A Family Physician's Approach to Sleep Deprivation in Children

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ABSTR ACT

Sleep deprivation is not uncommon among children in Singapore. Children with deprived sleep may present with poor academic performance, learning disabilities and behavioural disorders. As a result of sleep deprivation, performance in complex tasks involving higher brain functions is affected more than simple memory tasks. Sleep quality rather than sleep quantity is associated with good cognitive learning and memory function. Regular sleep-wake patterns with good sleep schedules will reinforce this. Causes of sleep deprivation include insufficient sleep, fragmentation of sleep and increased need for sleep. The BEARS questionnaire is a useful screening tool for sleep deprivation. A clinical approach to exclude medical conditions that may cause excessive daytime sleepiness should be conducted and focused physical examination be performed. A two-week sleep log about the child's sleep habits and sleep-wake cycles should be recorded. Referrals to a sleep specialist should be made if any sleep disorders is suspected.

Keywords:
Sleep deprivation, learning and cognitive performance.

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INTRODUCTION

Sleep is not just simply rest. It is an active process[1]. The different aspects of sleep including the continuity, timing and pattern of different stages of sleep are necessary for restorative processes of the body to occur.[2]

In Singapore where academic excellence is of importance, sleep deprivation is common among school-going students. A survey conducted on 940 students in 28 secondary schools in 2007 revealed that only 2.6% of them were getting the recommended 9 hours of sleep. Up to 80% of the students were getting less than 8 hours of sleep a night.[3] This may be due to increasing demands of modern life on children.

A review is conducted on the causes and effects of sleep deprivation and the clinical approach to managing sleep deprivation in children.

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METHODOLOGY

A PubMed search was conducted in April 2011 with the following key words "sleep deprivation", "learning" and "cognitive performance". Citations that were relevant were shortlisted and the full text obtained for further study. Additional articles were retrieved through a manual search of reference lists in the shortlisted papers. A total of 64 articles were included in this review. The majority were observational studies.

SLEEP AND SLEEP DEPRIVATION

What is sleep?

During an average night's sleep, a person will experience about 4 or 5 cycles of sleep. One complete sleep cycle lasts about 90 to 100 minutes. Sleep is divided into Rapid Eye Movement (REM) sleep and non-REM (NREM) sleep. The sleep stages are measured by electroencephalogram (EEG), electro-myogram (EMG) and electro-occulogram (EOG).[4]

REM sleep has a role in memory consolidation.[5] REM sleep may be suppressed by alcohol, monoamine oxidase inhibitors, tricyclic antidepressants, stimulants, and some hypnotic/sedative drugs. Medications with prominent anti-cholinergic effects may also delay or suppress REM sleep.

NREM sleep represents the deepest sleep in humans and it has three stages. The first stage (N1) sleep is the transition from wakefulness to deeper sleep. It is the lightest stage of sleep. The second stage (N2) sleep, also known as intermediate sleep, is characterised by sleep spindles and k-complexes. The third stage (N3) sleep is frequently referred to as slow wave sleep[6].

Differences between a child and an adult sleep pattern [7,8]

During childhood, sleep is characterised by longer sleep duration, REM sleep and larger amount of slow wave sleep. The slow wave sleep gradually decreases as the child gets older. During this deep sleep (usually 1-3 hours after going to sleep) it is extremely difficult to arouse a child. When awakened at this time, the child often appears disorientated, confused and cognitively slow. Confused partial arousals including sleep-walking, talking and night terrors usually emerge from this state.

During puberty, there are some changes in the sleep regulation towards a more adult-like pattern of REM sleep. The number of arousals and wakefulness also increases with age. There is also an increase in daytime sleepiness and a shift in the circadian pattern towards a more owl-like tendency for later bedtimes and wake-up times.

Normal sleep requirement in children

Epidemiological studies have shown that total sleep duration decreased from an average of 14.2 hours at 6 months of age, to an average of 8.1 hours at 16 years of age. Consolidation of nocturnal sleep occurred during the first 12 months after birth. Subsequently there is a decreasing trend in daytime sleep. An average child of 2 years old would have spent a total of 10,000 hours asleep and about 7,500 hours in all waking activities combined.[9] The most significant decline in napping habits occurs between 1.5 years of age and 4 years of age.[10] From the age of 2 to 5 years, there will be an approximate even balance between sleep and wakefulness.

Learning and memory formation in sleep

There is a relationship between sleep, memory and learning capacity[11]. Sleep is important for consolidation of memory after learning and for efficient memory formation subsequently.[12] Pilcher et al [13] showed that sleep-deprived individuals functioned at a level that is comparable with the ninth percentile of non sleep-deprived individuals.

