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REVIEW ARTICLE

Developmental Implications of Sleep

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ABSTRACT

This review attests to the fact that the connections between sleep and developmental issues including cognitive, developmental and emotional domains in early-to-late childhood are more complex than as reflected in early writings. In the face of broad and multifaceted nature of the fact, this work is relatively concise in coverage. Research has indicated significant changes from birth to early-childhood in sleep characteristics in terms of sleep patterns and sleep duration. Children show significant variation in their sleep characteristics as a function of environmental conditions and internal factors such emotional states or physical conditions. The qualitative and quantitative changes in sleep patterns during the early-childhood appear to be occurring in consonant with developmental features and implicated in cognitive, behavioral and emotional development of child. Even though the number of studies in children and adolescents is scarce, the associations between trouble sleep and emotional dysregulation have consistently reported that persist from childhood into early- to mid-adolescence. This review addresses three topics with regards to the importance of sleep in the childhood: i) characteristics of sleep and alteration in these characteristics from infancy to early childhood including development of more complex structures resemble adult sleep and consolidation of sleep wake cycle accompanied by quantitative changes in daytime naps and nighttime sleep; ii) associations between sleep and developmental domains, particularly cognitive and emotional development; and iii) importance of healthy sleep habits and sleep hygiene. The empirical evidence and theoretical considerations within the literature are refined and discussed herein.

Keywords: memory, emotional regulation, development, infant sleep, REM sleep, non-REM sleep

INTRODUCTION

Of 24-hour period a day, an average child spends more time asleep relative to all wakeful activities by the age of 3 years (Dahl, 1998). Sleep requirements including daytime and nighttime sleep are admittedly the highest during in the first three months of the newborn. Developmental studies also suggest that the time period also includes individual differences in diurnal variation and the development of sleep-wake rhythmicity during which sleep becomes more consolidated to nighttime by the end of the age three months, commensurate with formation of circadian rhythm (Burnham, Gaylor, & Anders, 2006). Although the total time spent in nocturnal sleep have gradually increases over the first three years, the total amount of 24-hour sleep decreases as with the decline in the amount of daytime sleep encompassing a number of naps in this period of the infancy. Beyond the first six months, total sleep time decreases to 14-15 hours a day by 18 months. During the toddler to preschool,

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daytime sleep is given up while nigh-time sleep remains constant (Ferber, 2006; Sheldon, 2014).

Not only do the quantitative sleep characteristics change but also the sleep pattern, in effect, reveals distinct features from the adult's typical sleep pattern and substantially varies from early infancy to toddlerhood. Sleep in neonates partitions from indeterminate patterns: active (rapid eye movement (REM) sleep) and quiet sleep (non-REM sleep). Infant sleep pattern is marked by oscillations between these two qualitatively distinct sleep phases. Active sleep, which resembles of that REM-sleep is characterized by more tense muscle tone, eyelid fluttering, irregular breathing, and rhythmic startles. Quiet sleep, which resembles of that non-REM sleep is characterized by regular breathing, not eyelid fluttering, and little movement (Blumberg, Karlsson, Seelke, & Mohns, 2005).

Sleep pattern in adulthood shows different characteristics that slow-wave-sleep (SWS) comes at the outset, and the REM sleep occurs in the eventual part of each sleep cycle, with a total sleep cycle lasting about 90-100 minutes. Contrarily, newborn falls into a light sleep state known as active sleep (REM-sleep) during which newborns can easily awake and likely to be dreaming, remains for 25 minutes or more after which newborns pass to a deeper sleep state to be less likely to awaken, known as quiet sleep (non-REM sleep) (McNamara, Lijowska, & Thach, 2002). However, a proportion of sleep time could not be precisely attributable to either of these sleep patterns rather is accordingly classified as indeterminate. Furthermore, those of newborn spend as much as 75% of total sleep time a day in active sleep (Poblano, Haro, & Arteaga, 2008; Sadeh, Dark, & Vohr, 1996). The proportion of active sleep gradually falls over the first few months after birth to around 25% of total sleep time that approaches to adult proportion. At around 3 months of age, non-REM sleep predominates to earlier stages of sleep, and active sleep becomes more organized into later parts of the sleep cycle. Contrarily to activity seen in the active sleep before, inhibition to muscle tone in the REM cycle as per adult sleep occurs at around 6 months of age. Continuous sleep gradually lengthen and consolidated into night sleep over the first year of newborn during which total sleep has diminished from 18 hours a day at term to 15 hours a day (Ficca, Fagioli, & Salzarulo, 2000).

