CLINICAL REVIEW

What are the determinants of children's sleep behavior? A systematic review of longitudinal studies

Laura S. Belmon [a, b, *], Maartje M. van Stralen [c, **], Vincent Busch [b], Irene A. Harmsen [b], Mai J.M. Chinapaw [a]

[a] Amsterdam UMC, Vrije Universiteit Amsterdam, Department of Public and Occupational Health, Amsterdam Public Health Research Institute, Van der Boechorststraat 7, NL-1081 BT, Amsterdam, the Netherlands
[b] Department of Epidemiology & Health Promotion, Section Youth, Municipal Health Service Amsterdam, the Netherlands
[c] Faculty of Science and Amsterdam Public Health Research Institute, Department of Health Sciences, Vrije Universiteit Amsterdam, the Netherlands

ARTICLE INFO

SUMMARY

To develop evidence-based healthy sleep interventions for children, this review provides insight into the behavioral determinants of sleep behavior. Hence, the objective of this review is to systematically review the longitudinal evidence on determinants of children's sleep behavior.

Studies were identified from searches in PubMed, PsycINFO, and Web of Science, until January 2017. Longitudinal studies investigating the association between potential determinants and sleep behavior (duration, quality and timing) in healthy children aged 4—12 years were included. The methodological quality was scored and the results were summarized using a best-evidence synthesis. We followed the PRISMA statement guidelines in order to summarize the evidence accurately and reliably.

Twelve of the 45 included studies were rated as 'high quality'. We found strong evidence for child age and moderate evidence for screen time, past sleep behavior, and a difficult temperament as determinant of sleep duration. For determinants of sleep quality, evidence was either insufficient or inconsistent. We found moderate evidence for week schedule as a determinant of sleep timing, with later bed- and wake times in weekends. More high quality studies, which are extensive, collaborative, and multidisciplinary, are needed into the determinants of all dimensions of sleep behavior.

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Abbreviations

None.

Glossary of terms

None.

Introduction

Healthy sleep behavior can be defined as the combination of adequate sleep duration, good sleep quality, and regular sleep timing [1—4]. Healthy sleep behavior has been associated with improved quality of life, and a lower risk of being overweight, type 2 diabetes and cardiovascular disease [5—7]. Despite these health benefits, an increased number of children are not meeting the recommended amount of sleep of 9—12 h per night [8]. For example, Singh and Kenney (2013) found that the percentage of US children aged 6—17 years with fewer than 7 days of adequate sleep, at least 9 h per night, increased from 31% in 2003 to 42% in 2012 [9]. Additionally, previous studies have reported poor sleep quality among children [10—13]. Moreover, a recent meta-analytic review showed that 13% of Dutch children aged 6—13 years have difficulty falling asleep and 7% with sleeping through the night [14]. Thus, interventions that stimulate healthy sleep behavior in children seem warranted.

To develop healthy sleep interventions for children, it is crucial to know which factors (or determinants) underlie healthy and unhealthy sleep behavior. Previous reviews of mainly cross-sectional studies investigated several behavioral correlates of sleep, such as screen behavior and electronic media use [15—17].

* Corresponding author. Amsterdam UMC, Vrije Universiteit Amsterdam, Department of Public and Occupational Health, Amsterdam Public Health Research Institute, Van der Boechorststraat 7, 1081 BT Amsterdam, The Netherlands.
** Corresponding author. Faculty of Science and Amsterdam Public Health research institute, department of Health Sciences, Vrije Universiteit Amsterdam, De Boelelaan 1105, 1081 HV Amsterdam, the Netherlands.
E-mail addresses: l.belmon@vumc.nl (L.S. Belmon), maartje.van.stralen@vu.nl (M.M. van Stralen).

These reviews found that screen time, mobile devices and TV-related factors (i.e., amount of TV viewing, presence of a TV in the bedroom, TV content) are related to unhealthy child sleep [15–18]. Furthermore, Bernier et al. [19] reported in their narrative review that different social-environmental and psychological factors within the family environment are important for children's sleep, such as parental psychological adjustment, parenting, and parent-child attachment security. Finally, a recent review [18] showed that establishing a bedtime routine contributes to healthy sleep in young children. These routines include calming activities, such as story-telling, bath-time or a massage. However, these earlier reviews were mainly based on cross-sectional studies [15–18], providing a lower level of evidence. Therefore, the focus of this review will be on longitudinal studies, which includes evidence from stronger study designs, as these studies measure an exposure at a time point prior to the health outcome [20,21]. Furthermore, most of these reviews were limited to only one determinant category [16,17,22]. However, someone's health is not only part of, and influenced by, behavioral determinants at the individual level, but it is also influenced by the environment someone lives in, such as their family (e.g., parents, caregivers, grandparents), social networks (e.g., classmates, neighbors), organizations (e.g., sport clubs, primary school), communities, and societies [23,24]. This implies that we need an overview of all potential determinants for a socio ecological approach to healthy sleep intervention development.

Our review specifically focuses on primary school-aged children, as children's sleep behavior is different from that of preschool- or secondary school children [25], and likely the determinants will be as well. In many countries, around the age of 4 years, children start (pre)school, which implies the development of a new daily routine. Then, around the age of 12 years, a time that children usually start their secondary school education and when they experience changes in their biological sleep rhythm [25], there are again major changes in their sleep routines.

