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CLINICAL REVIEW

Many naps, one nap, none: A systematic review and meta-analysis of napping patterns in children 0–12 years

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SUMMARY

The onset of monophasic sleep, in which napping ceases and sleep consolidates into a single night period, is a key developmental milestone of childhood. Yet to date, there is little consensus regarding the timing of cessation of napping in children. The aim of the current study is to examine global evidence regarding napping patterns in childhood, and, through meta-analysis, describe patterns of napping cessation and duration observed in children aged 0–12 y. A systematic search of all published, original research articles reporting children's napping patterns, by age, was conducted. The quality of studies was assessed, and meta-analysis of eligible studies undertaken. Risk of bias and heterogeneity of measurement was high. Current evidence indicates that less than 2.5% of children cease napping prior to age 2, while 94% cease napping by age 5. The preschool period (3–5 y; 36–60 mo) represents a particularly dynamic period in napping cessation, with large variation in rates of napping across studies evidencing potential ecological effects. Future studies should focus on understanding of the underlying mechanisms explaining individual variations in napping patterns and the extent to which patterns of napping may represent a marker of child development.

Introduction

The early years of life are characterised by a dynamic transition in sleep patterns [1]. As children age, sleep transitions from polyphasic sleep, characterised by multiple sleep periods across the 24-h cycle; to biphasic sleep in which napping occurs once per day; and finally monophasic sleep in which habitual napping ceases and all sleep consolidates into a single night episode. The rate of which this transition occurs varies across children and the meaning of this variation is not well understood [2,3]. The purpose of this study is to examine world-wide evidence regarding napping patterns in childhood and, through meta-analysis, describe patterns of napping cessation and duration observed in children aged 0–12 y.

Current research suggests that cessation of habitual napping corresponds to a changes in sleep need, neurocognitive function [2–4] as well as maturation of bio regulatory circadian and homeostatic processes [5–7]. A key interest is the impact of napping on 24-h sleep duration. A recent systematic review [2] reported that while napping in the first two years of life is essential for obtaining sufficient sleep, beyond this age napping is associated with reduced night sleep; thus a redistribution in 24-h sleep timing. Building evidence also suggests that the rate and timing of sleep consolidation and cessation of napping may be a marker of developmental cognitive change. A mix of review, correlational, and quasi-experimental studies describe mixed results of napping for children's cognition and learning [3,8–13]; a key distinguishing feature being the age and regular napping patterns of the children studied. Benefit for learning and emotional regulation is typically found for younger children, who are less likely to have ceased habitual napping [2,3,11,12]. One study of preschool children (3–5 y) [9], reported a positive effect of napping on learning and memory consolidation, however these effects were only observed for habitual nappers (≥5 d/wk). Correlational

Abbreviations: ASD, autism spectrum disorder; GORD, gastro-oesophageal reflux disease; PRISMA, preferred reporting items for systematic reviews and meta-analyses.

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studies based on parent reported sleep patterns suggest sleep consolidation (day/night sleep ratio) is a marker of neurocognitive maturity and show that children who cease napping earlier are more advanced on neurocognitive [7] and language assessments [14]. Further, longitudinal analyses report that later sleep consolidation is a risk factor for language delay [15]. These studies direct attention to the changing function of napping across development and suggest that individual cessation patterns may be a marker of clinical significance.

Genetic and ecological factors may influence children's napping patterns [4,15–17]. Data from behavioural genetics studies, for example, indicate that whilst early napping patterns (prior to 18 mo) are highly heritable [15,17], across time napping trajectories are increasingly explained by shared environmental effects (18-mo = 33% variance; 30-mo = 48%; 48-mo = 79%) [16]. There is also evidence of socio-cultural variations in childhood napping patterns [4,18]. For example, in a study of 29,287 infants and toddlers (birth-36 mo) across 17 countries/regions, Mindell and colleagues [19] report small, statistically significant differences in napping frequency and duration across nations. However, this study does not provide data on napping prevalence or age of cessation and does not extend beyond the first three years of life. To date there is little-to-no consensus on timing of napping cessation in children. Yet such knowledge is important in three distinct ways; 1) to inform understanding of sleep development in pediatric populations; 2) to better understand the role of napping in meeting children's 24-h sleep need and 3) to inform future research to establish reference points for distinguishing typical from atypical sleep behaviours that may signify the need for clinical investigation or intervention.