Sleep is defined as a state of immobility accompanied by decreased responsiveness and the body tries to recover –so called as rebound effect- the lost amount after deprivation, which can be interpreted as that it is not simply a period of reduced alertness (Siegel, 2005a). In comparison to food deprivation, sleep deprivation may be more fatal in some species (Rechtschaffen, 1998), and neuronal activity during REM sleep exceeds those which occur during most waking states (Maquet et al., 2004). The sleep-wake cycle in human beings is mainly governed by two systems: homeostatic and circadian. The latter entrains the rest-activity cycle of the body to exogenous environmental cues; the sleep-dark cycle is recognized as having a crucial role in circadian rhythmicity through suprachiasmic nucleus. The endogenous clock of humans is close to a 25 hours period entrained to 24 hours according to environmental cues, so-called zeitgebers. Despite some evidence point out that fetal functions may have a premature circadian rhythm synchronized to maternal rest-activity cycles (Lunshof et al., 1998; Rivkees, 2003), there is a gradual maturation of circadian rhythmicity over the three-month period after birth, which leads to a differentiation in the day-night cycle of behavior and physiological activity (Rivkees, Mayes, Jacobs, & Gross, 2004).

The sleep in human beings is more than simply a passive process governed by cyclical changes and the need for two phases of sleep in the early-childhood gives cause for speculations with respect to the functions of sleep. The infant brain goes on developing rapidly during the first three months of birth with going into a plateau in development thereafter. In this period, REM sleep predominates and progressively reduces as a proportion. Notably, an enriched milieu increases the size of neocortex and the number of synaptic connections in newborn rats; however, the process was impeded in large as the REM sleep was deprived by using medication. These deprived rats showed greater anxiety and impaired sleep (Mirmiran et al., 1983; Mirmiran, Vandepoll, Corner, Vanoyen, & Bour, 1981).

The REM sleep over activates the visual system of the brain which can be suggestive of that keeping the visual system active through REM sleep appears to be essential to brain development and plasticity, particularly in newborns (Marks, Shaffery, Oksenberg, Speciale, & Roffwarg, 1995).

The strong inverse association between body size and total sleep duration is suggestive of the role of sleep in oxidative stress. Transition between sleep and wake states during the nighttime sleep is thought to be associated with hemeostasis (e.g., hunger) and development of self-regulation (e.g., emergence of secure attachment) (Anders, Goodlin-Jones, & Sadeh, 2000; Goodlin-Jones, Burnham, & Anders, 2000). In comparison to adult sleep cycles, much shorter sleep cycles lasting about 50 minutes, largely compromised of light sleep lead to a tendency to awaking much more easily and frequently. Infants are more receptive to arousal in active sleep that tentatively functions as a preventive factor for sudden infant dead syndrome (Kato et al., 2003) and seems to serve to brain development; contrarily, quiet sleep seems to be central in physical restoration and memory consolidation, even though the functions of sleep still remain speculative (Heraghty, Hilliard, Henderson, & Fleming, 2008; Siegel, 2005b). Neocortical maintenance and energy conservation as well as immune function is thought to be potential by-products of the quiet sleep in the infancy which is isomorphic to slow wave sleep phases in adults (Bryant, Trinder, & Curtis, 2004).

