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SPECIAL ARTICLES

# Consensus Statement of the American Academy of Sleep Medicine on the Recommended Amount of Sleep for Healthy Children: Methodology and Discussion

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Members of the American Academy of Sleep Medicine developed consensus recommendations for the amount of sleep needed to promote optimal health in children and adolescents using a modified RAND Appropriateness Method. After review of 864 published articles, the following sleep durations are recommended: Infants 4 months to 12 months should sleep 12 to 16 hours per 24 hours (including naps) on a regular basis to promote optimal health. Children 1 to 2 years of age should sleep 11 to 14 hours per 24 hours (including naps) on a regular basis to promote optimal health. Children 3 to 5 years of age should sleep 10 to 13 hours per 24 hours (including naps) on a regular basis to promote optimal health. Children 6 to 12 years of age should sleep 9 to 12 hours per 24 hours on a regular basis to promote optimal health. Teenagers 13 to 18 years of age should sleep 8 to 10 hours per 24 hours on a regular basis to promote optimal health. Sleeping the number of recommended hours on a regular basis is associated with better health outcomes including: improved attention, behavior, learning, memory, emotional regulation, quality of life, and mental and physical health. Regularly sleeping fewer than the number of recommended hours is associated with attention, behavior, and learning problems. Insufficient sleep also increases the risk of accidents, injuries, hypertension, obesity, diabetes, and depression. Insufficient sleep in teenagers is associated with increased risk of self-harm, suicidal thoughts, and suicide attempts.

**Commentary:** A commentary on this article apears in this issue on page 1439.

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## 1.0 INTRODUCTION

Healthy sleep requires adequate duration, appropriate timing, good quality, regularity, and the absence of disturbances and disorders. Sleep duration is a frequently investigated sleep measure in relation to health outcomes. Many studies have shown that adequate sleep duration is associated with better attention, behavior, cognitive functioning, emotional regulation, and physical health among children.[1–3]

A panel of 13 experts in sleep medicine and research used a modified RAND Appropriateness Method[4] to develop recommendations regarding the sleep duration range that promotes optimal health in children aged 0–18 years. The Consensus Recommendations[5] were previously published, and this report expands on the methodology, results of the literature search, key findings from published research, overview of discussion by the panel members during the in-person meeting, and limitations of the process to answer the critical question: How much sleep is needed for optimal health in children?

## 2.0 METHODS

The American Academy of Sleep Medicine (AASM) Sleep Duration Consensus Conference used a modified RAND Appropriateness Method (RAM)[4] to establish consensus for the amount of sleep needed to promote optimal health in children and teenagers.

### 2.1 Expert Panel Selection

In accordance with the recommendations of the RAM, the Sleep Duration Consensus Conference panel comprised 13 voting members, including a moderator. All panel members are experts in sleep medicine and/or sleep science. The panel members were recommended by the Board of Directors of the AASM.

Panel members were sent a formal letter of invitation from the AASM and were required to complete Conflict of Interest disclosures before being officially accepted. To avoid further conflicts, panel members were not permitted to participate in similar consensus activities by other organizations.

**Table 1**—Data extracted from studies for evidence tables.

| | |
|---|---|
| 1 | Study design |
| 2 | Oxford grade |
| 3 | Number of study participants |
| 4 | % of female participants |
| 5 | Method by which sleep duration was obtained |
| 6 | Age range of child participants |
| 7 | Major outcomes and conclusions |

## 2.2 Modified RAND Appropriateness Method

The RAND Appropriateness Method uses a detailed search of the relevant scientific literature, followed by two rounds of anonymous voting to determine consensus on the appropriateness of a recommendation. The first round of voting is completed without panel interaction to prevent panel members from influencing each other's votes. The second round of voting occurs after a panel discussion of the available evidence and Round 1 voting results.

In a modification to RAM, the Consensus Conference included a third round of voting, which considered all available evidence and the previous voting results, to establish a single recommendation for the amount of sleep needed to promote optimal health for each age group in children. The third round also involved a discussion of the merits of recommending an optimal sleep duration range versus a simple threshold value. The final Consensus Recommendations resulted from the third round of voting.

The charge to the Consensus Conference panel was to determine a sleep duration recommendation for healthy children. Panel members voted on the appropriateness of one-hour increments ranging from < 6 to ≥ 18 hours of sleep. One-hour increments were selected because these were the most commonly reported units in epidemiologic and experimental studies. Substantial heterogeneity was present in the sleep duration assessment instruments. The consensus recommendations focused on overnight and daytime nap durations when appropriate as napping is considered biologically normal under the age of 7 years. The final recommendations were based on the one-hour values that were determined by the panel to be "appropriate" to promote optimal health in children.

## 2.3 Detailed Literature Search and Review

The AASM Board of Directors charged the panel with developing a recommendation for sleep duration in healthy children. This charge coincides with the goals of the National Healthy Sleep Awareness Project (NHSAP) and with the Sleep Health Objective of Healthy People 2020 to "increase the proportion of students in grades 9 to 12 who get sufficient sleep."[6]

The scope of the recommendation was limited to children aged 0–18 years. After a preliminary review of the literature, prior Centers for Disease Control and Prevention (CDC), AASM, and National Sleep Foundation (NSF) recommendations, as well as commonly frequented websites, the following age groups were created: < 12 months, 12 months to < 3 years, 3 years to < 6 years, 6 years to < 13 years, and 13–18 years. There was substantial overlap of age groups within the literature, and this was discussed during the in-person conference.

**Table 2**—Health domains.

| | |
|---|---|
| 1 | Cardiovascular health |
| 2 | Developmental health |
| 3 | Human performance |
| 4 | General health |
| 5 | Immunology |
| 6 | Longevity |
| 7 | Mental health |
| 8 | Metabolic health |
| 9 | Cancer |
| 10 | Pain |

A preliminary search of the literature and specific National Library of Medicine Medical Subject Headings (MeSH) terms identified several health outcomes that were most commonly examined in relation to sleep duration in children. Based on this evidence, the panel decided to focus on the relationships between sleep duration and the following 10 health categories: cardiovascular health, developmental health, human performance, general health, immunology, longevity, mental health, metabolic health, pain, and cancer.