The human memory is divided into two main types - declarative and procedural memory. Declarative memory refers to memories accessible to conscious recollection ("knowing that"). Procedural memory comprises memories of how to perform specific skills ("knowing how"). These memories may be related to motor, visual or even verbal domains. They are usually unconsciously learned.[14]

Undisturbed sleep helps in formation of the declarative memory thereby improving retention rates.[15] This occurs in the early part of the nocturnal sleep.[16] The consolidation of the procedural memory occurs in REM sleep. This takes place in the late part of nocturnal sleep.[17,18] Improved motor performance skill is proportional to the duration of time spent in REM sleep.[19]

Both REM and NREM sleep are necessary for learning and memory. For an efficient consolidation of both knowledge (declarative) and skills (procedural), the worst enemy is sleep deprivation.[16] Some kind of "intentionality" has to be present at learning for later consolidation of the memories during sleep. A sleep-dependent gain in skill occurs only under intentional learning conditions.[20]

Sleep deprivation

Sleep deprivation exists when sleep is insufficient to support adequate alertness, performance and health. Acute sleep deprivation refers to no sleep or a reduction in the usual total sleep time, usually lasting one or two days. In contrast, chronic sleep deprivation exists when the individual routinely sleeps less than required for optimal functioning.

Sleep reduction affects metabolism of glucose. It also increases gherlin levels and decreases leptin production thus leading to increased risk of weight gain and obesity.[21] Sleep deprivation in patients with blocked nasal airway may also lead to hypertension and cardiovascular mortality. It is also observed that sleep-deprived children exhibit hyperactive attention deficit symptoms.[22] After sleep deprivation, performance in abstract and complex tasks involving higher brain functions declines more than in performance of simple memory tasks.[23]

Common Causes of Sleep Deprivation (Appendix 1)

The causes can be divided into three groups: [24]

i) **Insufficient sleep**
Insufficient sleep can be due to insomnias and circadian rhythm sleep disorders.

ii) **Sleep fragmentation**
This includes behavioural disorders, sleep-onset association disorders, respiratory-related disorders, movement disorders, parasomnias, medical causes (e.g., asthma, GERD, eczema) and environmental causes (light, noise, co-sleeping).

iii) **Increased need for sleep**
This includes temporary hypersomnolence, recurrent hypersomnolence and persistent hypersomnolence, neurologic disorders, medical disorders, drug-related, and narcolepsy.

Appendix 1: Common Causes of Sleep Deprivation

1. Insufficient Sleep
1a. Insomnia:
i) Adjustment
ii) Psycho-physiological
iii) Paradoxical
iv) Behavioural
v) Inadequate sleep hygiene
vi) Insomnia because of alcohol and medications
vii) Mental (depression, bipolar, ADHD)
1b. Circadian rhythm sleep disorders:
i) Delayed sleep phase syndrome
ii) Non-24-hour sleep-wake schedule
iii) Sleep entrainment difficulties
(blindness, developmental delay and mental retardation)
2. Fragmented Sleep
2a. Behavioural Disorders
2b. Sleep onset association disorder
2c. Sleep disordered breathing:
i) OSA
ii) Upper airway respiratory syndrome
iii) Hypoventilation

iv) Central sleep apnea
2d. Movement disorders:
i) Periodic limb movement
ii) Restless leg syndrome
iii) Bruxism
iv) Head banging
2e. Parasomnias:
i) Night terrors
ii) Sleep talking
iii) Sleep walking
iv) Confusional arousals
(asthma, eczema, seizures, noise, light, co-sleeping)

3. Increased Need for Sleep
3a. Head trauma
3b. Increased intracranial pressure:
i) Medical (infection, metabolic)
ii) Drug related (illicit drugs, medications)
iii) Recurrent hypersomnolence
iv) Narcolepsy (primary, secondary)

ROLE OF SLEEP IN LEARNING & MEMORY CONSOLIDATION

Evidence of how sleep deprivation affects learning

Sadeh et al did the first study that objectively measured sleep onset and daytime sleepiness using actigraphical monitoring devices. It was found that older children had more sleep fragmentation compared to younger children and they concluded that sleep loss is strongly associated with learning and attention deficits.[25]

Sleep schedules may affect the academic performance in students. Increased daytime sleepiness as a consequence of poor quality of sleep will impair students' cognitive function and behaviour. Studies have found that students with higher grades reported regular sleep-wake pattern with more total sleep.[26,27,28] There is an increase in problems of sleep onset, enuresis and night awakening in students with poor academic performance as compared to normal sleepers with higher grades.[29]

