ENCYCLOPEDIA
on Early Childhood
Development

Organization and Development of Sleep in Early Life

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December 2020, 2e éd. rév.

Introduction

Our understanding of the development of sleep patterns and behaviours in human infants and young children has advanced significantly since the 1950s, when polysomnographic (PSG) recordings first described the neurophysiology and organization of rapid eye movement (REM) and non-rapid eye movement (NREM) sleep states.[1,2] Today, in the U.S., standards of practice, official nosologies and certification processes have been established. The American Academy of Sleep Medicine certifies clinical laboratories and the technicians who record sleep, and the American Boards of Internal Medicine, Pediatrics and Psychiatry/Neurology have collectively agreed to certify board eligible clinicians in a new sub-specialty, Sleep Disorders Medicine. A pediatric section of the Associated Professional Sleep Societies (APSS), the national professional organization of sleep specialists, held its first scientific meeting in 2005 and has met annually ever since.

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How is sleep measured? Polysomnography remains the “gold standard,” recording a number of psychophysiological systems: peripheral muscle tone (electromyogram, EMG) from sub-mental muscles, horizontal and vertical eye movements (electrooculogram, EOG) from electrodes placed peri-orbitally, the electroencephalogram (EEG) from an array of scalp electrodes, and cardiac, respiratory and peripheral motor activity from thermistors placed around the chest, airway and limbs. Eye movement, muscle tone and EEG patterns are the primary parameters used to score REM and NREM sleep states. Patterns of obstructed breathing, heart rate irregularity and episodic behaviours, including limb movements, are associated features useful in diagnosing specific sleep disorders.

The EEG pattern during REM sleep is low voltage, fast, resembling the EEG of wakefulness, the EMG pattern is inhibited and the EOG is characterized by bursts of vertical and horizontal saccadic eye movements. Heart and respiratory rates are rapid and irregular. In REM sleep, neuronal firing, neurotransmitter release and uptake, and metabolic rates also resemble patterns of waking. Mental activity during REM sleep is present and is reported as dreams. Thus, during REM sleep, an individual appears asleep, but for the most part the central nervous system is highly activated. In infants, REM sleep has been called Active Sleep.

In contrast to the psychophysiological activation of REM sleep, NREM sleep is characterized by more basal, organized patterns of physiological inhibition. Both respiratory and heart rates are slowed and more regular. The EEG is synchronized with specific slower frequency waveforms. In infants NREM sleep is also called Quiet Sleep. The EEG of Stage 1 NREM sleep resembles the tracing of REM sleep; however, respiratory and heart rate patterns are regular, and saccadic eye movements are absent. The EEG of stage 2 NREM sleep contains K complexes and sleep spindles . Stages 3 and 4 NREM sleep have varying amounts of slow, high-voltage synchronized delta waves. In newborns, only two sleep states – REM sleep and NREM sleep – can be distinguished. By 6 months of age, the specific EEG waveforms that are used to sub-classify the four stages of NREM sleep have emerged.

In human newborns, REM sleep occupies 50% of total sleep time.[3] REM and NREM sleep states alternate with each other in sleep cycles that recur periodically through the sleep period approximately every 50 minutes. In the neonatal period, sleep begins with an initial REM period, and each sleep cycle includes as much REM sleep as NREM sleep. No early- and late-night differences in REM-NREM sleep distributions are found. The shift in the temporal organization of states during the course of a night's sleep, which begins in the second month of life, reflects the

maturation of internal central nervous system timing mechanisms.[4] That is, biological clocks mature to regulate both the ultradian and circadian control mechanisms that result in sleep-wake state consolidation. REM sleep decreases proportionately as NREM sleep increases, and NREM Stage IV sleep moves to the first third of the sleep period as REM sleep becomes more prominent during the last third of the sleep period.[5-9] The circadian sleep-wake cycle changes from a polyphasic rhythm during the newborn period to a diurnal rhythm by 4-6 months of age, as sleep consolidates to the nighttime, and waking, except for 1-2 brief daytime naps, consolidates in the daytime.[10-12] The morning nap is usually given up in the second year of life and the afternoon nap in the third to fourth year of life.[9,13] Only recently have we begun to understand how these early biological developmental changes are affected by family, cultural and psychosocial influences.

Subject

Parental concerns about sleep in young children are common.[14,15] During the first year of life, parents often are most concerned about issues related to consolidation. That is, concerns about irregular napping and frequent and prolonged night waking. During the toddler period, concerns may shift more to behaviours that resist sleep. That is, concerns about going to bed at an appropriate time and falling asleep quickly and easily. They ask, “What is normal? What is to be expected? How will my child’s development be affected?” A large literature addresses these issues but relatively little is known about their origins.[16-21] Does the infant who awakens and cries regularly during the night, or the toddler who can’t fall asleep easily, become sleep deprived with subsequent developmental and/or behavioural consequences? Or, are these behaviours more distressing for the parent, especially the working parent, exhausted by repeated late evening and/or middle-of-the-night ministrations to their child? How long should these behaviours be tolerated? What should be done?