Therefore, this systematic review summarizes the current evidence on potential determinants of children's sleep behavior for the age of 4–12 years based on longitudinal studies, taking into account their methodological quality. It aims to provide an overview of determinants of children's sleep behavior and stimulate future intervention development of healthy sleep interventions for children.

Methods

We performed a systematic search in PubMed, PsycINFO, and Web of Science until 6 January 2017. The search strategy included three elements used in AND-combination: 1) sleep behavior (e.g., sleep, bedtime, night waking), 2) determinant (e.g., association, relation, predictor), and 3) age (e.g., child, preschool, primary school, elementary school). Terms were used as MeSH-headings when available and title or abstract search. The full protocol including the search strategy can be accessed at PROSPERO (https://www.crd.york.ac.uk/PROSPERO/), registration number CRD42017060562.

Eligibility criteria

Eligibility criteria were as follows:

1) Subjects were healthy children.
2) The dependent variable was a measure of sleep behavior (i.e., sleep duration, sleep quality or sleep timing) assessed at a mean age between 4 and 12 years.

3) The study had a longitudinal design, meaning that the determinant was measured at a time point prior to the sleep outcome [20,21].

We excluded articles that focused on specific target groups (e.g., narcolepsy, apnea), certain publication types (e.g., editorials, case reports), and included only peer-reviewed articles published in English.

Study selection

First, two independent reviewers (LB and MvS or VB) screened all titles and abstracts that were identified through the database searches for potentially relevant articles. Where there was disagreement about the utility of an article, the article was reviewed in the full-text phase. The reference lists of all relevant articles were checked for additional records. Next, two independent reviewers (LB and MvS or VB or IH) checked the full-text papers. Any disagreement was discussed with a third researcher, until we reached consensus. This resulted in 45 papers that met the eligibility criteria.

Data extraction

Data from the full papers was extracted by one researcher (LB) and checked by a second researcher (MvS) using a piloted form, designed for this review. Consensus was reached by discussing disagreements. If no consensus was reached a third reviewer (VB or IH) was consulted. The following data were extracted from the included articles: 1) study characteristics (i.e., authors, year of publication, country, cohort), 2) characteristics of the study population (i.e., number of participants, age, gender, race/ethnicity), 3) follow-up period, 4) measure of sleep behavior, 4) type of determinants, 5) type of statistical analysis, 6) confounders, and 7) main results. We aimed to present the most accurate, complete results from each included study. Therefore, multivariable analyses were presented where possible and otherwise univariable analyses were presented. In addition, subgroup analyses were presented when performed for specific subgroups based on age, gender, socioeconomic status, or ethnicity.

Definition of sleep behavior

Sleep behavior includes the domains sleep duration, sleep continuity or efficiency, sleep timing, alertness or sleepiness, and sleep quality or satisfaction [4]. Daytime alertness or sleepiness was not included in this review, because we considered this to be an outcome of short sleep duration, irregular sleep timing or low sleep quality [26].

- **Sleep duration** was defined as the amount of sleep obtained within 24 h [4].
- **Sleep quality** was defined as a composite of identifiable sleep features such as sleep efficiency, sleep latency, night awakenings and wake after sleep onset [3], but also the subjective assessment of 'good' or 'poor' sleep [4].
- **Sleep timing** was defined as the placement of sleep within the 24 h day [4] and the variability in this sleep placement, including the variability in bedtimes and wake times.

Categorization of determinants

Determinant was defined as a factor that is longitudinally associated with sleep behavior. The determinants were divided into different categories: demographic (e.g., age, gender, ethnicity),

biological (e.g., body composition, puberty status), psychological (e.g., affect, stress), behavioral (e.g., screen time, physical activity, past sleep behavior), social environmental (e.g., parent–child relationship), and physical environmental (e.g., TV or computer in the child's bedroom) determinants. The determinants were presented separately per sleep outcome (i.e., sleep duration, sleep quality, and sleep timing). The results were scored as positive (+) when a positive significant association was found, as negative (−) when a negative significant association was found, and scored with (0) when an insignificant association was found. An association was considered significant at a p-value of ≤ 0.05.

Quality assessment

The criteria list for assessment of the methodological quality of the included studies can be found in Table S2. The quality assessment tool of Chinapaw et al. [27] was used to assess study quality, which was based on existing quality criteria lists [28–30]. The list of 13 items is categorized in four dimensions: 1) study population and participation (three items); 2) study attrition (four items); 3) data collection (three items) and 4) data analysis (three items). Furthermore, some criteria relate to informativeness (I, 5 items) and some to validity/precision (V/P, 8 items). The validity/precision criteria were: 1) the participation rate at baseline was at least 80% or the non-response was not selective; 2) response at short-term follow-up (i.e., up to 12 months) was at least 80% and the response at long-term follow-up was at least 70% of the number of participants at baseline; 3) there was not selective non-response during follow-up measurement(s); 4) adequate measurement of the determinant(s); 5) adequate measurement of sleep behavior outcome(s); 6) the determinant(s) is/are assessed at a time point prior to the measurement of the sleep behavior outcome(s); 7) the statistical model used was appropriate; and 8) the number of cases was at least 10 times the number of the independent variables. A study was scored as positive (1) if the study provided an informative description of the criterion at issue and met the quality criterion; as negative (0) if a study provided an informative description, but an inadequate performance or if the study lacked a description; or as unknown