REM sleep is marked by great neuronal activity and is the sleep phase generally defined by preponderance of vivid dreams. REM sleep is also characterized by states of consciousness most reminiscent to wakefulness and most likely to be associated with hyper-associative thinking (McCarley, 2007; Van Der Kloet et al., 2013). This phase occupies one-fifth of the total amount of sleep in adults, a relatively small proportion compared to infant sleep. In comparison to adulthood, the increased proportion of infant REM sleep is linked to immaturity at birth and convincing evidence strongly support the premise that the REM sleep is implicated in neuronal development and plasticity in the brain (Graven, 2006; Siegel, 2005b). Memory and learning functions of sleep are more commonly associated with REM sleep, particularly in memory consolidation (Hill, Hogan, & Karmiloff-Smith, 2007; Siegel, 2001).

Although a prominence has been placed on brain stem in regard to the systems deemed to modulate sleep, daytime behaviour regulation is more likely to be linked to neocortex. Three lines of research have focused on distinct features of neural systems particularly involved in sleep and waking behaviours, albeit almost all were conducted among adults (Beebe, 2008). It has been well-established that prefrontal cortex is unusually sensitive to sleep deprivation (Durmer & Dinges, 2005; Goel, Rao, Durmer, & Dinges, 2009; Harrison & Horne, 2000; Selvi, Gulec, Agargun, & Besiroglu, 2007). Severe attention deficits are observed in sleepy adults that give credence to the research interest on implications of prefrontal cortex that is extended to the parietal lobes in the attention process (Mazza et al., 2005; Palm, Persson, Bjerre, Elmqvist, & Blennow, 1992). Finally, recent research on memory has pointed out the linkages of sleep deprivation to hippocampal regions (Ellenbogen, Payne, & Stickgold, 2006; Stickgold & Walker, 2007). The development of prefrontal cortex has a prolonged period of maturation process extending through ten years of age, sensitivity of this region to sleep deprivation could have more substantial implications in children and adolescents (Dahl & Lewin, 2002).

Sleep and Brain Development

Sleep cycles are essential to the development of neurosensory and motor systems as well as underlying neural circuitry of memory systems in the fetus and neonate and maintenance of brain plasticity over the lifetime. Inversely considering, interference with the sleep cycles may result in severe disruption in cognitive and motor development. Sleep deprivation, particularly REM deprivation, in neonates and infants may create permanent deficits on development of neural circuitry of primary sensory systems: somatesthetic (touch), kinesthetic (motion), proprioseption (position) chemosensory (smell and taste), auditory (hearing), vision (seeing), limbic (emotion and social learning), and hippocampus (memory). (Penn & Shatz, 1999).

Preservation of sleep and sleep cycles are of vital importance for creation of primary systems in the fetus and neonates that REM sleep becomes consolidates at about 28 to 30 weeks' gestational age. REM sleep provides the endogenous stimulation prerequisite for development of long-term neural circuitry that forms basic structure of sensory cortex and brain stem nuclei (Graven & Browne, 2008).

Brain plasticity is essential to adapt to the environment and needs in person that refers to preservation of the capacity to change and learn in line with internal and external demands. Oscillations between REM and non-REM sleep are critical for the preservation of brain plasticity that is largely dependent on continual activation and certain growth factors (nerve growth factor, neurotropic factor and ubiquitin). These factors are responsible for producing a specific protein central to maintenance of long-term memory and the activation process is closely associated with REM sleep beginning in the late fetal stage (Graven & Browne, 2008). Graven (2006) proposed a three-stage architecture of sleep-related learning as to long-term memory consolidation process: acquisition phase, pre-consolidation phase and long-term storage phase. In the first phase of acquisition, a person creates short-term neuronal circuits in the neocortical brain areas in response to sensory input (i.e., objects or events) during wakefulness that are retained as long as repeated or intensely processed. The REM sleep is the crux of consolidation of sensory inputs and long-term memory storage stage that follows quiet non-REM sleep (pre-consolidation-second stage) in which initially encoded external inputs in the neocortical areas are processed, and unrelated information are eliminated. Briefly explained, sleep cycles are crucially implicated in the information processing that includes encoding in the neocortical areas while an individual awake, than transferring the encoded inputs to amygdala, hippocampus and parahippocampal areas for interpretation and elimination of redundant parts during the slow-wave sleep (non-REM sleep) and back transferring and long-term storage of processed inputs into the neocortical areas during REM-sleep.