Methods

A review protocol was developed using the preferred reporting items for systematic reviews and meta-analyses (PRISMA [20,21]) guidelines and prospectively registered via PROSPORO (Registration #: CRD42015020149).

Search strategy

An extensive search for relevant studies published by December 18, 2018 was conducted using the following electronic databases: PubMed, Embase ONLY Embase.com, PsycINFO (via Ebscohost), CINAHL (via Ebscohost), Cochrane, Scopus, Web of Science, ProQuest Dissertation & Theses Global. Searches identified papers that contained the following key words: ("day time sleep" OR "daytime sleep" OR nap* OR "day?sleep" OR "sleep consolidation") AND (child* OR infant* OR bab*) AND (longitudinal OR cohort OR cross?sectional OR "population stud*") and were developed in consultation with a liaison librarian. The exact search terms, limiters used and outcomes for each database are provided in Table S1. Reference lists from papers identified by searches were also examined to identify potential papers for inclusion.

Inclusion and exclusion criteria

All published, full-text original research articles published in any language, and employing longitudinal or multiple cross-sectional designs and reporting napping in children aged 0–12 y were reviewed. Studies of children regardless of, gender, geographical location, socioeconomic status, health status or ethnic group were included. Napping was defined as periods of sleep, measured using observational (e.g., actigraphy), parent/carer or self-report (e.g., survey or sleep diary) or physiological (e.g., polysomnography) measurement that occurs during daytime hours. Studies that included napping as part of total or 24-h sleep measurement were included only if the napping component could be reasonably differentiated from night-time sleep or if napping was indicated by a ratio of day-to-night time sleep (an index of sleep consolidation). Consistent with the focus on naturalistic, changes in developing napping patterns by age, a range of study designs were excluded (i.e., single case reports, studies conducted at a single age-point and experimental studies [e.g., drug trials]).

Study selection

A four-step approach to the selection of studies was undertaken. First, two review authors independently examined the title and abstract to determine whether they met the inclusion criteria. Second, full-text versions of relevant articles were obtained, and authors conducted a preliminary screening to assess if they contained information on daytime sleep (using key words "day sleep", "daytime sleep", "nap" and "napping"). Third, full texts of identified articles were assessed against the full inclusion criteria, with rationale for inclusion or exclusion recorded. Where full text articles were not available online, the authors were contacted via email to request subsequent full-text publications. Consulting bi-lingual academics translated full-text articles published in languages other than English (N = 18). Any decisions on inclusion, data extraction and risk of bias scoring, was then completed by these authors in consultation with the authorship team. Finally, decisions for inclusion or exclusion were based on consensus amongst study authors. Where multiple studies reported on the same data source, only one study was included in qualitative and quantities analyses, with the corresponding papers indicated.

Quality assessment

The quality of each of the studies was assessed using the quality assessment checklist for prevalence studies [22]. The measure comprises 10 items, assessing both internal (selection and non-response bias) and external (measurement and analysis bias) validity. Studies are rated on each item to generate a total risk of bias score, categorised as low (0–3), moderate (4–6) or high (7–10). As napping patterns may change rapidly, the length of the shortest prevalence period was set between 1 wk and 1 mo. Consistent with reports of validity in sleep diary measurement [23], only diary report studies that included ≥3 d of diary records were rated as low risk for evidence of reliability of measurement. Two authors independently assessed and scored all articles. The initial scoring produced high agreement (ICC = 0.92). Any discrepancies were subsequently discussed to reach consensus. When insufficient information was available to accurately score an article, effort was made to obtain further detail through direct email contact with study authors prior to final assessment.

Meta-analyses

Meta-analyses were conducted to establish prevalence of napping cessation, and changes in duration of napping, by age. To establish estimates of napping cessation, all studies that provided data on the proportion of children not napping at a particular age-point were analysed. For studies that reported napping duration or absence/presence of napping, cessation was based on the proportion of children having "0-min" napping, or "no naps", respectively, within the measurement period. Napping cessation could not be estimated for studies in which frequency of napping (i.e., "regular"

or "usually" naps) was reported, as the converse of this could not be accurately assumed to be zero. The proportion of children ceasing to nap and napping duration was estimated for several age groups (≤12 mo [≤1 y; min possible = 0 − max possible = 12.99], >12.0 to ≤24 mo [>1 y to ≤2 y; 12−24.99], >24.0 to ≤36 mo [>2 y to ≤3 y; 24−38.99], >36.0 to ≤48 mo [>3 y to ≤4 y; 36−48], >48.0 to ≤60 mo [>4 y to ≤ 5 y; 48−60.99], >60 mo [>5 y; 60−155.99]) using Meta [24] (version 4.9-4), meta for [25] (version 2.0-0), and R [26] (version 3.5.1) packages. Proportions were transformed via the Freeman-Tukey double arcsine method (back transformations are presented) [27]. The Clopper-Pearson method was used to estimate confidence intervals for individual proportions [28]. Meta-analysis of duration included studies where duration averages were only based on children who napped and excluded studies where duration was inclusive of non-napping children or their inclusion could not be reliably inferred.