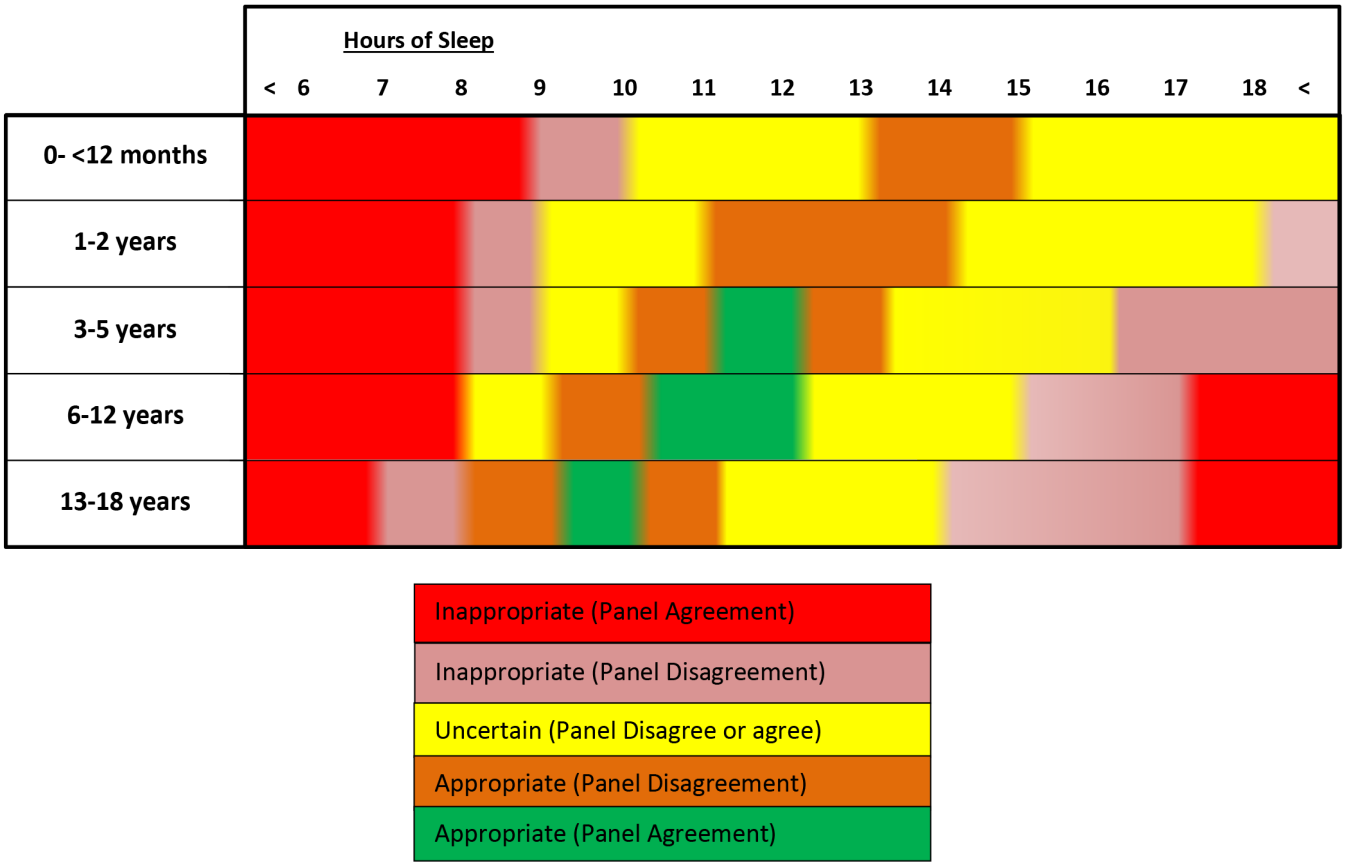
After establishing the health categories, a detailed literature search was performed in PubMed on October 1, 2015. The search terms used for the literature search are detailed in the supplemental material. The search was restricted to studies in human children ages 0–18 years, published in English, with no publication date limit. Case reports, editorials, commentaries, letters and news articles were excluded from the search results. The initial search produced 1,040 publications. The search results were reviewed based on title and excluded *a priori* for the following reasons: focus on sleep quality or fatigue instead of sleep duration, assessing sleep duration in specific disorders or sleep disorders, experiments on total sleep deprivation, children sleeping outside normal day/night sleep schedules, assessments of sleep deprivation as a treatment (insomnia or depression), and focusing on medication effects on sleep duration. Application of these restrictions resulted in 864 publications.

The panel reviewed the abstracts of these remaining publications using the criteria described above. Citation pearl growing was used to capture additional important publications that were not identified by the search. Accepted publications were graded for quality using the Oxford criteria.[7] All accepted publications were reviewed in detail and the data listed in **Table 1** were extracted.

Based on the data extraction, accepted studies were subdivided into the categories listed in **Table 2**.

The extraction sheet and full text of all accepted publications were made available to the panel members for review. Each panel member was assigned to a particular health domain and asked to identify the most informative studies based on study design and evidence quality. After review of the literature, the domains of pain and cancer did not contain sufficient data to guide sleep duration recommendations and therefore were excluded prior to Round 1 Voting. After lengthy discussion at the conference, the domain of longevity was excluded prior to Round 2 Voting. A second PubMed literature search

**Figure 1**—Round 1 voting results.




Round 1 voting was based on voting across all age groups under the following eight domains: cardiovascular health, developmental health, human performance, general health, immunology, longevity, mental health and metabolic health.

was performed during the conference on February 19, 2016 to collect more recent relevant studies.

### 2.4 Round 1 Voting

Prior to the conference, panel members reviewed the accepted publications and extraction sheets. Based on their review of this material and their clinical and research expertise, members voted to indicate their agreement with the following statement, "Based on the available evidence, [x] hours of sleep is associated with optimal health within the [x] category in the [x] age group." "Hours of sleep" was categorized as: < 6 hours, 6 to < 7 hours, 7 to < 8 hours, 8 to < 9 hours, 9 to < 10 hours, 10 to < 11 hours, 11 to < 12 hours, 12 to < 13 hours, 13 to < 14 hours, 14 to < 15 hours, 15 to < 16 hours, 16 to < 17 hours, 17 to < 18 hours, ≥ 18 hours. The panel members voted using a 9-point Likert scale, where 1 meant "strongly disagree," 9 meant "strongly agree," and 5 meant "neither disagree nor agree." Panel median values were placed into three broader categories, with the following interpretations: 1–3 indicated disagreement with the statement, 4–6 indicated uncertainty, and 7–9 indicated agreement with the statement.

Panel members were instructed not to discuss the evidence or their votes with each other to ensure independence. Panel members' votes were collected by email and compiled to determine the median and distribution of votes. Individual results tables were created and distributed to the members at the consensus conference, displaying the distribution of votes (anonymously), the member's vote, and the median vote (**Figure 1**).

### 2.5 Conference Proceedings and Round 2 Voting

Prior to the conference, panel members were selected to become domain experts for each domain. At the conference, members reviewed the results of Round 1 voting for a domain, and then the domain experts presented a review of the best available evidence for that domain. Panel members then discussed the results of Round 1 voting, the accepted publications for the domain and any other relevant evidence. After discussion, panel members completed Round 2 voting for the age groups within the domain, following the same procedures from Round 1 voting. The conference proceeded in this manner for each domain.

### 2.6 Round 3 Voting and Development of Recommendations

Panel members reviewed and discussed Round 2 voting results for all domains and the entire body of accepted publications in preparation of voting on recommendation statements. After

discussions concluded, panel members completed Round 3 voting for a single recommendation of appropriate sleep duration range for each age group, following the same procedure as for Round 1 and Round 2 voting, but with the following statement: "Based on the available evidence, [x] hours of sleep is associated with optimal health in [x] age group."