Sleep Problems and Emotional Dysregulation

Studies have garnered consistent support on the link between sleep and emotional problems, albeit data have been collected from adult samples and such relations in children have received relatively less attention. As with the adult samples, investigations combining anxiety and depression have often reported substantial associations with a range of pediatric sleep problems (Gregory & Sadeh, 2012). Sleep problems bring out severe impairment in social, academic, cognitive, emotional and physical performance in as much as 25% to 40% of youth (Lofthouse, Gilchrist, & Splaingard, 2009; Meltzer & Mindell, 2008).

Proxy assessments with parents in two waves indicated that the magnitude of the linkages between trouble sleeping and anxiety/depression as young as 6 years of age progressively spread out through early-adolescence; those of children become to an age of 11 had greater risk of having anxiety/depression related to sleep difficulties in comparison to their childhood (Johnson, Chilcoat, & Breslau, 2000). As such, the magnitude of the connections was parallel in the mid-adolescence as compared to childhood (Gregory & O'Connor, 2002). Irrespective of sleep quality relations, anxiety scores were greater amongst whose parents reported bedtime resistance relative to non-resistant children (Gregory, Rijsdijk, Dahl, McGuffin, & Eley, 2006). Anxious children were more likely to go bed late and sleep less during weekdays on school nights; whilst those children revealed a strong rebound effect on weekends that they were falling asleep more rapidly and sleep longer than school days (Hudson, Gradisar, Gamble, Schniering, & Rebelo, 2009). With children and adolescents experiencing frequent nightmares, emotional difficulties were far more evident (Nielsen et al., 2000; Schredl, Fricke-Oerkermann, Mitschke, Wiater, & Lehmkuhl, 2009).

Sleep problems, irritability and self-destructive behaviours such as externalization are conceptualized as dysphoric states capturing severe impairment in emotional modulation and behavioral regulation (Kovacs et al., 2006). Sleep complaints are typical in depressive symptomatology rather than exception (Agargun et al., 2007). Considering children and adolescents, sleep impairments are prominent in the incidental cases with depression (Ivanenko, Crabtree, & Gozal, 2005). Several polysomnography studies of depression in children found that afflicted children had longer sleep latency, shorter REM sleep latency and longer REM sleep duration along with more frequent night wakings (Arana-Lechuga et al., 2008; Dahl et al., 1991). Using a cholinergic REM induction paradigm, Dahl et al. (1994) tested a developmental hypothesis that the children with major depression have similar underlying cholinergic change to adults with major depressive disorder. The results pointed out that, in comparison to controls, a shorter REM latency in children with major depression was typical which was suggestive of that those children with major depression have pre-existing abnormalities in their sleep architecture. A study similar study among adolescents with MDD also reported abnormal sleep patterns and suggested the incomplete maturation of cholinergic systems underlying REM sleep might be associated with depression in youths (McCracken, Poland, Lutchmansingh, & Edwards, 1997). In comparison to adolescents, using self-report measures, children with depression were less likely to have hypersomnia and reported less deterioration arising from sleep complaints (Alfano, Zakem, Costa, Taylor, & Weems, 2009; Ryan et al., 1987). Contrarily, using self-report assessment, such a discrimination as to associations between sleep impairment and depression could not be detected in comparisons between cases and non-cases of depression (Bertocci et al., 2005; Dahl et al., 1990; Puigantich et al., 1982).

Development of social skills has monumental importance during the transition from early to late-childhood. Youths, aged 8 to 11, who had social phobia and separation anxiety reported greater sleep disturbances (Gregory & Eley, 2005). Moreover, it was reported that sleep difficulties seem to be a co-occurring condition accompanying to types of anxiety problems in the childhood in which these relations become more specific during adolescence that morbidity of certain types of anxiety disorders as generalized anxiety, panic attacks and social anxiety disorders are more likely to be occurred alongside with sleep difficulties (Alfano et al., 2009). Further studies have a more specific focus and suggested a distinction between anxiety disorders in children in regard to the substantial links to sleep disturbances, but the findings were not unequivocal (Alfano, Beidel, Turner, & Lewin, 2006; Alfano, Ginsburg, & Kingery, 2007). Short amount of sleeping and poor sleep quality have consistently tied to externalization behaviours in children (Aronen, Paavonen, Fjallberg, Soininen, & Torronen, 2000; Chervin, Dillon, Archbold, & Ruzicka, 2003; Goodnight, Bates, Staples, Pettit, & Dodge, 2007) rather than adolescents (Moore et al., 2009) that emotional regulation deficits in relation to sleep disturbances may be reflected as behaviour difficulties in children.