For meta-analysis of both cessation and duration, random effects models using the restricted maximum likelihood estimator [29] and weighted least squares were used to summarize the studies. The random effect model is presented, to provide an estimate of average napping cessation for the *entire* population of studies [30]. Weighting was used to account for study and sample size discrepancies [31,32]. Heterogeneity between studies was assessed with Cochran's Q-test [33] (significant [<0.05] p-value indicates heterogeneity) and associated I^2 statistic [34] (0−100%, higher percentage indicates more heterogeneity). Studies identified as having high risk of bias were initially excluded and re-included on the basis of results from sensitivity analysis. R code to replicate, extend and explore the meta-analyses is available in supplementary document 10 and also at Mendeley (https://doi.org/10.17632/c6bkfn9598.1).

Results

Database search and data extraction

Search results and data extraction for each search stage are presented in Fig. 1. Of the full-text papers reviewed, 343 were published in English, with the remainder published in Chinese (n = 6), German (n = 5), French (n = 4), Japanese (n = 2) and Spanish (n = 1). At the full text level, 321 articles were excluded. Nine articles provided all (n = 4) or some (n = 5) of their napping data in figure form only, which could not be readily extracted. Correspondence with study authors for these papers provided additional extractable data for two studies [35,36]. Studies without any extractable napping data were included in qualitative analyses only. In total, 44 papers met criteria for inclusion (Table 1). Forty-one papers were published in full-text in English, and one each in Chinese, German, and French. Studies included those with longitudinal (n = 24; 55%) and multiple cross-sectional (n = 20; 45%) designs.

Quality assessment

Most studies were rated as having moderate (n = 20, 45.4%) to high (n = 21, 47.7%) risk of bias (Fig. 2). Key sources of external