(?) if the study gave an unclear or incomplete description of the item. The maximum points given to a single criterion was 1. Criterion 8 and 9 were scored on a scale ranging 0–1. For example, if a study assessed four different determinants of which one was measured by a reliable tool a score of 0.25 was given. A positive score was given only if the paper described the instrument, which was used to measure determinant(s) or sleep outcomes, as valid or reliable and referred to a validity/reliability study or if the study used a valid objective measurement instrument. We then traced the studies to which the authors referred, to determine the reliability/validity scores of measurement instruments used in the included studies. Instruments that measured sleep behavior outcomes that we considered valid were polysomnography and actigraphy [31–35], although recent research has shown that actigraphy has some drawbacks [36,37]. For biological/demographic variables, a positive score was given if a standardized protocol was followed, and trained researchers assessed the determinants. A positive score was also given to standard socio-demographic determinants (e.g., age, gender, household size). If the study referred to another publication describing the design or other relevant information about the same study, we retrieved the additional publication to score the criteria of concern. Two researchers (LB and MvS) independently assessed the quality of the studies. Any disagreement between the two researchers was discussed and if necessary resolved with a third researcher (VB or IH). For each study, we calculated a total methodological quality score by counting the number of items that had scored positively on the validity/precision (V/P) criteria divided by the total number of validity/precision criteria (i.e., 8). We considered a study to be of high quality if the methodological score was at least 0.75, i.e., 75% of items scored positively. A lower score was defined as low quality.

Level of evidence

Best evidence synthesis was applied to summarize the results and draw conclusions regarding the level of evidence. We based the rating system on that of Chinapaw et al. [27], consisting of three levels (i.e., strong, moderate, insufficient). We divided the level
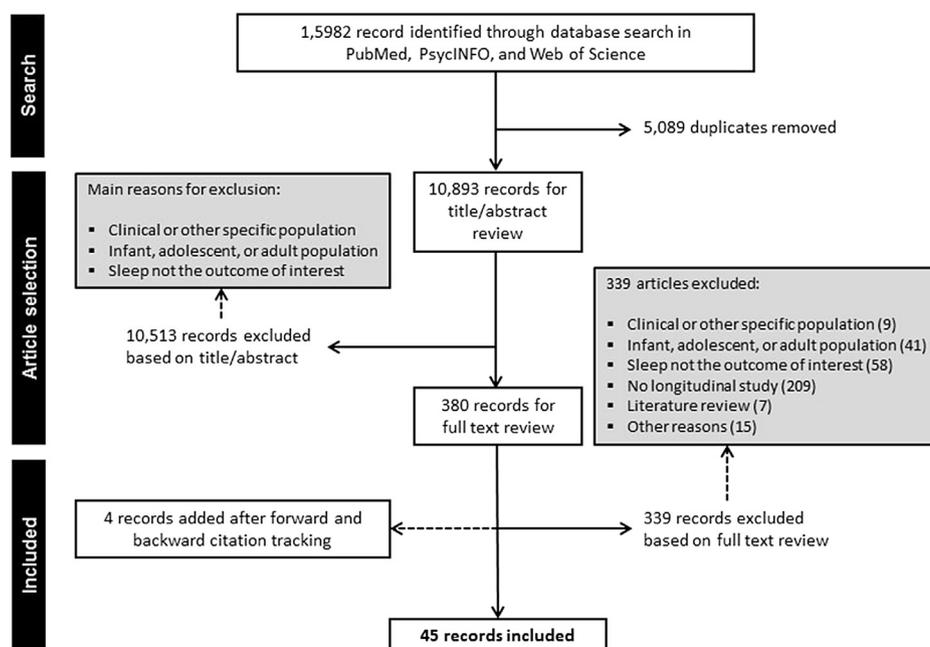

Fig. 1. Flow chart of the review process.

Table 1
Evidence for the determinants of sleep duration.