Based on the results of Round 1 and Round 2 voting, the conference discussions, and with the agreement of all the panel members, the infant (0 to 12 months) category was reduced to 4 to 12 months. This decision was based on the lack of evidence in this 0–4 month old age group. Thus, no recommendations were made for children under 4 months of age for any of the categories.

Upon completion of Round 3 voting, the panel members reviewed the voting results and developed the recommendations. The age groups and hour ranges were simplified to those presented in the consensus statements for the purposes of simplifying recommendations and ensuring clarity.

The final recommendations were submitted to the AASM, Sleep Research Society (SRS), American Academy of Pediatrics (AAP), and American Association of Sleep Technologists (AAST) Boards of Directors for their endorsements.

## 3.0 SUMMARY OF LITERATURE

The following sections summarize the key evidence considered by the panel in developing the recommendations while acknowledging that a complete evaluation of the evidence is beyond the scope of this consensus process.

For each domain, the panel reviewed studies with children from all over the world, addressing sleep duration and health outcomes across the prespecified age ranges. Within each domain, there were topics without information for some of the age groups, and often studies spanned several of our prespecified age groups. Studies that assessed the relationship between sleep duration and the search term of interest were the most informative. Many studies reported more than one outcome. However, emphasis was placed on longitudinal or cross-sectional cohort studies that reported sleep duration in unselected general populations as well as smaller studies of unconstrained sleep in healthy children. Some studies only provided correlation or regression coefficients and thus were minimally informative. Others reported the association between general health and sleep duration, but only at a limited number of thresholds. In most studies, sleep duration was assessed by parent or child self-report. Polysomnographic data and actigraphy were considered when appropriate such as in studies of unconstrained sleep in the laboratory or at home. Systematic comparisons between studies were challenging and in most cases not possible. The following domains and information were reviewed.

### 3.1 General Health

In the general health domain, the number of children in each study ranged from less than 25 to over 74,000.

Within the 4-months to < 12 months age range, there were few studies. However, two large prospective birth cohorts indicated that over a 24-hour period, healthy infants slept slightly > 13 to slightly > 14 hours.[8,9] Furthermore, infants sleeping for lesser amounts of time had a greater likelihood of quality of life issues later in childhood.[9]

For children in the 1 to < 3 years and 3 to < 6 years age ranges, there were only a small number of studies to review. One cohort study reported sleep durations between 11 and 12 hours in normal children.[8] Limited data also suggested that sleeping less than 10 hours was associated with a greater risk of accidental injury[10] and reduced quality of life several years later.[11]

More studies were available that addressed general health outcomes in older children including those with polysomnographic data during unconstrained sleep.[12,13] In the 6 to < 13 years age group, the panel observed that this was a period of rapid physical and mental development with more sleep appropriate for children at the lower end and less sleep for those at the higher end of the age range. Most informative was a large meta-analysis of children from 20 countries that indicated children between 9 and 12 years of age slept approximately 10 hours per night.[14] In addition, data were available suggesting children sleeping 10 hours or more per night reported better health.[15] In the 13–18 year age range, increased rates of injury were noted for those sleeping less than 7 or 8 hours[16,17] and better health was reported for those sleeping 9 hours or more.[15] A meta-analysis found that in teenagers, sleep declined continuously from between 9 and 10 hours at age 13 to between slightly less than 8 to slightly greater than 9 hours at age 18 years of age.[15] Extended sleep duration was noted on weekends compared with weekdays.

In summary, limited information indicates that there is a continuous decline in the amount of sleep required for normal general health. Lesser amounts are associated with poorer overall health and reduced quality of life later in childhood. However, there is little information regarding any impact of excessive sleep on overall health.

### 3.2 Cardiovascular Health

Many of the studies in the cardiovascular domain examined the relationship between sleep duration and hypertension. Others looked at body mass index, waist circumference, serum lipids, C-reactive protein (CRP), and hemoglobin A1C (HbA1C). Most studies were cross-sectional, observational, retrospective or cohort design; none were randomized controlled studies. The number of participants varied from as few as 20 to just over 5,500. No studies in this domain included children younger than 5 years of age. Most studies focused on adolescents and teenagers.

The majority of studies suggested a shorter sleep duration was associated with either an increased risk of hypertension or actual hypertension. However, the definition of "short/shorter" sleep was different between the studies. For children > 5 years, studies suggested a shorter sleep duration (< 10 hours,[18] some < 9 hours,[19] some < 8 hours,[20,21] and one < 5 hours[22]) was associated with either an increased risk of hypertension or actual hypertension. One study showed an increased odds ratio of hypertension in girls who slept > 9.5 hours.[23] Another study suggested that < 10 hours of sleep was associated with hypotension (systolic blood pressure < 100 mm Hg) in preschoolers.[18]

Conversely, there were also data to suggest no adverse effect of sleep characteristics on cardiovascular health.[24–26]

In summary, evidence indicates that shorter sleep duration of < 5 hours is associated with increased risk of hypertension. However, there is some suggestion that in girls regularly sleeping more than 9.5 hours, hypertension risk is increased.

### 3.3 Metabolic Health

Many studies in the metabolic domain specifically targeted the relationship between sleep duration and overweight/obesity. Other metabolic parameters studied included: waist circumference, insulin resistance (HOMA-IR), bone mineral content, triglycerides, C-reactive protein, HbA1c, leptin, and ghrelin. Most were cross-sectional studies of community-based populations. The number of participants in studies ranged from 62 to 81,390.

Most studies demonstrated a negative association between sleep duration and overweight/obesity. Shorter sleep durations were also associated with increased risk for developing overweight/obesity. Two meta-analyses found sleep duration inversely correlates with obesity in children 0–18 years.[27,28] For each hour increase in sleep, the risk of overweight/obesity decreased. Children under age 10 years show a more linear dose-response relationship of sleep duration and weight status. Additionally, there is evidence of a stronger inverse relationship for sleep duration and weight status in boys compared with girls.[28]

A longitudinal study of 915 children aged 6 months to 3 years, showed infant sleep duration of less than 12 hours per day was associated with higher body mass index (BMI) z scores and increased odds of overweight during subsequent preschool years.[29] Similarly, in a cohort study of 1,930 children ages 0–13 years, in younger children, ages 0–4 years, sleep duration of less than 11 hours was subsequently associated with increased risk of being overweight/obese. However for children ages 5–13 years, sleep duration was not associated with subsequent weight status.[30] Other cohort studies report similar findings.[31] A large cross-sectional study of 3,875 infants and 3,844 children (up to age 7 years) showed that sleep duration did not predict obesity; however, obese children ages 6 to 7 years were found to sleep approximately 30 minutes less than non-obese children.[32] In a cross-sectional study of 1,229 children ages 5 to 11 years, children who slept less than 10 hours per weeknight were 5 times more likely to be overweight than those who slept at least 12 hours on weeknights.[33] In another large cross-sectional study of 8,274 children ages 6 to 7 years old, children with sleep duration shorter than 10 hours had an increased odds ratio to develop obesity.[34] In a cross-sectional study of 6,576 children, ages 7–11 years, children who slept < 9 hours per night had a higher risk for overweight, obesity, and abdominal obesity compared to children who slept 10–11 hours.[35] In a study of 319 children ages 10–17 years, total sleep time was negatively correlated with overweight/obese status.[36] Similar findings were observed in a larger cross-sectional study of 6,324 children ages 7–15 years. Boys who slept < 10 hours per night had increased odds of overweight compared to children sleeping > 10 hours.[37] In 3,311 children 12.5 to 17.5 years, shorter sleep duration < 8 hours was associated with increased BMI, body fat, and waist and hip circumferences.[38] A cohort study of 1,303 children aged 5–29 months showed that children sleeping < 10 hours per night consumed approximately 50 more kcal per day than children sleeping 11–12 hours,[39] suggesting that changes in appetite may be a possible mechanism for a relationship between short sleep and weight status. Of note, one study of children ages 6–17 years reported no independent association between insufficient sleep and childhood obesity; however, no sleep duration information was provided by parents.[40]

