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Cognition and objectively measured sleep duration in children: a systematic review and meta-analysis☆

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ABSTRACT

Background: Sleep recommendations are widely used to guide communities on children's sleep needs. Following recent adjustments to guidelines by the National Sleep Foundation and the subsequent consensus statement by the American Academy of Sleep Medicine, we undertook a systematic literature search to evaluate the current evidence regarding relationships between *objectively* measured sleep duration and cognitive function in children aged 5 to 13 years.
Methods: Cognitive function included measures of memory, attention, processing speed, and intelligence in children aged 5 to 13 years. Keyword searches of 7 databases to December 2016 found 23 meeting inclusion criteria from 137 full articles reviewed, 19 of which were suitable for meta-analysis.
Results: A significant effect ($r = .06$) was found between sleep duration and cognition, suggesting that longer sleep durations were associated with better cognitive functioning. Analyses of different cognitive domains revealed that full/verbal IQ was significantly associated with sleep loss, but memory, fluid IQ, processing speed and attention were not. Comparison of study sleep durations with current sleep recommendations showed that most children studied had sleep durations that were not within the range of recommended sleep. As such, the true effect of sleep loss on cognitive function may be obscured in these samples, as most children were sleep restricted.
Conclusions: Future research using more rigorous experimental methodologies is needed to properly elucidate the relationship between sleep duration and cognition in this age group.

Introduction

Adequate sleep during childhood is regarded as an imperative component of effective learning and successful school performance.[1,2] In adults and adolescents, sleep loss results in inattention, slower reaction times, diminished cognitive processing speed, and worse memory performance.[3–9] However, a meta-analysis by Astill and colleagues[10] found only a modest association ($r = .08$, 85% confidence interval = .06 to-.10) between sleep duration and cognition in children aged 5 to 12 years. The results of Astill et al suggest that less than 1% of the variance in cognitive performance is explained by sleep duration. In addition, domains typically sensitive to sleep loss, such as sustained attention and memory, showed no significant relationship to sleep duration. Indeed, Astill et al found that only executive functioning, school performance, and tasks that rely upon the integration of multiple cognitive domains showed small but statistically significant associations with sleep length. The authors posit several potential explanations for these findings, including the novel idea that brain immaturity may prevent children from experiencing sleep-derived benefits to sustained attention. Specifically, they argue that if brain networks related to attention and cognition which are affected by sleep loss in adults (such as the default mode network and the frontoparietal

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network) are insufficiently developed in children, this may help to explain (*a*) why children perform worse than adults and (*b*) why children do not display worsening performance following sleep loss.

This issue has applied ramifications for children, parents, and policy makers. Current sleep recommendations and decisions regarding school start times and extracurricular workload are based, at least partially, on the assumption that sufficient sleep is crucial for children's optimal cognitive functioning.[11] Thus, it is difficult to reconcile the meta-analytic results with experimental findings that memory and attention are impacted by sleep loss.[12,13] A recent meta-analytic review by de Bruin and colleagues examined the effect of experimentally manipulated sleep duration on cognition and found only modest or no effects of sleep duration on several aspects of cognition. These findings suggest that findings of small or no effects similarly occur in the limited adolescent literature.[6]

When interpreting meta-analytic results, consideration must be given to the quality of the scientific literature included. In the previous review, for example, over 40% of studies relied upon subjective measures of sleep.[10] Subjective assessments of sleep are prone to inaccuracies and reporting biases and, in children, rely on parental report. Parents may only become aware of sleep times and night waking if the child fails to fall asleep independently and wakes during the night and requires attention. Resultantly, studies that use subjective measures to estimate "average" or "typical" sleep duration are likely to be limited in their ability to estimate the strength of the relationship between sleep and cognition because they may not accurately reflect typical sleep.

To explore the relationship between sleep duration and cognition in children in greater depth, a panel of pediatric sleep experts from the Australasian Sleep Association was convened to conduct a systematic review of the sleep literature and provide an up-to-date summary and meta-analysis of studies examining this relationship. Because of the inherent problems and questionable validity of children's self-reported sleep[14,15] which may have contributed to the small effects found previously, only studies including objective measures of sleep were included. Furthermore, these studies were appraised to identify methodological limitations that impact this field of research, including the reliability of sleep estimates obtained, study design, and range of sleep durations and cognitive tasks assessed, and specific recommendations for future research identified.