Difficulties in morning arousal and the need for afternoon naps are predictors of poor school achievements. Pilcher et al showed that reduction in total sleep for one night impaired the ability to complete cognitive tasks.[30] Students can lose up to 2 hours of sleep per night if there is early starting time of the school. Better neurocognitive performance in these students is seen in the afternoon than in the morning.[31] The decrease in performance after awakening from sleep only lasted several hours, in line with the concept of sleep inertia.[32,33]

It is also postulated that sleep quality rather than sleep duration is the component associated with memory performance.[34] The amount of time in bed has no relationship with school attentiveness.[30,35]

Most children are able to compensate for brief periods of sleep restriction with impairment only emerging after prolonged sleep restriction or total sleep deprivation.[36,37] Learning before sleep enhances memory consolidation.[33] Sleep deprivation in adults was found to affect the mood changes more than the cognitive or motor functions.[13]

Sleep disordered breathing leading to sleep deprivation

Sleep disordered breathing (SDB) is a continuum ranging from primary snoring to severe obstructive sleep apnea (OSA) syndrome. In a study of children between 3 -12 years old, it is reported that up to 25% of them suffered from snoring and 10% had OSA.[38] Snoring and intermittent hypoxia in children are significantly associated with school failures. Snorers had twice the risk of poorer school performance and the association became stronger with increased snoring frequency.[39]

SDB is associated with behavioural problems, reduced academic performance and neurocognitive learning.[40,41,42,43,44] The consequence of frequent night time arousal resulting in sleep fragmentation impacts greatly on learning and memory tasks.[45] Gozal et al showed that neurocognitive morbidity from SDB may be only partially reversible. The learning deficit which developed during childhood may hinder school achievement later on.[46]

Improvements in learning and memory achieved after sleep

Children who extended their period of sleep significantly improved their memory performance.[47] Another study showed that enhanced recall was related to periods of sleep[48]. Consolidation of the memory is enhanced when the interval of wakefulness between learning and sleep is short. It also did not matter if the learning was done in the morning, afternoon or at night. There is no difference in the rate of forgetfulness as the benefit of sleep on retention recall is stable over 48 hours. The enhanced recall memory was best seen in those who slept after they had learnt a new task.

Declarative memory consolidation is enhanced after periods of night time sleep but a wake period of the same duration does not.[49] High periods of NREM sleep are important in the consolidation process of declarative memory. Sleep itself allows a qualitative change in memory more than just consolidation.[50] Learning of new abstract concepts is affected after sleep loss.[37]

Neural activation in sleep following learning

Functional MRI in sleep-deprived patients using a verbal learning task revealed increased prefrontal activity and decreased hippocampal activity, compared to controls who experienced normal sleep; indicating more effort was required for successfully completing the task.[51,52] Therefore short duration of sleep or naps in periods of 10 minutes will improve alertness and performance for up to 1 hour. The optimal duration of nap seems to be 10 minutes and if it is any shorter, there is no benefit. There appears to be a need for a fixed period of NREM sleep especially, stage 2 or stage 3 sleep.[53] The above findings were noted in adults and whether this finding can be extrapolated to children remains to be seen.

LIMITATIONS OF CURRENT STUDIES ON SLEEP AND SLEEP DEPRIVATION

Most of the studies are small, observational studies rather than large, randomised controlled trials. Some of the studies are based on self-reports and recall questionnaires. This may inadvertently introduce bias. There are different measures being tested hence outcome measures are not comparable. The participants involved in these studies may exhibit the "Hawthorne effect" and limit the accuracy of the results.

MEASUREMENT OF SLEEP DEPRIVATION

i) Sleep deprivation is ascertained by a thorough history and use of a screening questionnaire like the BEARS questionnaire [54,55] or the Children's Sleep Habit Questionnaire[41].

BEARS questionnaire [54]

Owens and Dalzell developed a quick 5-question screening tool that professionals can use with children and adolescents called the BEARS.

The 5 questions are: (1) Bedtime problems, (2) Excessive daytime sleepiness, (3) Awakenings during the night, (4) Regularity of evening sleep time and morning awakenings, and (5) Sleep-related breathing problems or snoring. Almost twice as many children's sleep problems were identified when the BEARS was used in a clinical setting instead of leaving it up to professionals to ask questions on their own.

Strengths of BEARS

It is easy to remember these brief questions because of the short "BEARS" acronym. It is a quick, simple screening tool for paediatric professionals to use for children from 2 to 18 years of age. This is to determine whether a child needs a more comprehensive sleep-screening inventory.