In terms of other metabolic parameters, in a cohort of 652 children, chronic short sleep duration was associated with higher waist circumference, higher insulin levels, and greater HOMA-IR attributed to adiposity.[41] Higher HOMA Indices were also observed in high school-aged children who slept < 6.48 hours.[42] In children ages 4–7 years, there was increased bone mineral content in children who slept longer than 8 hours.[43]

A sample of 62 obese 8- to 17-year-old children studied with polysomnography (PSG) showed a U-shape curve for metabolic parameters such as HbA1c and insulin suggesting an ideal range of 7.5–8.5 hours of sleep for this group of children.[44] A U-shape curve was also observed in a study of 387 children ages 13–17 years, where HOMA-IR was 20% higher when sleep duration was < 5 hours or > 10.5 hours.[45]

Furthermore, higher C-reactive protein was observed in 13–17 year old children with < 9 hours sleep duration.[46]

In summary, short sleep duration is associated with an increased risk for overweight/obesity, particularly in younger children < 10 years, and in boys. There is also evidence that short or long sleep duration is associated with disruption of other metabolic parameters including appetite and glucose/insulin metabolism.

### 3.4 Mental Health

The variables of interest in the mental health domain related to mood (e.g., depression, anxiety, suicidality, emotional regulation, irritability and self-esteem); risk-taking behaviors (e.g., drug use); problematic behaviors (e.g., defiance and tantrums); and attention-deficit/hyperactivity disorder (ADHD) symptoms (e.g., hyperactivity, impulsivity, and inattentiveness). Studies included approximately 100 to 30,000 participants.

Limited data were available for children in the 4 months to less than 12 months age range. One study looked at the longitudinal sleep trajectories of approximately 3,000 children beginning at age 0–1 year with follow-up at age 6–7 years.[9] Those children who were persistent short sleepers and poor sleepers had more difficulties with emotional, social and physical functioning at age 6–7 years when compared to "typical sleepers" who slept approximately 14.5 hours of sleep at age 0–1 year and 10.75 hours of sleep at age 6–7 years. Similarly, there were few studies on sleep duration and emotional/mental health within the 12 month to < 3 year old and 3 to < 6 year old age categories. One study collected almost 33,000 parental surveys regarding child sleep duration and the emotional and behavioral regulation of these children at 18 months and 5 years of age.[47] Children who had short sleep duration of ≤ 10 hours at 18 months were at significantly greater risk of concurrent

and subsequent incident emotional and behavioral problems compared to a reference group of children receiving at least 13 hours of sleep at 18 months.[47]

Studies reviewed for children ages 6–13 years of age focused on associations between total sleep duration and affect, emotional regulation, irritability, relationships with peers/family, and perceived health. Experimental studies of sleep restriction or sleep extension showed that participants sleeping more than 9 hours (mean 9.8 hours) had better emotional lability scores and less restless/impulsive behaviors per teacher reports compared to those sleeping an average of 8.4 hours.[48] In a similar study, children with a mean of 9.3 hours of sleep had significantly higher positive affect scores and parent-reported emotional regulation compared to children sleeping a mean of 8.1 hours.[49] In contrast, no group differences were detected in negative affective scores and child-reported emotional regulation ratings. In cross-sectional studies, data were more mixed. For instance, impulsivity scores were significantly higher among children ages 7–8 years sleeping < 7.7 hours compared to those sleeping > 7.7 hours, but no group differences were found in total ADHD global scores.[50] Likewise, there were no relationships between children sleeping less than 10 hours and their affective scores or reported peer/family relationships, but those sleeping ≥ 10 hours reported better overall health.[15]

In contrast, the literature review showed a clearer relationship between sleep duration and mental health among adolescents, 13–18 years of age. Adolescents sleeping ≥ 9 hours of sleep had significantly better life satisfaction scores, fewer general health complaints, and better quality relationships with family compared to those sleeping less.[15] Of greatest concern in the adolescent population are associations between short sleep duration and suicidal thoughts/behaviors and substance abuse. In one cross-sectional survey of 27,939 adolescents, participants who slept 7–8 hours reported less feelings of hopelessness, less tobacco use, less alcohol use, less illicit drug use, fewer suicidal thoughts, and fewer suicidal attempts compared to participants who reported sleeping 6–7 hours per night.[51] Of note, this study showed a negative correlation between more sleep and less concerning behaviors, but after 9 hours of sleep, an increase in these behaviors was noted. This finding suggests a U-shape curve to sleep among adolescents in which too little or too much sleep is associated with mental health problems and substance abuse. To this point, another study showed that teens sleeping ≤ 5 hours and ≥ 10 hours had more suicidal attempts than those sleeping 8 hours per night.[52]

In summary, there are limited data for infants 4 months to 1 year, but based on the literature, 14.5 hours of sleep seems appropriate. Available longitudinal data on sleep duration for toddlers suggests that at least 13 hours of sleep are beneficial for future mental health outcomes. In school-aged children, there are conflicting data, but children sleeping at least 10 hours report less health complaints and children with < 8 hours of sleep have increased reports of ADHD behaviors. Experimental data suggest at least 9 hours of sleep is necessary for adequate behavioral functioning. In teens, data suggests that 8–9 hours of sleep seems optimal for mental health and < 8 hours is associated with increased inappropriate behavior, including suicidal attempts, and substance abuse. In this population, more than 10 hours of sleep was also associated with an increase in suicidality, although causality cannot be ascertained.

### 3.5 Immunologic Health

The panel reviewed only 13 studies with respect to loosely defined immunological health and sleep duration. All studies were cross-sectional, observational, or cohort design, and none were randomized controlled studies. The number of participants varied from as few as 54 to just under 1,500. The majority of study participants were older children, adolescents, and teenagers. Sleep duration was measured via a mix of self-report, parent report, actigraphy, or in some cases, the method of measurement was not even reported.