Determinants	# samples	LoE[a]	Association with sleep duration	
			High quality studies	Low quality studies
Demographic determinants				
Child age	3	S	− [38,40]	− [39]
Higher SES	7	Inc	+ [38,41,42]	+ [44,45] 0 [43,46]
Gender (male)	6	Inc	0 [42] [47][b] − [38,41] [47][b]	0 [45–39]
Ethnicity/race (non-white, non-native)	4	Inc	0 [42]−[38]	0 [43] [45][c] − [45][c]
Maternal age	1	Ins		0 [45]
Maternal fulltime employment	1	Ins		− [44]
Family structure	4	N		0 [43–46]
Biological determinants				
Puberty	2	Inc	0 [40]−[38]	
Gestational length	1	Ins		0 [45]
Birth weight	1	Ins		0 [45]
Illness/disorder	1	Ins		+ [48]
Body composition (i.e., BMI, fatness)	3	N	0 [50]	0 [48,49]
Stress response system	2	N	0 [51]	0 [48]
Psychological determinants				
Temperament	2	M		− [44,46]
Anxiety symptoms	2	Inc	0 [41]	− [46]
Self-regulation	1	Ins		+ [52]
Depression symptoms	1	Ins		− [41]
Externalizing symptoms	1	Ins	0 [41]	
Evening affect (i.e., positive and negative)	1	Ins		0 [53]
Activation (arousal of affect)	1	Ins		+ 0 [53][d]
Deactivation (arousal of affect)	1	Ins		0 [53]
Stress	1	Ins	0 [54]	
Loneliness	1	Ins		0 [55]
Mother's perception of the positive qualities of the child	1	Ins		0 [46]
Behavioral determinants				
Past sleep behavior (i.e., duration, quality)	7	M	+ [40]	+ [43,46,48,63–65] 0 [46]
Screen time (i.e., combination of TV, computer, video games)	4	M		− [56–59]
TV viewing	5	M		− [45,58,60–62]
Computer use/gaming	2	Inc		0 [58]−[62]
Sleep problem	3	Inc	0 [47]	0 [63–44]
Bad dreams	1	Ins		0 [46]
Mandatory nap time at child care centers	1	Ins		− [66]
Mobile phone/cordless phone use	1	Ins		0 − [67]
Physical activity	1	Ins	− [68]	
Breastfeeding duration	1	Ins		0 [45]
Child play	2	N		0 [45,59]
Social environmental determinants				
Weekend schedule	3	Inc	+ [40]	0 [69]−[38]
Maternal depression	2	Inc	0 [51]	− [46]
Parental bedtime behavior	2	Inc	0 [47]	0 [46] [47][f]
Parental nighttime behavior	1	Ins		0 [46]
Regular bedtime routine	1	Ins		+ [70]
Parental monitoring of media use	1	Ins		+ [57]
Parental rules at meal time	1	Ins		+ 0 [71][e]
Frequent family meals	1	Ins		+ 0 [71][e]
Frequent activity with parents	1	Ins		0 − [71][e]
Less time spent alone after school	1	Ins		+ [71]
Parental alcohol abuse or dependence	1	Ins		0 [72]
Parent-child physical conflict	1	Ins	0 [42]	
Morning school time schedule	1	Ins		− [73]
Holiday	1	Ins		+ [69]
Sleep timing (i.e., early bedtime and late wake time)	1	Ins		+ [74]
Daily routines	1	Ins		+ [43]
Father-child attachment security	1	Ins	+ [75][g]	
Mother-child attachment security	1	Ins	0 [75]	
Maternal feeling of efficacy as a mother	1	Ins		0 [46]
Parental feeling of parental impact	1	Ins		0 [46]
Marital conflict	3	N	0 [75,76]	0 [48]
Physical environmental determinants				
Presence of media in the bedroom (e.g., TV, computer)	3	Inc		0 [62] [60][d] − [45] [60][d]
Environmental radiofrequency electromagnetic field exposure	1	Ins		− [67]
Radiofrequency electromagnetic field exposure from indoor sources (i.e., cordless phone, Wi-Fi)	1	Ins		0 [67]
Spring season	1	Ins	− [38]	
Maternal smoking	1	Ins		0 [45]

High quality studies are studies with a quality score of ≥75%. SES = Socioeconomic status; BMI = Body Mass Index.

[a] LoE = level of evidence: S = Strong, M = Moderate, Inc = Inconsistent, Ins = Insufficient, N = No evidence.

[b] Sleep duration was measured with >1 measurement instrument and the associations differed between instruments.

[c] Both nativity and ethnicity were measured showing different results.

[d] Both within subject analysis and between subject analysis were reported and showed different results.

'insufficient evidence' into two separate levels (i.e., insufficient and inconsistent). The levels of evidence take into account the number, the methodological quality (V/P), and the consistency of outcomes of the studies:

- **Strong evidence:** consistent findings in multiple (≥2) high-quality studies.
- **Moderate evidence:** consistent findings in one high-quality study and at least one low-quality study, or consistent findings in multiple (≥2) low-quality studies.
- **Inconsistent evidence:** inconsistent findings in multiple (≥2) studies.
- **Insufficient evidence:** only one study available.

Following the directions of Chinapaw et al. [27], results were considered consistent if at least 75% of the studies showed results in the same direction and if the results were significant (P < 0.05). If there were two or more high-quality studies, we disregarded the studies of low methodological quality in the evidence synthesis; those studies were therefore not incorporated in the conclusion.

Results

Description of studies

The literature search yielded 10,893 articles after duplicates were removed (Fig. 1). Based on the title and abstract, 10,513 were excluded, with another 339 articles excluded based on full text. Four more articles were identified from the reference lists of included articles, resulting in 45 studies for inclusion in this review.

The extracted data are presented in Table S1. The articles were published between 1982 and 2016 (median 2013). In total, 45 manuscripts described 39 studies based in North-America (n = 17), Europe (n = 19), Australia (n = 5), Israel (n = 2) New Zealand (n = 1) and Brazil (n = 1). The study samples at baseline ranged from 24 to 17055 participants (median n = 385). Most of the included studies used a prospective cohort design (n = 40). Other designs were cluster-randomized cross-over (n = 2), randomized controlled trial (n = 1), quasi experimental (n = 1) and natural experiment (n = 1). The majority of studies investigated two or more sleep behavior outcomes (n = 24). Fifteen studies only focused on sleep duration, four studies solely on sleep quality and two on sleep timing.