Limitations of BEARS

Its main shortfall is that it does not ask questions about excessive leg or other movements during sleep and may overlook many children who have Periodic Limb Movement Disorder, Restless Leg Syndrome, or other parasomnias. No validity or reliability studies have been conducted on the BEARS.

Children's Sleep Habit Questionnaire (CSHQ)[41]

The CSHQ is a 33-item questionnaire for children from 4 to 10 years of age that is rated by parents on a 3-point scale. It is available only in English. The CSHQ scores the following domains: (1) bedtime resistance, (2) sleep duration, (3) parasomnias, (4) sleep-disordered breathing, (5) night awakenings, (6) daytime sleepiness, (7) sleep anxiety, and (8) sleep onset delay.

Strengths of the CSHQ

Its rating scale is well-defined to prevent misinterpretation by parents, and the cut-off score to refer children for a comprehensive evaluation is clearly defined. It can predict some of the major paediatric sleep disorders, such as SDB and various night-time behavioural problems. It is the only paediatric sleep inventory to date that screens for sleep anxiety.

Limitations of the CSHQ

(i) Children from differing ethnic backgrounds or socioeconomic levels may give different results. The SDB scale has lower than desirable test-retest reliability. The CSHQ is not designed for use with adolescents or in private practices or school settings. It is recommended that CSHQ only be used in research settings by sleep specialists with predominantly Caucasian, English-speaking children.

ii) Sleep deprivation can also be measured more scientifically with a polysomnogram (PSG), Multiple Sleep Latency Test (MSLT) or Multiple Wake Test (MWT)[56] (Appendix 2). PSG is the gold standard for evaluating sleep disorders and also provides information about the daytime sleepiness in children[24]. The PSG is abnormal in parasomnias, sleep apnoea and narcolepsy. It will be normal in problems that are of behavioural origin[57].

iii) It is difficult to determine what constitutes normal quantity of sleep. One approach involves determining how long before a patient would awaken spontaneously if he is left to sleep. An alternative approach involves determining how alert the patient feels after different durations of sleep. Alertness is normal if the patient awakes feeling refreshed and is capable of moving through the day feeling alert without effort, even when placed in boring situations.

Once the normal quantity of sleep for an individual (i.e. the nightly sleep quota) has been determined, the sleep deficit can be estimated as illustrated by the following example. If a person whose nightly sleep quota is eight hours and sleeps only seven hours, there would be a one-hour sleep deficit. That sleep deficit is carried over to the next day. A seven-hour sleep debt will accrue after seven days if one hour of sleep is lost nightly. Cumulative partial sleep deprivation can be equivalent to acute total sleep deprivation.

Individuals can still be sleep deprived when they sleep for more than eight hours. This is usually because of disturbances in the quality of sleep. Sleep quality is determined by the number of arousals or awakenings, as well as the percentage, duration and type of sleep stages.[58] As few as five awakenings per hour of sleep can result in daytime sleepiness and/or performance deficits even after a single night of disruption.[59] Individuals are unaware of the arousals because their duration is only in seconds and the individual then returns to the same sleep stage that was interrupted. Sleep is thus not only important after learning for consolidation of memory, but also in preparing the brain for efficient memory formation.[12]

Appendix 2: Polysomnography [62]

Sleep is generally measured during an all-night sleep study or polysomnogram (PSG), which involves simultaneous recording of several physiologic variables. Sleep studies require attachment of electrodes to the scalp for recording the EEG, to the face near the right and left eyes for measurement of rapid eye movements, and to the chin for measurement of muscle tone.

Other physiologic parameters, such as airflow and breathing effort, oxyhemoglobin saturation, leg movements, electrocardiogram, and body position may also be measured depending on the purposes of the sleep study. All measurements are performed continuously throughout the patient's usual sleep period. All physiologic tracings are then analysed, and a final report of sleep quantity and quality is prepared and interpreted.

Multiple sleep latency test (MSLT) [63]

The multiple sleep latency test (MSLT) is an objective measure of daytime sleepiness. It was developed because patients frequently appear to be unaware of just how sleepy they are. The test is based upon an operational definition of sleepiness: the sleepier an individual is, the faster he will fall asleep. The following protocol is typically used:

• The patient is given 4 to 5 opportunities to nap, usually at two-hour intervals during the day.

• On each occasion, the individual is asked to lie down on a bed in a quiet, darkened sleep room and fall asleep as quickly as possible. The EEG, eye movements, and muscle tone are measured during the test.

• The latency from wakefulness to sleep onset is measured to determine the "sleep latency." Each session is terminated after 15 minutes of sleep.