One study suggested that sleep duration of 8–8.9 hours was associated with a healthier immune profile (cortisol, immune cell counts, and cytokines).[53] Another study noted an inverse relationship between CRP and sleep duration with higher CRPs noted in those sleeping less than 8 hours.[46] Other studies showed no relationship between sleep variables and inflammation (fibrinogen, IL-6, and CRP).[54] No studies suggested too much sleep was harmful.

In summary, based on very limited and less than ideal quality evidence, it would seem that sleep durations less than 8 hours are associated with worse overall immunological health, and that optimal sleep is between 8–9 hours for older children and adolescents.

### 3.6 Human Performance

The human performance domain included a wide range of outcomes including: neuropsychological testing (e.g., emotional responses, cognitive performance, academic achievement); school grades; rating scales for attention, behavior or executive functioning; ratings scales for behavioral persistence (sustained attention), well-being, health behaviors and complaints; suicide or accident risk; subjective reports of daytime sleepiness; and measured electroencephalography (EEG) arousals. Most studies were cohort or cross-sectional studies of community-based populations; prospective, longitudinal cohort data were rare. Some studies utilized a case-control study design. Other studies used an experimental design to compare the effects of sleep deprivation or sleep extension to the control condition. The number of participants ranged from less than 100 in most of the case-control or experimental studies to over 3,000 in some of the cohort studies.

In a small experimental sample of 10 children aged 30–36 months, loss of a daytime nap resulting in total 24-h sleep duration of less than 11 hours was associated with more negative emotional responses.[55] In preschoolers, sleep durations of less than 8 hours in the previous 24 hours were associated with a more than 2-fold increased risk of accidental falls.[56] In a large prospective longitudinal cohort study of 1,492 children aged 6 years, it was found that children with sleep durations less than 10 hours as toddlers and preschoolers had higher parent-reported hyperactivity indices and lower cognitive performance.[57] In 812 school-aged children, sleeping less than 9 hours per night was associated with worse teacher-reported academic achievement, but did not impact domains of attention, motivation, or relationships.[58] In 74 children ages 6–12 years,

one week of sleep restriction to 6.5 hours resulted in increases in teacher-reported academic difficulties and attentional problems compared with "optimized" sleep (at least 9 hours).[59] In 33 children ages 7–11 years with a mean baseline sleep duration of 9 hours 20 minutes, sleep extension of approximately 30 minutes was associated with improved alertness; whereas modest sleep restriction (approximately 1 hour) had opposite effects.[48] Among 77 children ages 9–12 years with a baseline sleep duration of 8.1 hours, cognitive performance testing improved with a 1-hour extension, but worsened with a 1-hour restriction.[60] In 32 children ages 8–12 years with a baseline sleep duration of 8.8 hours, 4 days of sleep restriction to 8 hours compared to 4 days of sleep extension to 9.3 hours, resulted in impairment of memory and attention.[49]

Several studies reported on both school-age and teen participants. Self-reported sleep durations of less than 10 hours for children and less than 9 hours for adolescents were associated with increased somatic health complaints (higher odds ratios) when compared to their full sleep conditions.[15] Among 3,011 children 6 to 16 years, short sleep duration (less than the median hours for each of 4 age groups defined by school grade levels) was associated with self-reported daytime tiredness in school.[61] In a large sample of 1,691 participants ages 10–19 years, sleep duration that was one hour less than "optimum" self-reported sleep (which varied by age) predicted lower academic achievement scores, with a larger effect on the older group.[62] This study also suggested a U-shape effect where much longer sleep durations were associated with worse performance.[62] In a small sample of 16 adolescents, 5 nights of experimental sleep restriction to 6.5 hours resulted in inattention, diminished learning and lowered arousal in a simulated classroom when compared to a "healthy" sleep condition of 8 hours.[63] Lower parent-ratings of executive function and participant performance were associated with self-reported sleepiness in an urban cohort of 236 teens, but not with sleep duration measured by actigraphy.[64] Among a large cohort of 2,716 teens, sleeping less than 8 hours per night was related to more self-reported tiredness, inferior behavioral persistence (sustained attention), less positive attitude toward life, and lower school grades, as compared to sleeping longer durations.[65] Daytime tiredness and behavioral persistence mediated the relationship between short sleep duration and positive attitude toward life and school grades. Except for self-reported tiredness, there were no differences between sleeping 8–9 hours and sleeping more than 9 hours. Students who started school 20 minutes later received reliably more sleep and reported less tiredness.[65] In a large cohort of 1,564 teens, sleeping less than 8 hours was associated with lower cognitive performance for boys, but not girls.[66] Finally, in a large cohort of 1,362 teens, sleeping less than 8 hours, compared to more than 9 hours, per night was associated with greater risk of suicide, while sleeping 8 to 9 hours was not.[67]

In summary, among various outcomes that comprise human performance, there are sufficient and compelling data to support recommendations for sleep durations of at least 11 hours for toddlers, 10 hours for preschoolers, 9 hours for school-aged children, and 8 hours for teenagers to support optimal performance.

### 3.7 Developmental Health

Many studies in the developmental health domain targeted the associations between sleep duration and neurobehavioral and neurocognitive measures. There was significant overlap in studies reviewed for this domain, most often with the mental health and human performance domains. Sample sizes ranged from 10 participants (randomized cross-over design) to 35,956 (meta-analysis). There were often methodological issues about assumptions of directionality of relationships and variation in reference categories used for "normal sleep duration." The covariates differed widely by study and there was significant heterogeneity in outcomes. Results also differed by gender and ethnicity. The panel members noted that besides being associated with child development, short sleep duration has the potential to affect parent-child interactions, which increases the complexity of health interactions.

Short sleep duration has a negative association with cognitive performance in a number of age groups based on longitudinal (< 10 hours,[57] < 9 hours,[58] < 11 hours[68]) and cross-sectional (< 9 hours[15,69]), (< 8 hours[70]), (< 11 hours[71]) studies; however, some studies have reported a U-shape relationship with too much sleep time associated with poorer cognitive performance.[68]

For children aged 11–13 months, the proportion of total daily sleep occurring at night has been positively correlated with the development of communication and problem solving skills.[72] Young children's poorer language function was positively associated with shorter sleep hours during the night.[73] For preschoolers (4 years) and school-aged children (10 years), short sleep duration (< 11 hours) was negatively associated with receptive vocabulary.[74] Poor emotional regulation and reactivity have been associated with short sleep duration (30–36 month-olds,[55] 18-month-olds[47] for < 13 hours, and 2.5–6 year-olds for < 10 hours[57]), but one study reported a U-shape relationship.[75] Shorter sleep duration has been associated with poorer morning and daytime mood in infants.[76] As mentioned above in the mental health domain, short sleep duration at 18 months (< 13 hours) predicted more emotionally reactive and aggressive behavior at 5 years.[47] Persistent short sleep duration (from 0 to 7 years) has been associated with higher levels of child irritability and poorer emotional functioning.[9]

Additionally, naps may be important. Missing one nap by preschoolers produced more negative emotional responses[55] and nap provision improved toddlers' performances on a generalization task[77] and grammatical language patterns 24 hours later[78] compared with non-nap groups.