Most studies relied on child- or parent-report of sleep behavior (n = 29). Eight studies used an objective measurement instrument (i.e., actigraphy or polysomnography) to measure sleep behavior, and another eight studies used a combination of actigraphy with a subjective diary or log.

Study quality

Table S1 presents the overall quality scores. Further specification of the scores on individual quality items can be found in Table S3. The scores ranged from 31 to 94 percent. Twelve of the forty-five studies were of high quality.

Determinants of sleep duration

Table 1 presents an overview of the determinants of children's sleep duration.

Demographic determinants of sleep duration

Strong evidence for a negative association between child age and sleep duration was found [38–40]. In the study of Laberge et al. [39], this association was only found on schooldays. Inconsistent evidence was found for socioeconomic status (i.e., a combination of parental education level, socioeconomic status, household financial hardship and household income) [38,41–46], gender [38,39,41,42,45,47] and ethnicity [38,42,43,45] as determinants of sleep duration. There was insufficient evidence for maternal age [45], and maternal fulltime employment [44]. No evidence was found for an association between family structure (i.e., number of adults in family [43], household size [44], marital status [45], single parent family [46]) and sleep duration.

Biological determinants and sleep duration

There was insufficient evidence for gestational length [45], birth weight [45], and having an illness or disorder [48]. There was inconsistent evidence for puberty, as one high quality study found a negative association [38] and another high quality study found no evidence [40] for an association between puberty status and sleep duration. No evidence was found for body composition (i.e., child BMI [48,49], fatness [50]) and stress response system [48,51] as determinants of sleep duration.

Psychological determinants and sleep duration

Moderate evidence was found for an inverse association between a difficult temperament and sleep duration based on two low quality studies [44,46]. There was inconsistent evidence for anxiety symptoms [41,46] as a determinant of sleep duration. Insufficient evidence was found for an association between sleep duration and self-regulation [52], depression symptoms [41], externalizing symptoms [41], evening affect [53], arousals of affect [53], stress [54], loneliness [55], and mother's perception of the positive qualities of the child [46].

Behavioral determinants and sleep duration

We found moderate evidence for an inverse association between total screen time and TV viewing, and sleep duration. Four low quality studies showed that more screen time was associated with shorter sleep duration [56–59], while five low quality studies showed this with regard to watching TV [45,58,60–62]. Additionally, we found moderate evidence (one high quality study and six low quality studies) for a positive association between past sleep duration and current sleep duration [40,43,46,48,63–65]. Inconsistent evidence was found for computer use and gaming [58,62] and having a sleep problem [44,47,63] in relation to sleep duration. Insufficient evidence was found for bad dreams [46], mandatory naptime at child care centers [66], mobile phone/cordless phone use [67], physical activity [68], breastfeeding duration [45]. No evidence was found for an association between child play and sleep duration [45,59].

Social environmental determinants and sleep duration

Determinants of sleep duration for which we found inconsistent evidence were week schedule [38,40,69], maternal depression

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^e Both associations for follow-up and change in sleep duration over time were reported and showed different results.
^f Only for maternal active comforting at nighttime measured with a sleep diary.
^g Only for girls.

[46,51], and parental bedtime behavior (i.e., different ways of settling the child to sleep and maternal presence at sleep onset) [46,47]. We found insufficient evidence for the following parental practices: parental monitoring of media use (i.e., the combination of limit setting on amount, limit setting on content and active discussion on media) [57]; use of a regular bedtime routine (e.g., reading or telling a story, praying, talking, singing or playing a game) [70]; parental rules during mealtimes (i.e., the children have to follow rules during mealtimes, including eating their meals at the dinner table, and tasting the food that is served even if they do not like it) [71]; having family meals together [71], frequent activity with parents [71], and less time spent alone after school [71], parental nighttime behavior (i.e., different parental behaviors when the child awakes at night) [46] and daily routines (i.e., morning-, bedtime-, and eating routines) [43]. Insufficient evidence was also found for parental history of alcohol abuse or dependence [72], parent-child conflict [42], morning school time schedule [73], holiday [69], sleep timing (i.e., early bedtime and late wake time) [74], and parent-child attachment security (i.e., mutual trust, alienation, communication) [75] as determinants of sleep duration. We found no evidence for the relation between marital conflict and sleep duration [48,75,76].

Table 2
Evidence for the determinants of sleep quality.