• Generally, a mean sleep latency of 5 minutes or less is considered indicative of severe daytime sleepiness, while a mean sleep latency of 15 minutes or longer is consistent with normal alertness. The abnormal appearance of REM sleep during two or more of the four to five naps is also thought to be consistent with a diagnosis of narcolepsy. MSLT is an objective measure of daytime sleepiness, and is generally performed on the following day of PSG to assess the degree of sleepiness and the timing of REM sleep onset. It is indicated in children with suspected narcolepsy and idiopathic hypersomnolence.

• MWT objectively measures the ability of an individual to remain awake for a defined period of time and mirrors the result of MSLT. It is indicated to assess the efficacy of treatment in patients with narcolepsy.

All these tests are complicated investigations requiring the expertise of the sleep specialists and are beyond the scope of this paper.

Maintenance of Wakefulness (MWT)[64]

The MWT objectively measures the ability of an individual to remain awake for a defined period of time. It is based on the premise that individuals with a greater degree of sleepiness are less likely to remain awake than individuals with less sleepiness.

This test is used to assess a patient's ability to maintain wakefulness throughout the day. This test is helpful in assessing the efficacy of an individual's treatment for sleep-disorders and driving safety.

MWTs are generally performed during the day, immediately following an overnight PSG. It involves four, 40-minute test periods at 2-hourly intervals, throughout the day. Patients are required to stay awake throughout each test period (brain waves and eye movements are recorded to enable wakefulness and sleep-states to be determined).

The MWT should *not be considered a substitute for the MSLT* because the tests can give conflicting results, even when the same individual is given both tests on the same day. There are several several possible reasons for conflicting results. The MWT and

MSLT may measure different processes - the tendency to fall asleep (ie, the MSLT) and the ability to stay awake (ie, the MWT).

Indications - The MWT may be used to assess an individual's response to therapy. It is the direction of change, not the degree of change, that is meaningful in this situation because the degree of change that is clinically significant has not been established.

Maintenance of wakefulness test - The maintenance of wakefulness test (MWT) is a variant of the MSLT. However, it differs in its goals as well as in the nature of the instructions given to the patient. Patients are typically tested while reclining in a quiet, darkened room. Instead of being asked to fall asleep as quickly as possible, they are requested to stay awake for as long as possible.

Conceptually, the MWT is a test of the individual's ability to stay awake, and it is therefore believed to be a more practical test of whether a person's sleepiness is likely to impair the ability to drive or work. The MWT also allows the element of motivation to enter into the equation, as is likely to be the case in real life situations.

CLINICAL APPROACH TO SLEEP DEPRIVATION IN CHILDREN FOR FAMILY PHYSICIANS

1. A high index of suspicion is needed in order to detect sleep deprivation in children.[60]

2. A systematic approach to exclude conditions causing insufficient sleep, fragmented sleep and increased need for sleep should be conducted (Appendix 1). The commonest are SDB, organ-specific problems, decongestants, caffeine and sweets.

3. The BEARS questionnaire is a useful screening tool to help assess whether the child has any sleep deprivation.[54,55]

4. A sleep log (Appendix 3) should be recorded. It includes the time of going to bed, time of going to sleep, night wakings and what happens at each waking, what time the child wakes in the morning, whether the child needs to be woken up and if the child is easy or difficult to wake as well as having any daytime symptoms.

5. Focused physical examination including vital signs, ENT and a neurological examination should be performed.

6. Treat the reversible causes if sleep deprivation is confirmed and refer to a sleep specialist for an overnight PSG if SDB or OSA is suspected.

CONCLUSIONS

• Sleep is important for learning and memory. Sleep quality rather than sleep duration is associated with memory performance.
• Sleep deprivation is common in children and SDB must be excluded. Poor sleep quality due to SDB is associated with behavioural problems, reduced academic performance and learning.[34,40,41,42,39,43,44,61]
• The BEARS questionnaire is a useful screening tool for evaluation of sleep deprivation.
• In the management of sleep deprivation, it is important to uncover the root causes and treat accordingly.

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Appendix 3: Sleep Log

Name: ________________ NRIC No.: ________________ Age: ________________ Sleep ✓ Awake ✗

Address: ________________________________

Medications (if any): ________________________________

Day	7 am	8	9	10	11	12	1 pm	2	3	4	5	6	7	8	9	10	11	12 mn	1	2	3	4	5	6

Sleep log - as a physical record of sleep pattern for the patient

architecture in infants and children. J Clin Neurophysiol 1996;13(3):184-97. doi:10.1097/00004691-199605000-00002
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