In one study, sleeping less than 8 hours per night was associated with poorer cognitive performance on reasoning abilities for adolescent boys but not adolescent girls.[66] Another study showed that adolescents had positive associations between sleeping less than 8 hours and poorer school grades.[65] The single meta-analysis of 35,956 children aged 5 to 12 years did not specify sleep duration, but reported that longer sleep duration was associated with better cognitive performance (e.g., implicit memory, intelligence, and school performance) and fewer behavioral problems.[79] Shorter sleep duration has been linked to school-aged children's and adolescents' attention

problems,[49,59,63,80] restless/impulsive behavior[48] (< 9 hours) and deterioration in vigilance[60] (30-minute sleep restriction).

The cited range for normal sleep duration is wide, ranging from 14.5 hours during infancy[9] to 9–10 hours at school entry and pre-adolescent children[9,81,82] to about 8.5 hours in late adolescence.[83] Studies do not consistently exclude forms of sleep problems. For example, in younger children, the proportion of sleep at night, sleep efficiency and difficulty settling demonstrate the complexity of explicating relationships between sleep duration and developmental well-being.[72,73] A large, cross-sectional study of 4–9-year-olds did not demonstrate consistent relationships between sleep duration thresholds and learning, based on parent-completed 24-hour time-use diaries.[84] Only at ages 6 to 7 years did they report a positive relationship between at least 10 hours of sleep per night and mathematical thinking, language, and literacy based on cutoff points on diagnostic categories from teacher report. The findings were difficult to interpret because plots showed most children averaged between 10 to 12 hours of sleep per night. Thus the variance in sleep duration appeared quite limited and the dichotomizing of measures into problem/no problem reduced the information available for testing.

In summary, there appears to be consistent relationships between inadequate sleep duration and development of children's cognition, language, memory, executive function, emotional regulation, and reactivity.

### 3.8 Longevity

This area focused on sleep patterns in pediatric age groups and how those patterns affect longevity. Seventy-four studies were identified in the initial review. Thirty-seven of the studies associated sleep duration with accidents, suicidal ideation, insomnia, stress, depression, or anxiety. The other 37 studies associated sleep duration with cardiovascular, metabolic, pulmonary, allergy/atopy, and obesity-related conditions. None of the articles either evaluated or demonstrated any direct relationship between sleep duration and longevity in the pediatric population. Although some of the associations, such as increased risk of suicidal ideation or adverse cardiovascular risk factors could impact longevity, those outcomes were not specifically addressed in any of the studies. Therefore, no recommendation was made for optimal sleep duration at any age as related to longevity.

## 4.0 STRENGTHS AND WEAKNESSES OF THE LITERATURE

The panel recommendations were based on literature characterized by several strengths. Taken together, studies on sleep duration include data on hundreds of thousands of children and teenagers, studied across several continents, aggregated over several decades. The studies include cross-sectional and longitudinal epidemiologic designs, randomized controlled trials, meta-analyses, and a range of other designs. Studies in the mental health category appear to have the strongest evidence.

A number of important limitations in both epidemiologic and lab-based studies are also evident. First, most of the studies reviewed were cross-sectional, thus findings were correlational, precluding statements of causation. Second, sleep duration was ascertained for a limited time frame around the assessment, with multiple ages grouped together despite obvious differences in development. For example, some studies included participants aged 8–18 years, and it is unknown how the results would have differed had the participants' data been grouped as pre-adolescent vs adolescent with a different age cut-off. Some studies may have had insufficient adjustment for confounders. Additionally, without prospective, long-term studies, pediatric sleep duration data on outcomes such as longevity are lacking.

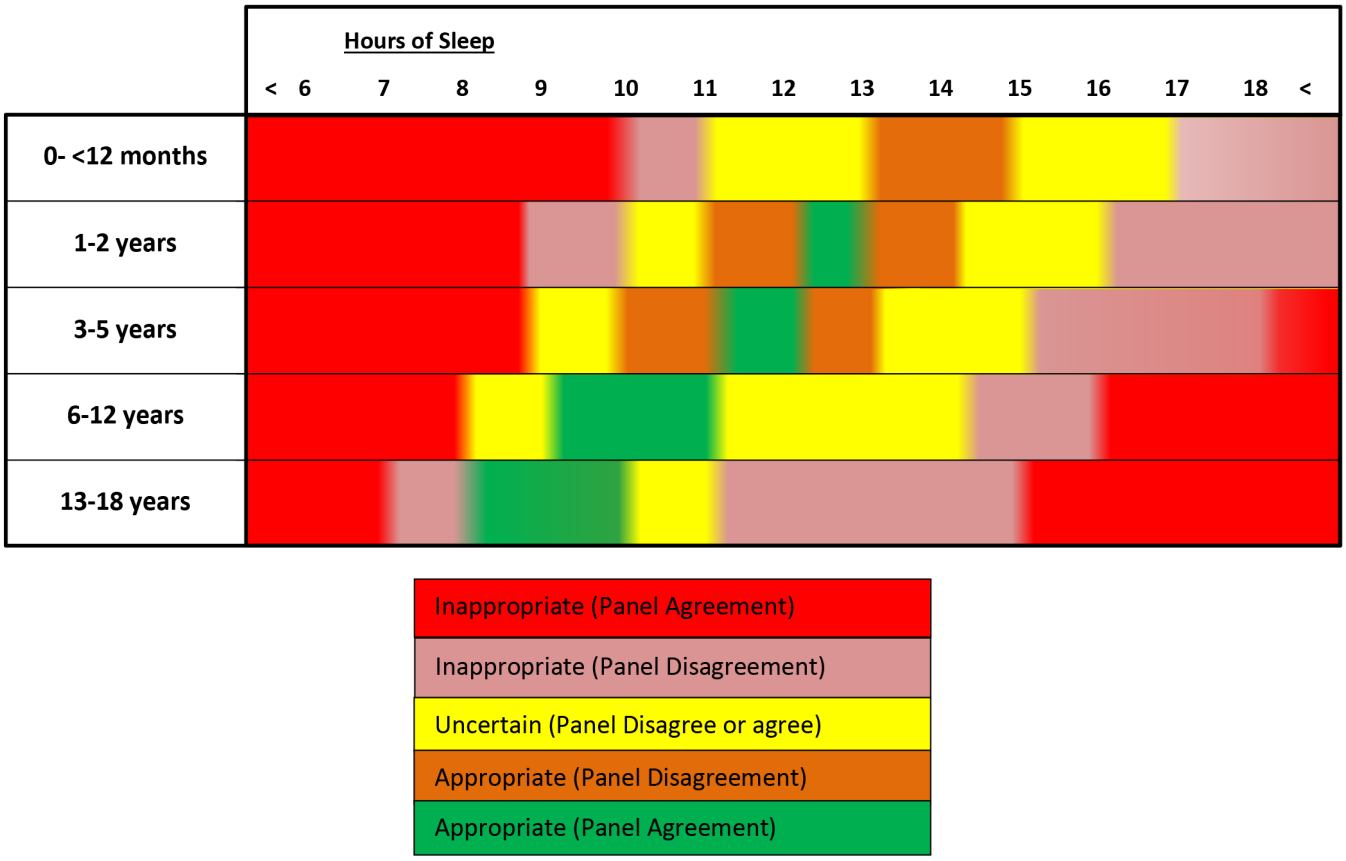
Furthermore, the methods of sleep assessment present limitations. Most studies described sleep duration obtained from parental report, or child report when age-appropriate. This may be less accurate than averages from daily report on sleep diaries. Parent- or self-reported duration may over- or underestimate sleep duration measured objectively by actigraphy or polysomnography. Additionally, studies varied in how sleep duration was reported, i.e., per 24 hours or overnight sleep. Duration reporting was discussed extensively by panel members to determine the best means to evaluate the available literature and provide appropriate sleep duration recommendations in the predefined age groups of children. Survey questions often had good face validity, but most were not formally validated with psychometric analyses. Multiple surveys also gathered health outcomes such as height, weight, and lists of medical problems, by parental or child report; relying on these reports may be a source of measurement error. Also, measures of sleep duration often do not capture information about the regularity of sleep patterns, the timing of sleep, or the quality of sleep, all of which could directly affect sleep duration and health outcomes.