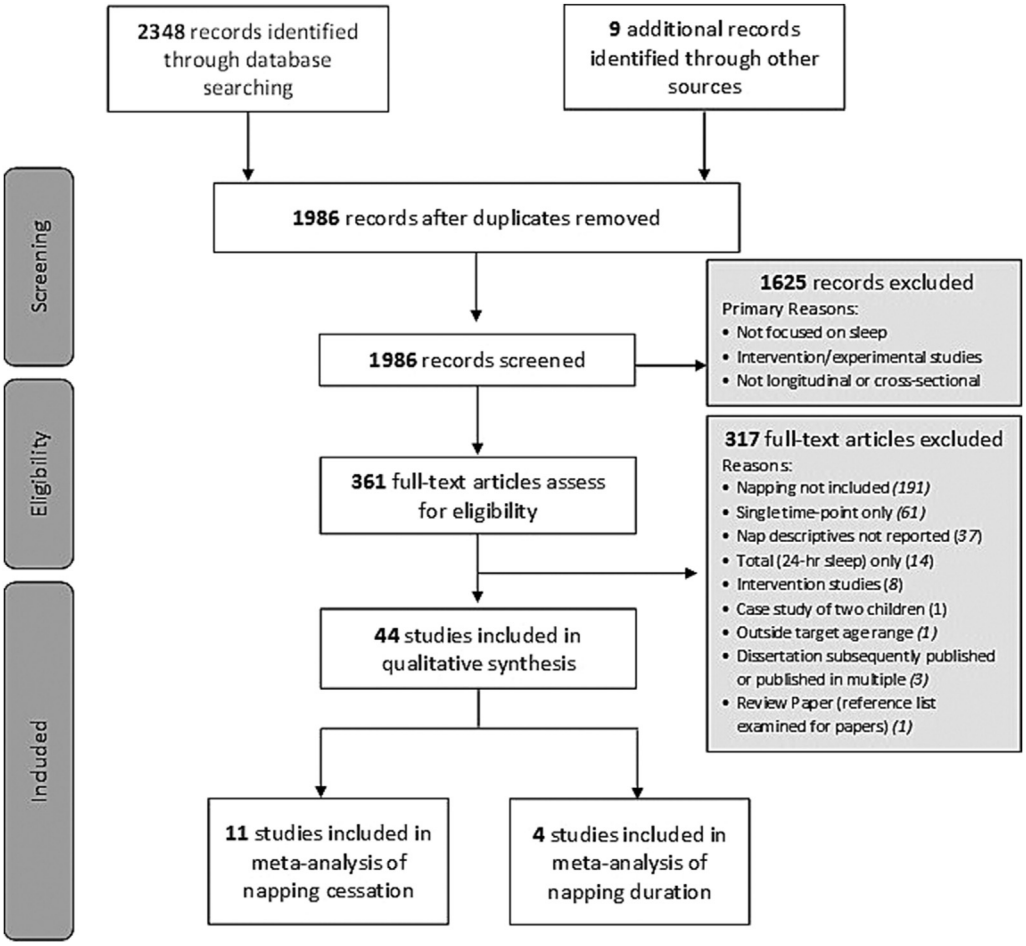

Fig. 1. PRISMA flow diagram.

Table 1
Sample, recruitment and design characteristics of longitudinal and cross-sectional studies of napping in children (0–12 y).