Research Context

Answers to the above questions about sleep are studied by several methods: polysomnography (traditionally in the laboratory, but now also in the home); actigraphy (usually in the home), videosomnography (usually in the home), and parent-report instruments such as sleep logs, sleep diaries and structured questionnaires. Often, many of these methods are used simultaneously.[22-25] Automated scoring algorithms for actigraphic recordings and, more recently, for video recordings make these methods popular as both clinical and research tools.[26,27] The actigraph may be worn for the entire 24-hour day, recording all of the subject’s sleep-wake activity. In

contrast, the video camera records only the sleep and waking behaviour in bed. However, the video camera also records the contextual variables associated with going to bed, falling asleep and waking during the night. The more comprehensive research context for understanding the unfolding of infant sleep-wake patterns in early development utilizes a transactional model that assesses several of these multiple factors that impact the parent-child relationship.[28,29] Proximal influences on the relationship include the primary caregiver's current state of physical and psychological well-being, the primary caregiver's own childhood experiences of being parented, including their experiences around sleep, current social support networks, the family's economic and household condition, and the infant's temperament and physical health. Stressors, such as infant physical illness or maternal depression also serve as proximal factors that directly impact parent-child interaction and the child's sleep. How the young child falls asleep (alone, being rocked by a parent, with a pacifier, etc.) and the parental behaviours surrounding night wakings (time to response, promotion of self soothing, etc.) all affect the consolidation of sleep. More distal factors in the transactional model include the broader cultural context and belief systems of the family and more indirect environmental influences.[30-33]

Key Research Questions

Questions for further research far outnumber answers currently available. Which of the several methods of measuring sleep in these young populations is most suited? How should the problems of concordance between different recording methods be resolved?[22,24,34,35] Is sleep organized differently in children with clinical disorders, especially neurodevelopmental disorders, than in typically developing children? Are the structured instruments and parent questionnaires valid for children with medical disorders? Large-scale, cross-cultural, population-based, longitudinal epidemiologic studies are essential if professionals are to advise parents about what the range of "normal" sleep behaviours are for a particular age group of children.[36,37] How are such studies to be mounted? Is co-sleeping salutary or harmful for the infant's health, physical well-being and autonomous development? What kinds of treatment (behavioural, psychopharmacologic, psychotherapeutic) should be employed and when? Which, if any, infant, parent or psychosocial factors optimizes sleep behaviour? What is the relationship between nighttime sleep disruption, daytime sleepiness and daytime behavioural disruption? What are the long-term implications of chronic sleep disturbances in early childhood?

Recent Research Results

There is a strong association between parent-infant interaction around sleep and the emergence of infant sleep behaviours. Parents who actively rock or hold their infant until asleep (i.e., more involved in settling their infant to sleep), in contrast to parents who allow their infants to fall asleep on their own, have infants who present more night waking problems.[38,39-41] These associations might result from a direct effect of parental behaviour on infant sleep or from infants with difficult temperaments who demand more parental involvement during the night.[42]

The important role of parents has been established by prevention studies that have demonstrated that changing parental knowledge about infant sleep prior to the child's birth can promote better sleep.[43,44] Moreover, clinical studies on behavioural interventions for clinical management of sleep problems have demonstrated that using parents as the primary interveners produces reliable and durable changes in infant sleep. Specifically, it has been shown that an infant's sleep can improve dramatically when parents succeed in reducing their bedtime and nighttime involvement.[45,46] Thus, it is important to recognize that in early childhood, sleep behaviours may be specific to a particular relationship or setting. A child may nap at the daycare center but not at home (or vice-versa), or a child may fall asleep more easily when the babysitter puts the infant to bed than when the parent does (or vice-versa). Sometimes, infants and young children's sleep behaviours present differentially with mothers and fathers.

Many studies have reported that sleep disturbances in young children are fairly persistent and may be related to earlier sleep patterns. A recent study described the persistence of sleep problems from 12 months of age to 4 years in 12% of a sample with mostly night waking problems.[47] It has been reported that sleep problems tend to persist in up to 30% of children studied to 8 years of age.[48]

Studies in school age children suggest that nighttime sleep disruption may affect daytime behaviour, particularly with problems of irritability, hyperactivity and attention,[47,49-51] marital disruption and increased environmental stress.[52,53] A study in preschool children examined sleep patterns from parent diaries and reported that variability in amount of sleep, in bedtimes and in lateness of bedtime predicted less optimal adjustment in the preschool.[54] As expected, improvements in sleep with a therapeutic intervention with toddlers were associated with improvements in daytime behaviour.[55]

Conclusions

Sleep plays an important role in development, and patterns that develop early may persist with subsequent behavioural consequences. It is important to understand the complex array of biological and psychosocial factors that transact on the path to healthy sleep. Much more research is needed.

Implications for Policy and Service

Understanding how sleep develops normally, what factors promote healthy sleep and how sleep disorders emerge, is a lifespan issue of significant scope. The public health and economic burdens of disturbed sleep are staggering. Road fatalities related to sleepiness, especially when coupled with alcohol/drug use are crippling. Work-related injuries and work-related errors (particularly in the health professions) related to sleep loss and daytime sleepiness are also serious. In childhood, disorders such as attention deficit hyperactivity disorder and behavioural disruptions in autism, traumatic stress disorder and depression are often associated with underlying sleep disorders. Children with fragmented or insufficient sleep may exhibit learning, retention and recall problems in school. They may be less able to inhibit emotional responses and, thus, be prone to impulsive or violent outbursts. Finally, in young infants and toddlers, disrupted and/or problematic sleep is a stress on the entire family. Child abuse may result as the worst-case scenario; parental inability to function appropriately at work (especially two working parents) may result as the best. The costs of disordered sleep to society, to the healthy development of children, and to the well being of families are huge. Early exposure to good sleep hygiene is an imperative.

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