Determinants	# samples	LoE[a]	Association with sleep quality	
			High quality studies	Low quality studies
Demographic determinants				
Child age	1	Inc		0 − [97][c]
Gender (male)	3	Inc	0 [47]−[41,42]	
Ethnicity/race (non-white, non-native)	3	Inc	+ [41,42]	− [77]
Higher SES	4	Inc	+ [41] 0 [42][c]	+ [46] 0 − [77]
Single parent family	2	Inc		0 [77][c] − [46] [77][c]
Parental age at birth child	1	Ins		0 [77]
Biological determinants				
Child BMI	1	Ins		0 − [48][c]
Illness/disorder	1	Ins		0 [48]
Stress response system	2	N	0 [51]	0 [48]
Psychological determinants				
Temperament	2	Inc		0 [46]−[77]
Depression symptoms	1	Ins	− [41]	
Externalizing symptoms	1	Ins	0 [41]	
Positive evening affect	1	Ins		+ [53]
Negative evening affect	1	Ins		0 − [53][d]
Activation (arousal of affect)	1	Ins		+ 0 [53][d]
Deactivation (arousal of affect)	1	Ins		0 − [53][d]
Loneliness	1	Ins		0 − [55][c]
Mother's perception of the positive qualities of the child	1	Ins		0 [46]
Anxiety symptoms	2	N	0 [41]	0 [46]
Behavioral determinants				
Past sleep behavior (i.e., duration, quality)	7	Inc		+ [48,63−65,77] [46] [78][c] 0 [46][c] [78][c]
Multiple causes of night waking	1	Ins		0 − [77][c]
Bad dreams	1	Ins		0 [46]
High risk for infant sleep disturbances	1	Ins	0 − [47][b]	
Screen time	1	Ins		− [59][g]
Mobile/cordless phone use	1	Ins		0 [67]
Outdoor play	1	Ins		+[g] 0 [59][c]
Total daytime PA	1	Ins	0 − [68][c]	
Daytime MVPA	1	Ins	0 − [68][c]	
Evening MVPA	1	Ins	+ 0 [68][c]	
Social environmental determinants				
Marital conflict	3	Inc	0 [75][c] − [75][cg]	0 [48]−[76][f]
Parental nighttime behavior	1	Ins		0 − [46][e]
Parent-child physical conflict	1	Ins	− [42]	
Maternal beliefs about limit setting for parental involvement at night	1	Ins		+ [78]
Parent-child attachment security (i.e., mother and father)	1	Ins	0 [75]	
Maternal feeling of efficacy as a mother	1	Ins		0 [46]
Parental feeling of parental impact	1	Ins		0 [46]
Week schedule	1	Ins	− [40]	
Parental alcohol abuse or dependence	1	Ins		0 [72]
Maternal depression	3	N	0 [51]	0 [46]
Parental bedtime behavior	4	N	0 [47]	0 [77,78] [46][e] − [46][e]
Physical environmental determinants				
Environmental radiofrequency electromagnetic field exposure	1	Ins		0 [67]
Radiofrequency electromagnetic field exposure indoor sources	1	Ins		0 [67]
Nighttime aircraft noise	1	Ins		0 [98]

High quality studies are studies with a quality score of ≥75%. SES = Socioeconomic status; BMI = Body Mass Index; PA = Physical activity; MVPA = Moderate to vigorous physical activity.
[a] LoE = level of evidence: S = Strong, M = Moderate, Inc = Inconsistent, Ins = Insufficient, N = No evidence.
[b] Sleep quality outcomes were measured with >1 measurement instrument and the associations differ between instruments.
[c] Associations differ between sleep quality outcomes.
[d] Both within subject analysis and between subject analysis were reported and showed different results.
[e] Associations are different for parental sub behaviors.
[f] Only for low SES.
[g] Only for girls.

Physical environmental determinants and sleep duration

Insufficient evidence was found for the examined physical environmental determinants.

Determinants of sleep quality

Table 2 presents the evidence for determinants of children's sleep quality.

Demographic determinants and sleep quality

We found insufficient evidence for parental age at the birth of their child [77] as a determinant of sleep quality. Inconsistent evidence was found for all other explored demographic determinants of sleep quality.

Biological determinants and sleep quality

There was insufficient evidence that child BMI or having an illness or disorder was related to sleep quality [48]. No evidence was found for an association between stress response system (i.e., the parasympathetic nervous system) and sleep quality [48,51].

Psychological determinants and sleep quality

Inconsistent evidence was found for a difficult temperament as a determinant of sleep quality [46,77]. We found no evidence for the determinant anxiety symptoms [41,46]. Insufficient evidence was found for all other examined psychological determinants.

Behavioral determinants and sleep quality

We found inconsistent evidence for an association between past sleep behavior (i.e., sleep quantity and quality) and current sleep quality outcomes [46,48,63,64,78]. We found insufficient evidence for all other examined behavioral determinants.

Social and physical environmental determinants and sleep quality

Inconsistent evidence was found for marital conflict in relation to sleep quality [48,75,76]. We found no evidence for marital depression [46,51] and parental bedtime behaviors (i.e., different ways of settling the child to sleep and maternal presence at sleep onset) [46,47,77,78]. Insufficient evidence was found for all other social- and physical environmental determinants in relation to sleep quality.

Determinants of sleep timing

Table 3 shows the evidence for the determinants of sleep timing. We found moderate evidence for a negative association between weekend schedule and sleep timing [40,69,74]. There was inconsistent evidence for child age [39,74,79] and gender [39,47,80] as determinants of sleep timing. Insufficient evidence was found for all other investigated determinants.

Discussion

The aim of this review was to summarize the peer-reviewed literature on determinants of sleep duration, sleep quality, and sleep timing in children aged 4–12 years old. Twelve of the 45 included studies were of high methodological quality. We found moderate evidence for more screen time, a difficult temperament, and unhealthy sleep behavior in the past as determinants

of shorter sleep duration. We found strong evidence for age, however, this implies that older children have shorter sleep duration, not that it is inadequate sleep. Additionally, we found moderate evidence that children have later bedtimes and wake times during the weekend compared to weekdays, which is known to affect the circadian rhythm as recently mentioned in another review [81].