Current National Sleep Foundation (NSF) and American Academy of Sleep Medicine (AASM) guidelines recommend that children aged 6 to 13 years obtain between 9 and 11 hours of sleep per night.[11,16,17] As many, if not the majority, of children worldwide experience sleep which falls below the recommended range, it may be that linear associations between "typical" sleep and cognition are attenuated because of the restriction in the range of sleep durations. As such, sleep durations in the included studies will be compared to current NSF and AASM sleep recommendations for children to determine whether a paucity of studies with sleep durations that span the recommended range may minimize the true effects of sleep duration on cognitive performance in children.

Methods

A systematic literature search was conducted to identify all studies (up to December 2016) that examine the association between objectively measured sleep duration (ie, using actigraphy or polysomnography [PSG]) and children's cognitive function in school children aged 5 to 13 years, inclusive.

Systematic search strategy

A systematic search strategy of 7 electronic databases (EBSCOhost [*CINAH*], Ovid [*Medline, Embase, PsycArticles, PsycInfo*], Cochrane, Web of Science, Scopus, Informit Health Database, PubMed) was used to identify studies for review. The search terms used were (Children *or* Adolescen* *or* Youth *or* Young People *or* Pediatric *or* Paediatric) *and* (Sleep *or* Wake After Sleep Onset (WASO) *or* Sleep Onset Latency (SOL) *or* bed time / bedtime *or* wake time / waketime *or* sleep efficiency) *and* (Cognit* *or* Reaction Time *or* Attention *or* PVT *or* Psychomotor Performance *or* Memory *or* IQ *or* Intelligen* *or* Problem solv* *or* Neuropsych*). A preliminary search determined the scope and relevance of candidate databases. All abstracts were screened for inclusion criteria. Potentially eligible articles were read in full, and only relevant articles were kept for review. In cases where only an abstract was available, the study's authors were contacted, and an interlibrary loan request was made for the full-text copy of the article. If a full-text copy of the article was unavailable, the study was excluded. Reference lists of included studies were then reviewed to identify additional eligible articles.

Criteria for inclusion and exclusion

Any study that examined the association between objectively measured school children's sleep duration (as a function of sleep time, not time in bed) and cognitive function was considered for review. A *school child* was defined as a healthy child aged 5 to 13 years, inclusive. This age range was chosen to align with sleep recommendations of the NSF[43] but also to include school-aged children from those countries where children attend school at age 5 (eg, New Zealand, Australia, and Canada). *Sleep time* was defined as total nocturnal sleep duration as measured by actigraphy or PSG. *Cognitive function* was defined with a quantifiable and in most cases standardized measure of children's intelligence, memory, and/or attention.

All prospective observational and experimental full-text studies published in English that presented an association of healthy children's sleep time with a cognitive variable were accepted for inclusion for this review. Studies that did not provide details of the mean sleep duration of the study sample examined were excluded, as were studies written in a language other than English and studies that examined special and clinical populations of children (eg, children with a diagnosed sleep disorder or disorders that impact neuropsychological functions of cognition, attention, and memory). In studies where cases or special population groups were compared with healthy controls, only the control data were used. Studies were also excluded if they compared cognitive scores that were measured both before sleep and after sleep, thus presenting "overnight change." Included studies, alternatively, measured cognition at a single time point to allow consistent comparisons between effects.

Studies were read and reviewed by 2 independent reviewers, and the following data were extracted: study author, year of publication, country where the study was conducted, sample size, number of male and female participants included for analysis, method of sleep measurement (actigraphy or PSG), number of nights assessed, sleep duration, cognitive measure, and key findings. When the country where the study was conducted was not reported, the location was assumed to be the same as that of the first author's affiliations.

Data analyses

Meta-analyses were conducted using Comprehensive Meta-Analysis (Biostat, Inc, USA). Effect sizes from the cross-sectional studies were converted to Pearson *r* correlations and subsequently transformed to Fisher *z*. Effect sizes from the experimental studies were converted to Cohen *d* values and subsequently transformed to Fisher *z*. To be included in the meta-analyses, studies had to report direct correlations between cognitive variables and sleep duration. Where studies provided outcomes of multiple regression analyses, authors were contacted to obtain the direct correlations, and these were

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