Experimental designs have important limitations as well. Most studies included short periods of sleep duration manipulation, almost always < 2 weeks. The acute effects of sleep deprivation may not approximate real-world effects of chronic sleep deprivation. Few studies examined sleep duration in the range between 8 and 12 hours. This likely reflects the aim of experimental studies, which often try to maximize differences in outcomes by contrasting extreme sleep duration groups. The absence of experimental groups in these sleep duration ranges creates some uncertainty in recommendations due to lack of data. Many studies also lack generalizability because of small sample sizes that may not represent the population in terms of age, sex, race, ethnicity, socioeconomic status, or health history. Many studies investigated groups of children across multiple ages at different developmental stages, but reported a single result. PSG measurements of sleep duration may not be an accurate measure of typical sleep duration given the different sleep environment (lab) and weak correlations with parental or child self-reported duration.

## 5.0 VOTING SUMMARY

Voting results from all 3 rounds are presented in **Figures 1–3**. Napping was discussed for age appropriate groups, and reflected in the final recommendations for children through age

**Figure 2**—Round 2 voting results.




Round 2 voting was based on voting across all age groups under the following seven domains: cardiovascular health, developmental health, human performance, general health, immunology, mental health and metabolic health.

5 years explicitly, with the understanding that some healthy children up to age 7 years may habitually nap. The panel discussed several reasons for why short or long sleep durations may be inappropriate for each age group after incorporating findings from the literature and criteria for sleep disorders. All values are per 24 hours.

For infants, there was consensus that < 12 hours of sleep per 24 hours was inappropriate to support optimal health. There was also consensus that a range of 12 to 16 hours was appropriate to support optimal infant health. Consensus could not be reached on 16 to 18 hours due to uncertainty given the lack of data in this sleep duration range. However, there was consensus that ≥ 18 hours of sleep was inappropriate. There was also consensus that no recommendations could be made in infants < 4 months of age, due to the paucity of published outcomes in infants this young.

For children aged 1 to < 3 years, there was consensus that sleep duration of < 10 hours was inappropriate. There was consensus that 11 to 14 hours per 24 hours was appropriate. Uncertainty was observed in the 10–11 hour range and 14 to 16 hour range, with panel consensus that sleep times longer than 16 hours in this age group were inappropriate.

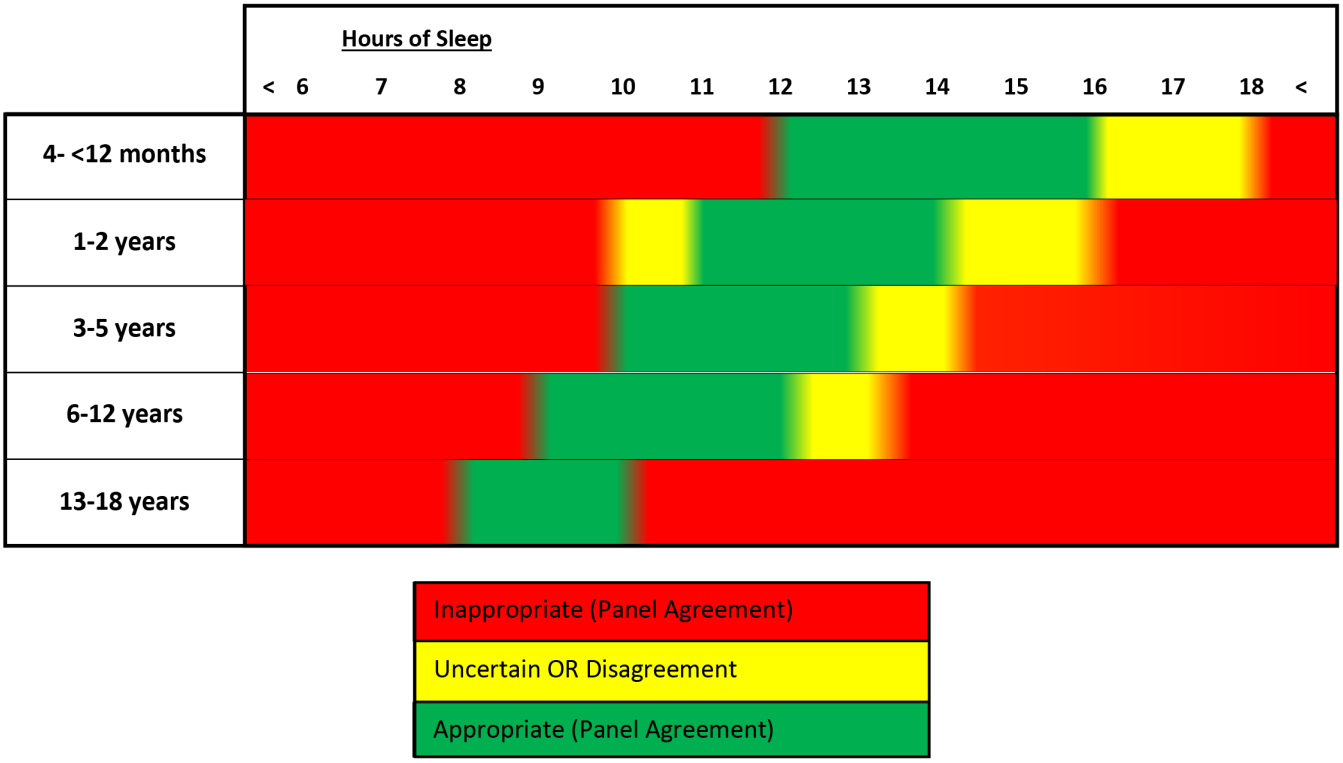
For children aged 3 to < 6 years, there was consensus that sleep duration of < 10 hours or more than 14 hours was inappropriate. There was consensus that 10–13 hours of sleep was appropriate. Uncertainty existed in the 13 to 14 hour duration range. The panel discussed that the sleep needs of a 3-year old preschooler may be vastly different than the sleep needs of a 6-year old first-grader.