Due to the low methodological quality of the included studies we found evidence for only a few determinants of children's sleep behavior. One identified modifiable determinant of children's sleep duration is screen time. Explanations for the negative impact of screen use are that it stimulates brain activity and suppresses melatonin production due to the light from screens [82]. Moreover, screen use may replace bedtime activities and routines that are relaxing [82] and possibly promote more adequate sleep duration [83]. Another finding was that the duration of sleep of older children is shorter. However, it is not clear if older children sleep less than the recommended hours, specifically less than 10 h for preschoolers (3–5 years) and 9 h for schoolchildren (6–9 years) [8] and could therefore be an interesting question for future research. Sleep duration was also shorter among children with a difficult temperament. Children with a difficult temperament can be quickly irritable, have difficulty adapting to new situations, and are usually moody [84,85]. In addition, a recent review [86] showed that being anxious can be seen as a dimension of a difficult temperament. However, our review found inconsistent evidence for anxiety symptoms in relation to the duration of sleep. Still, a difficult temperament may be a helpful determinant to identify children at risk for inadequate sleep duration. Furthermore, we found that children's sleep timing is later during the weekends. A self-evident explanation is that children do not have to attend school during the weekend and therefore parents may not enforce strict bedtimes. Previous research suggests that it is important for children to have consistent bedtimes and wake times to prevent the disturbance of their circadian rhythm [81]. This is also in line with another review [18] that found moderate support (i.e., four cross-sectional studies of which three showed consistent findings) for maintaining a regular sleep schedule with consistent sleep times. Thus, future interventions should at least focus on limiting children's screen time and promote consistent sleep timing. This may be achieved by appropriate parental practices (e.g., parental limiting of media use [57], regular use of bedtime routines [70]). However, convincing evidence for certain parental practices as determinants of healthy sleep behavior is currently lacking, mainly due to single studies of limited quality. Therefore, more high quality studies examining the determinants of children's sleep behavior are recommended. In addition, we suggest that different research fields (e.g., medicine, public health, neurology) combine their knowledge of children's sleep behavior and its determinants, because collaborative and multidisciplinary studies have the ability to examine it from different perspectives.

The determinants of children's sleep behavior found in this review exist on different levels of the socio ecological model [23,24]. These different levels are mainly the individual and interpersonal level. For example, limiting children's screen time is relevant on the individual (i.e., child) and interpersonal (i.e., parents, siblings) level. Although determinants also exist on the organizational (e.g., mandatory naptimes in child care centers), societal (e.g., environmental radiofrequency electromagnetic field exposure), and supranational (e.g., spring season) level. Therefore, healthy sleep interventions for children need to target multiple levels of the socio ecological model.

Table 3
Evidence for the determinants of sleep timing.

Determinant	# samples	LoE[a]	Association with sleep timing	
			High quality studies	Low quality studies
Demographic determinants				
Child age	3	**Inc**		+ [74][b] 0 [39][b]
				− [79] [39,74][b]
Gender (male)	3	**Inc**	0 [47]	+ [39][b] 0 [80] [39][b]
Ethnicity/race (non-white)	1	**Ins**		− [80]
Maternal education	1	**Ins**		0 [80]
First born child	1	**Ins**		0 [80]
Biological determinants				
Child BMI	1	**Ins**		0 [80]
Maternal BMI	1	**Ins**		0 [80]
Puberty	1	**Ins**	0 [40]	
Behavioral determinants				
Sleep problem	1	**Ins**		0 [63]
Past sleep behavior	1	**Ins**	+ [40]	
Screen time	1	**Ins**		− [59][d]
TV viewing	1	**Ins**		0 − [62][b]
Computer use/gaming	1	**Ins**		0 − [62][b]
Outdoor play	1	**Ins**		0 [59]
Daytime physical activity	1	**Ins**		+ [80]
Social environmental determinants				
Weekend schedule	3	**M**	− [40]	− [69,74]
Marital conflict	1	**Ins**	− [76][c]	
Maternal active comforting at bedtime	1	**Ins**	− [47]	
Maternal active settling by movement at bedtime	1	**Ins**		0 [47]
Maternal presence at bedtime	1	**Ins**		0 [47]
Morning school time schedule	1	**Ins**		+ − [73][b]
Early sleep timing (i.e., early wake- and bedtime)	1	**Ins**		+ [80]
Holiday	1	**Ins**		− [69]
Physical environmental determinants				
Presence of media in the bedroom (e.g., TV, computer)	1	**Ins**		0 [62]
Maternal smoking during pregnancy	1	**Ins**		0 [80]

High quality studies are studies with a quality score of ≥75%. BMI = Body Mass Index.
[a] LoE = level of evidence: S= Strong, M = Moderate, Inc = Inconsistent, Ins = Insufficient, N= No evidence.
[b] Associations differ between sleep timing outcomes.
[c] Only for low SES for sleep onset variability, only for African-Americans for wake time variability.
[d] Only for boys.