It was indicated that, even though the studies were scarce in number, such associations seem to be influenced by chronological age. An account for the fact may be that the range of variation in sleep habits are more likely to be observed in early ages as well as impairments in sleep can be attributed to developmental characteristics. Therefore, sleep complaints typical in early ages appear to be more easily compensated by children and less likely end up with affective problems. However, in comparison to adolescents, sleep seems to have more rigorous relations with behavioural problems in children that may tentatively arise from emotional dysregulation. Additionally, there appears to be a distinction between assessment modality that a great proportion of the investigations have utilized parent or teacher forms of proxy measures as well as self-report measures in sleep studies amongst children and adolescents. A well- established difference between subjective sleep quality and objective sleep quality points out that subjective experiences of sleep can well differentiate from objective assessments of sleep (Edinger et al., 2000; Espie, 2002). Reported differences as well as failed discriminations in relations with sleep as to developmental periods may substantially be associated with the assessment approach in terms of subjective or objective assessment procedures. Despite the mixed findings, sleep seems to be critical in behavioral and emotional development that reciprocal relations between emotional and behavioral regulation and sleep variables in developmental periods requires far more attention and should be warranted.

Developing Healthy Sleep Habits in Children

Sleep routines in children significantly varies. The bedtime rituals encompass all activities that occur as your child prepares for bed or while he or she fall asleep. The sleeping child may be swaddled or clothed; may sleep in his own room or share a room with his or her siblings; may fall asleep nursing at the breast or sucking on a bottle. A child may go to bed at times with no routines or may follow an exact schedule each night. Routines seem to differ due to families and cultures, but not all routines work equally well (Ferber, 2006).

Even though scholars place prominence on some bedtime rituals, there are few absolute rules and if routine of caregivers is working, in person, and child falls asleep easily with less frequent night awakings then it would be fine. For example, if the caregiver have the habit of rocking her child or rubbing child's back to sleep for approximately half an hour each night, it would tentatively be repeated the ritual once or more along the night to get the child asleep. Infant may be awake when put down on bed and she falls asleep on her own. These patterns of sleep practices can be regarded as fine in the first few months. But if an infant have more night awakings (e.g., more than two or three times a night) by about three months of age or if she still has not settled night sleep by five or six months of age, the sleep routines should be more thoroughly analyzed (Ferber, 2006).

Following the same routines as consistently as possible is placed emphasis in sleep programs. The child should be aware about what routines and how long does each routine (such as tooth brushing, bedtime activities) take time. Bedtime is often a time of separation anxiety and mapping out something special with the child for as much as thirty minutes would be helpful in soothing him. Also overdose stimulation that excite child would end up a rise in alertness and interfere with fall asleep easily. Good sleep hygiene practices such as falling asleep independently, a judicious bedtime before 9.00 PM, an established bedtime routine, and sleeping in bedrooms are found to be antecedents of good sleep in youth and strongly recommended (Mindell, Meltzer, Carskadon, & Chervin, 2009).

Taken together the emphasized connections between sleep and cognitive, behavioral and emotional domains of development, even though these relations should be more profoundly unmasked and the potential mechanisms of mutual linkages should be defined in children adolescents, disturbance in one level may result in significant influences on other aspects of development prevailing to multiple aspects of functioning. On the other hand, simple prevention strategies such as sleep hygiene education to parents may tentatively prevent from later more adverse consequence of sleep problems and sleep-related dysregulations. The further developmental and contextual conceptualizations and empirical work ideally using prospective longitudinal design in regard to the relations between sleep and development are needed.

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Conflicts of Interest

The author does not declare any conflict of interest.

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