For children aged 6 years to < 13 years, there was consensus that sleep duration of 9 to 12 hours was appropriate and that > 13 hours was inappropriate. There was uncertainty if 12–13 hours of sleep duration was appropriate.

For teenagers aged 13 to 18 years of age, there was consensus that < 8 hours or > 10 hours of sleep on a regular basis was inappropriate. There was consensus that 8 to 10 hours was appropriate for optimal health.

The panel discussed the merits of recommending sleep durations for multiple age groups vs collapsing all age groups to recommend 1 single sleep duration threshold. Implicit to a range recommendation is the conclusion that sleep duration above a certain amount of sleep is detrimental to health. The literature supported a clear cut-off in optimal sleep duration in the teenager group, as there were unambiguously better health outcomes within the recommended range, and clear negative outcomes and an increased likelihood of sleep disorders when nightly sleep durations were < 8 hours or > 10 hours. Within other age groups, due to the wide age ranges in studies and lack

**Figure 3**—Round 3 voting results.




Round 3 voting is based on voting summary across all age groups.

of published literature, there was often uncertainty on the outer ends of the agreed upon appropriate sleep duration ranges. The panel also discussed consideration of nap duration for age appropriate children. With these considerations in mind, the panel voted to recommend ranges for each age group. No age groups were collapsed and no age groups were further separated during the in-person meeting because voting in Round 1 had already taken place.

## 6.0 DISCUSSION

Sleep is a necessity for health. Meeting the need for sleep duration, timing, regularity, and quality requires volitional behaviors by parents and children, which are partially dictated by genetic and physiologic factors. However, a large proportion of inter-individual variability in sleep is likely explained by psychological, behavioral, social, cultural, and environmental factors. Sleep disorders also contribute to this variability.

For reasons stated above, the panel focused solely on the dimension of sleep duration, while recognizing the importance of other factors such as timing, regularity, and quality. The recommendations provide sleep durations that promote optimal pediatric health, but do not address other sleep factors. The panel excluded studies that focused on sleep factors other than sleep duration and studies that focused on total sleep deprivation (no sleep for 24 hours). Total sleep deprivation is not sustainable and thus not reflective of habitual sleep, which was the focus of the panel. In general, the total sleep time is high in infants and toddlers, with gradual reduction over time as one approaches pre-adolescence and adolescence. This change parallels the ontogeny of cerebral metabolism that was studied in 100 healthy children using positron emission tomography.[85] The reduction in total sleep time over the first decade is felt to be related to an initial overproduction, and subsequent pruning away of unnecessary synapses.[85]

All panel members agreed that too little sleep for each age group was unhealthy. The panel discussed thoroughly the appropriateness of longer sleep durations for each age group. The panel discussed the higher likelihood of sleep disorders often being associated with longer sleep times, which was then incongruent with sleep duration for *optimal* health. Another consideration was the lack of studies in children on sleep extension. There were a few U-shape curves that showed that both, too little and too much sleep were associated with poorer outcomes. The panel strongly encourages future experimental studies to examine the effects of sleep extension on health outcomes.

The panel recommendations reflect typical or habitual sleep duration, i.e., the ideal average sleep duration. However, the panel discussed that sleep duration in the real world is a dynamic process. Many children, particularly those who have experienced a delay in their circadian rhythms in puberty, have variable sleep schedules depending on school start times, work, and extracurricular activities that may curtail sleep on weekdays and extend sleep on weekends. More studies are needed to better characterize effects of this "social jet lag."

The panel discussed heterogeneity of sleep duration measurement at length: subjective report vs (more) objective actigraphy, parental report vs child self-report, time in bed vs time asleep, and inclusion vs exclusion of naps. Several studies have shown that self-report may differ substantially from objective measurement.

Polysomnography and actigraphy were utilized in some studies as objective measurements of sleep duration, and the panel discussed the strengths and limitations of these studies. Actigraphy may over-estimate sleep duration relative to self-report in poor sleepers. PSG directly records sleep, however, other factors such as "first night effect" or logistics such as set wake up times to end PSG recordings may be in place and thus not accurately reflect a typical night of sleep. Home sleep apnea testing is not currently recommended in children, and also does not provide accurate reflection of sleep time. As technology improves and the use of activity trackers becomes more widespread in the pediatric population, more data will be available to better measure sleep duration and compare time and effects within large participant samples.

## 7.0 FUTURE DIRECTIONS

The recommendations of the panel are intended to be a first step towards promoting adequate sleep duration for all children. The panel reviewed existing literature to achieve consensus, and realized that serious gaps in knowledge exist in the pediatric population. As more high-quality literature becomes available, the recommendations may change in the future. Based on this process, specific areas for future research consideration are presented:

1. Implement improved sleep duration measures and study designs, including intervention studies. As child development changes significantly from year to year, it is imperative to study narrower age groups, with validated studies and intervention designs to better delineate sleep deprivation effects on important outcomes such as mental health, physical health, and cognitive functioning. Small preliminary studies have begun to explore the effects of sleep extension on health and functioning in children. More studies are recommended (i.e., between 8 and 10 hours in adolescents) to systematically vary sleep opportunity in discrete steps between the upper and lower amounts using objective measurements of sleep physiology and cognitive performance. These studies should also examine longer time periods (e.g., 30 days), including weekdays and weekend days, to develop more precise dose-response curves for sleep and recovery effects within the ranges most often reported by children and parents. Studies that mimic typical sleep-wake cycles and lifestyles in each age group are needed.
2. Investigate downstream mechanisms linking habitual sleep duration to health and functioning. Intervention studies are needed to help clarify whether modifying sleep duration improves health outcomes in children. Such studies will help to explain whether sleep duration has a causal role in health and functioning vs operating as a marker of other processes.
3. Delineate the upstream physiologic, behavioral, social, and environmental factors that may play a role in sleep duration and health outcomes. Studies are needed to identify how genetics relate to individual sleep need and the response and resilience to sleep loss. Studies are also needed that explore the roles of race, ethnicity, socioeconomic factors, neighborhoods, school start times, and other factors that contribute to sleep duration.
4. Identify biomarkers of sleep need or sleep deprivation. Inexpensive, reliable, and feasible biomarkers could advance the goals of clinical care, public health, and public policy. In the future, biomarkers may allow clinicians to provide more accurate sleep schedule recommendations to children, parents, and policy makers to facilitate policy decisions (e.g., school start times and teen driving). Biomarkers may greatly assist research assessment of the long term consequences of sleep deprivation.

## CONCLUSIONS

The 13-member panel used a modified RAND Appropriateness Method to generate consensus recommendations for the amount of sleep to promote optimal health in children. Multiple rounds of evidence review, discussion and voting were conducted to arrive at the final recommendations. Additional research on the role of sleep duration at different stages in a child's growth and development will help increase the awareness of the importance of sleep and lead to improved health and well-being for children and families.

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