Sleep duration was the most frequently investigated sleep outcome, most likely due to it being easier to assess than other sleep outcomes. However, healthy sleep behavior is more than meeting the recommended amount of sleep [4] and the required amount of sleep differs per child [87]. Therefore, solely focusing on sleep duration does not recognize unhealthy sleep behavior. This idea is supported by the literature, as 53% of the included studies focused on more than one type of sleep behavior. We included duration, quality and timing as sleep outcomes in our review as these indicators showed a strong relation with various health and cognitive outcomes [88–91]. However, other sleep outcomes may also be important to consider in the context of healthy sleep behavior, such as sustained daytime alertness or sleepiness [4,87]. We did not include daytime alertness or sleepiness in this review as we considered this sleep outcome to be the most common direct consequence of inadequate duration, low sleep quality and irregular sleep timing [26]. Furthermore, the National Sleep Foundation [3] adopted a more extensive definition of sleep quality: 'a combination of constituent elements or processes judged as valuable'. Indicators of good sleep quality that were judged as valuable were 'shorter sleep latency, fewer awakenings, reduced wake after sleep onset, and higher sleep efficiency'. We included this more extensive definition in addition to that of Buysse [4], which included 'the subjective assessment of 'good' and 'poor' sleep (i.e., satisfaction/ quality) and 'the ease of falling asleep and returning to sleep' (i.e., sleep efficiency/continuity). Global consensus on definitions and operational applications of the sleep dimensions is urgently needed to further this research field.

Sleep behavior was measured with a wide variety of instruments, which impedes comparison across studies. These instruments included polysomnography, sleep logs or diaries, parent- or child reported questionnaires, actigraphy or a combination of these instruments. Polysomnography (PSG) is the golden standard in sleep research [32]. However, a disadvantage is that this method is developed for the clinical setting and not feasible for measuring children's sleep in their natural environment [92]. Actigraphs can be worn by children in their natural environment and recent studies suggest that actigraphy is a reliable and valid instrument to measure sleep duration [34,37,93,94]. However, the review conducted by Van de Water et al. [92] showed that actigraphy tends to overestimate sleep duration, due to low specificity in detecting wakefulness, and therefore underestimates sleep efficiency and number of night wakings [34,37,92–94]. Questionnaires were most frequently used to measure sleep behavior. Sleep time questionnaires showed strong correlations with actigraphy when assessing sleep duration [95]; however, this is unknown for other sleep outcomes. It is still unclear what instrument or combination of instruments provides the most reliable and valid data on different dimensions of sleep behavior (e.g., duration, quality and timing of sleep) in children's natural environment, showing the need for more research on measurement properties.

The majority (73%) of the included studies were of low methodological quality. Most studies had low participation rates at baseline (i.e., <80%) or low response rates at follow-up and almost half of the studies lacked the use of valid and reliable measures for both determinants and sleep outcomes. For sleep outcomes, most studies relied on child- or parent report with unknown validity and reliability or the provided information on reliability and validity was not relevant (e.g., the paper did not refer to a reliability or validity study, the validation study was performed in adolescents or adults). Additionally, studies often presented the Cronbach's alpha scores only and handled these as reliability scores, although this only gives information on the internal consistency of items within a construct and not about the reliability and validity [96]. Studies should choose measurement tools for both determinants and sleep outcomes with adequate validity and reliability, tested in a similar population of interest.

Strengths and limitations

Strengths of our study are the systematic approach, including the extensive search in three different online databases, the cross-reference check, following the PRISMA Guidelines and the limitation to longitudinal studies. Additionally, this review focused on healthy children instead of on clinical samples, which has been the case in the majority of previous reviews. Another strength is the inclusion of a quality assessment; although it was conducted by two independent reviewers, the scoring included some subjectivity which may be seen as a limitation. Another limitation might be that despite our selection of longitudinal designs with sleep behavior as an outcome variable, the directionality of the identified associations remains uncertain and reversed causality is possible. For example, we found that a difficult temperament was associated with shorter sleep duration, while it could also be that children seem to have a difficult temperament, because they do not meet the required amount of sleep.

Conclusion

The low number of high quality studies led to only finding moderate evidence for screen time, past sleep behavior, and a difficult temperament as determinants of children's sleep duration. Thus far, the field of sleep research has been fragmented, meaning it is studied in many different fields of expertise. Therefore, more high quality studies, which are larger, collaborative, and multidisciplinary, are needed to examine the determinants of all dimensions of healthy sleep behavior. To further the field of sleep research, consensus is needed on the key dimensions of sleep, their definition and the development of valid and reliable measures.

Recommendations for practice

- Healthy sleep development in children is influenced by determinants on different levels of the socio ecological model of health promotion, and therefore needs multilevel interventions.
- Recent developments regarding digital media seem to significantly influence children's sleep.
- Sleep can be seen as a multidimensional behavior and therefore needs interventions that promotes not only healthy sleep duration but also adequate sleep efficiency, timing and quality.

Research agenda

Findings in this review may influence the direction of future research by …

- Stimulating more high quality, extensive, collaborative, and multidisciplinary research which examines the determinants of sleep behavior in children.
- Stimulating more longitudinal determinant research on sleep dimensions other than solely sleep duration, such as sleep efficiency, timing and quality.
- Addressing the need for consensus on the definitions of the different dimensions of sleep and on the best method(s) to measure these dimensions in population-based epidemiological studies, which would enable cross-study comparisons of study findings.
- Stimulating large population-based studies among healthy school children in order to support preventive intervention development which promotes healthy sleep behavior and treats sleep problems.

Declaration of interest

None.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.smrv.2018.09.007.

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