Sleep Behavior and Sleep Regulation from Infancy Through Adolescence

Normative Aspects

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KEYWORDS

• Normal sleep behavior • Sleep regulation • Sleep homeostasis • Circadian • Variability

KEY POINTS

- This article (1) describes normal sleep patterns in children and adolescents, (2) depicts sleep stages and sleep electrophysiology in children, and (3) identifies changes in sleep-wake (homeostatic) and circadian regulatory processes across early human development.
- Three basic principles should guide our consideration of sleep during childhood and adolescence: first, sleep patterns exhibit large variability among children; second, sleep behavior must be viewed within a biopsychosocial framework; and third, sleep may provide undisturbed insights into the developing brain.

INTRODUCTION

Biologic determinants of sleep and the ways in which sleep biology and environment interact play major roles in establishing behavioral and developmental norms and expectations regarding normal and problematic children's sleep.[1] Although the primary role of social, family, and cultural systems on children's sleep behavior are recognized, less is known about the physiologic and the bioregulatory nature of children's sleep. This article (1) describes normal sleep patterns in children and adolescents, (2) depicts sleep stages and sleep electrophysiology in children, and (3) identifies changes in sleep-wake (homeostatic) and circadian regulatory processes across early human development. Jenni and LeBourgeois[2] provided a conceptual framework for understanding and predicting sleep-wake patterns in infants, children, and adolescents. This article summarizes the research on sleep-wake mechanisms during development in the context of the 2-process model of sleep regulation, which was first articulated by Borbély[3] in 1982. The article also highlights another line of recent research the undisturbed recording of cortical activity during children's sleep, which may be a useful tool to study aspects of brain maturation, function, and morphology during development.

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Three principles should guide our consideration of sleep during childhood:

- All aspects of children's sleep exhibit large variability among individuals and across cultures.
- Sleep behavior in children must be viewed within a biopsychosocial framework. Although sleep structure, organization, and regulation are primarily governed by intrinsic biologic processes, children's sleep is also shaped by cultural values, parental beliefs, and regulation of social systems.
- Sleep may provide undisturbed insights into the developing brain.

DEVELOPMENTAL PATTERNS OF HUMAN SLEEP BEHAVIOR

Newborn Period and Infancy

The sleep of newborns is distributed equally across day and night (**Fig. 1**). However, in the first few months of life, infants gain the ability to sustain longer episodes of sleep and waking[4,5]; as sleep becomes more and more consolidated toward the nighttime, nocturnal sleep duration increases, and daytime sleep declines (**Fig. 2**).[6] Although consolidated nocturnal episodes of sleep generally do not occur before 6 weeks of age, day-night differences in rest-activity behavior may be observed as early as in the first days of life in some babies.[7] The development of the 24-hour rhythm in sleep-wake behavior during infancy is driven by the emergence of both circadian and homeostatic sleep-wake processes (discussed later) as well as by parental daily activities (eg, feeding patterns). Most infants eventually begin sleeping through the night by the age of 6 to 9 months (ie, between 6–8 hours of nocturnal sleep without signaling).[8–10] A consolidated sleep episode throughout the nighttime is considered a major developmental milestone and is a central topic of infant care. In more than 70% of health supervision visits, infant sleep issues are discussed between parents and health care professionals.[11]

The average total sleep duration remains constant across the first year of life (see **Fig. 2**, mean 14 hours per day), although the most prominent feature of infant sleep is the large variability of sleep amount among individuals.[6] For example, at age 6 months, one infant may sleep as little as 10.5 hours, and another as much as 18 hours each day (at this age, the infant in **Fig. 1** slept 11.7 hours). This interindividual variability of sleep duration is never larger than in infancy (average standard deviation [SD] ± 1.9 hours during infancy compared with ± 0.8 hours SD from age 1–10 years), reflecting differences in the maturational tempo of early sleep-wake and circadian organization, although accuracy of parental observations and reports may also influence this apparent variation among the youngest children.

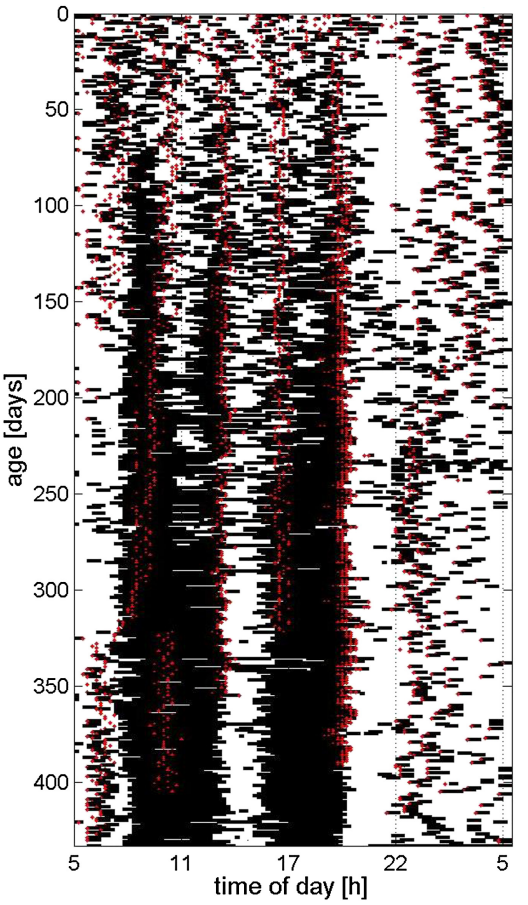

Fig. 1. Sleep-wake diurnal pattern across the first 425 days after birth in a healthy male infant recorded by daily sleep logs. Black and white areas represent waking and sleep, respectively. Red circles show feeding episodes.

Early Childhood

Although the large differences of sleep duration among individuals remain a typical characteristic of children's sleep behavior, the decrease of the sleep length across early childhood (as a consequence of the reduction of daytime naps) becomes most obvious.[6] Nearly all children stop routine daily napping between the ages of 3 and 5 years, even though large cultural differences exist.[12] Furthermore, night wakings remain a common issue in toddlers/preschoolers and may be considered a typical developmental phenomenon (20% wake up at least once each night,