. Jamison, and G. C. Patton. Washington, DC: World Bank.

Watkins, K., D. A. P. Bundy, D. T. Jamison, G. Fink, and A. Georgiadis. 2017. "Evidence of Impact of Interventions on Health and Development during Middle Childhood and School Age." In *Disease Control Priorities* (third edition): Volume 8, *Child and Adolescent Health and Development*, edited by D. A. P. Bundy, N. de Silva, S. Horton, D. T. Jamison, and G. C. Patton. Washington, DC: World Bank.

World Bank. 2011. *World Bank Group Education Strategy 2020*. Washington, DC: World Bank.