Reference	Study type	Country (language)	Sample (N)	Age range (Months)	Sample type	Recruitment setting	Measure[#]
Acebo et al 2005 [42]	Cross sectional	USA (English)	169	12–60	Non-clinical	Commercial survey firm, advertisements, word of mouth	P, D[i], N[i]
Aishworiya et al 2012 [43]	Cross sectional	Singapore (English)	372	24–72	Non-clinical	Local childcare centres	P, D
Armstrong et al 1994 [44]	Cross sectional	Australia (English)	3269	0–38	Non-clinical	Well-child screenings	P, D
BaHamman et al 2006 [45]	Cross sectional	Saudi Arabia (English)	1012	72–156[b]	Non-clinical	Elementary schools	P, D
Basler 1980 [46]	Longitudinal	Switzerland (German)	320	6–60	Non-clinical	Wave 1954–1979 neonatal units of a hospital[d]	P,D
Bat-Pitault et al 2017 [47]	Longitudinal	France (French)	133	6–24	Non-clinical	Maternity hospital	D
Bell & Zimmerman 2010 [48]	Longitudinal	USA (English)	1930	0–156[b]	Non-clinical	Households drawn by the census bureau	D
Blair et al 2012 [1]	Longitudinal	England (English)	11,478	6–130	Non-clinical	Expectant mothers	P, D
Bordeleau et al 2012 [49]	Longitudinal	Canada (English)	70	12–48	Non-clinical	Random birth from the Ministry of Health and Social Services	D
Bruni et al 2014 [50]	Longitudinal	Italy (English)	704	3–12	Non-clinical	Family paediatrician routine visits	D, N
Cheung et al 2017 [51]	Cross sectional	UK (English)	715	6–36	Non-clinical	Research databases, study advertisements	D
Crosby et al 2005 [18]	Cross sectional	USA (English)	1043	24–96	Non-clinical	Community sites, word-of-mouth, snowball sampling	P, D
Dong et al 2016 [35]	Longitudinal	China (Chinese)	262	1.4–12	Non-clinical	Local public hospital	D
Fernandez et al 2015 [52]	Cross sectional	Spain (English)	125	1–24	Non-clinical	Healthcare centres	D
Galland et al 2016 [39]	Cross sectional	New Zealand (English)	160	6–42	Non-clinical	Maternity clinic	D, N
Geiger et al 2010 [53]	Cross sectional	Switzerland (English)	60	90–134	Non-clinical	Primary schools	P
Ghaem et al 1998 [54]	Cross sectional	Australia (English)	102	1–36	Clinical (GORD)	Gastroenterology Department of Children's Hospital	P, D
Hanafin et al 2017 [55]	Longitudinal	Ireland (English)	29,898	9–60	Non-clinical	Random sampling from Child Benefit Register	P, D[g]
Humphreys et al 2014 [56]	Longitudinal	England (English)	10,777	6–140	Clinical (ASD)/ Non-clinical	Expectant mothers (ASD via National Educational Database)	D
Iglowstein et al 2003[h] [36]	Longitudinal	Switzerland (English)	493	6–84[c]	Non-clinical	Wave 1974-78: neo-natal units, wave 1978-93 unclear[d]	P, D, N
Laberge et al 2001 [57]	Longitudinal	Canada (English)	1146	120–156[b]	Non-clinical	French language school boards	P
Louis et al 1997 [40]	Longitudinal	France (English)	15	6–24	Non-clinical	Not reported	D
Mindell et al 2010 [19]	Cross sectional	Multi-country[e] (English)	29,287	0–36	Non-clinical	Parenting website	D[i]
Mindell et al 2011 [58]	Longitudinal	USA (English)	117	6–18	Non-clinical	"Recruited from the community"	D
Mindell et al 2016 [59]	Cross sectional	USA[f] (English)	841	0–36	Non-clinical	iPhone/iPad app for sleep in young children	D[i], T[i]
Murthy et al 2015 [60]	Cross sectional	India (English)	368	12–36	Non-clinical	Outpatient department, routine medical follow ups and crèches	P, D, N
Park et al 2002 [61]	Cross sectional	Japan (English)	615	72–1068[b]	Non-clinical	Randomly selected companies (parents were workers)	P[i], D[i], N[i]
Price et al 2013 [62]	Longitudinal	Australia (English)	10,090	4–111	Non-clinical	Australian Medicare Database	D
Schwichtenberg et al 2011 [j] [63]	Longitudinal	USA (English)	134	4–24	Clinical (pre-term birth)	Neonatal intensive care units	D, N
Seo et al 2010 [64]	Cross sectional	Korea (English)	3639	84–144	Non-clinical	Random sampling of elementary schools in districts	P, D
Smithson et al 2018 [65]	Longitudinal	Canada (English)	677	3–24	Non-clinical	Recruited during pregnancy (location not specified)	D
Sorondo & Reeb-Sutherland 2015 [66]	Longitudinal	USA (English)	40	5–12	Non-clinical	Local hospital and infant registries	D
Taylor et al 2015 [41]	Longitudinal	New Zealand (English)	194	36–84	Non-clinical	Maternity hospitals	P
Taylor et al 2018 [38]	Longitudinal	New Zealand (English)	380	12–60	Non-clinical	Single Maternity Hospital	D
Thorleifsdottir et al 2002 [37]	Longitudinal	Iceland (English)	668	12–240[b]	Non-clinical	Random sampling from National Register of Iceland	P
Tikotzky et al 2015 [67]	Longitudinal	Israel (English)	57	3–6	Non-clinical	Hospital prenatal courses, prenatal internet forums	D
Touchette et al 2013 [16]	Longitudinal	Canada (English)	983	6–48	Non-clinical	Birth records of the Quebec Statistics Institute	D[i]
Watamura et al 2004 [68]	Cross sectional	Not reported USA[a] (English)	83	12–36	Non-clinical	"Indicated interest in research participation at birth"	P, D
Weissbluth 1995 [69]	Longitudinal	Not reported USA[a] (English)	172	6–84	Non-clinical	Paediatrician's office	P, D, N
Wooding et al 1990 [70]	Cross sectional	New Zealand (English)	874	1–12	Non-clinical	Child-health community nurses provided lists	D[i], N
Yang et al 2009 [71]	Cross sectional	China (English)	1058	84–144	Non-clinical	Rural and urban primary schools	D
Young et al 2007 [72]	Longitudinal	Australia (English)	237	0–216[b]	Clinical (Rett syndrome)	Australian Rett Syndrome Database	P
Yu 2014 [73]	Cross sectional	Hong Kong (English)	1746	36–50	Non-clinical	Kindergartens	P, D
Yu et al 2017 [74]	Cross-sectional	Hong Kong (English)	1049	0–36	Non-clinical	Mailing lists from marketing firms and parenting websites	D, N

Note. [a]Location not reported, assumed from location of study authors; [b]Data extracted up to 12 y only (144 mo); [c]Full age range to 16 y (192 mo), napping only measured until 84 mo; [d]Information from email correspondence with authors, not reported in paper; [e]China, Hong Kong, India, Indonesia, Korea, Japan, Malaysia, Philippines, Singapore, Taiwan, Thailand, Vietnam; Australia, Canada, New Zealand, United Kingdom, United States of America; [f]Including Puerto Rico; [g]Duration reported for one time point only; [h]Napping data for this study also reported in [75]; [i]Data reported in figure form only; [j]Napping data for this study also reported in [32,76]; #P = Prevalence, D = Duration, N = Naps per day, T = Timing; ASD = autism spectrum disorder; GORD = gastro-oesophageal reflux disease; USA=United States of America.

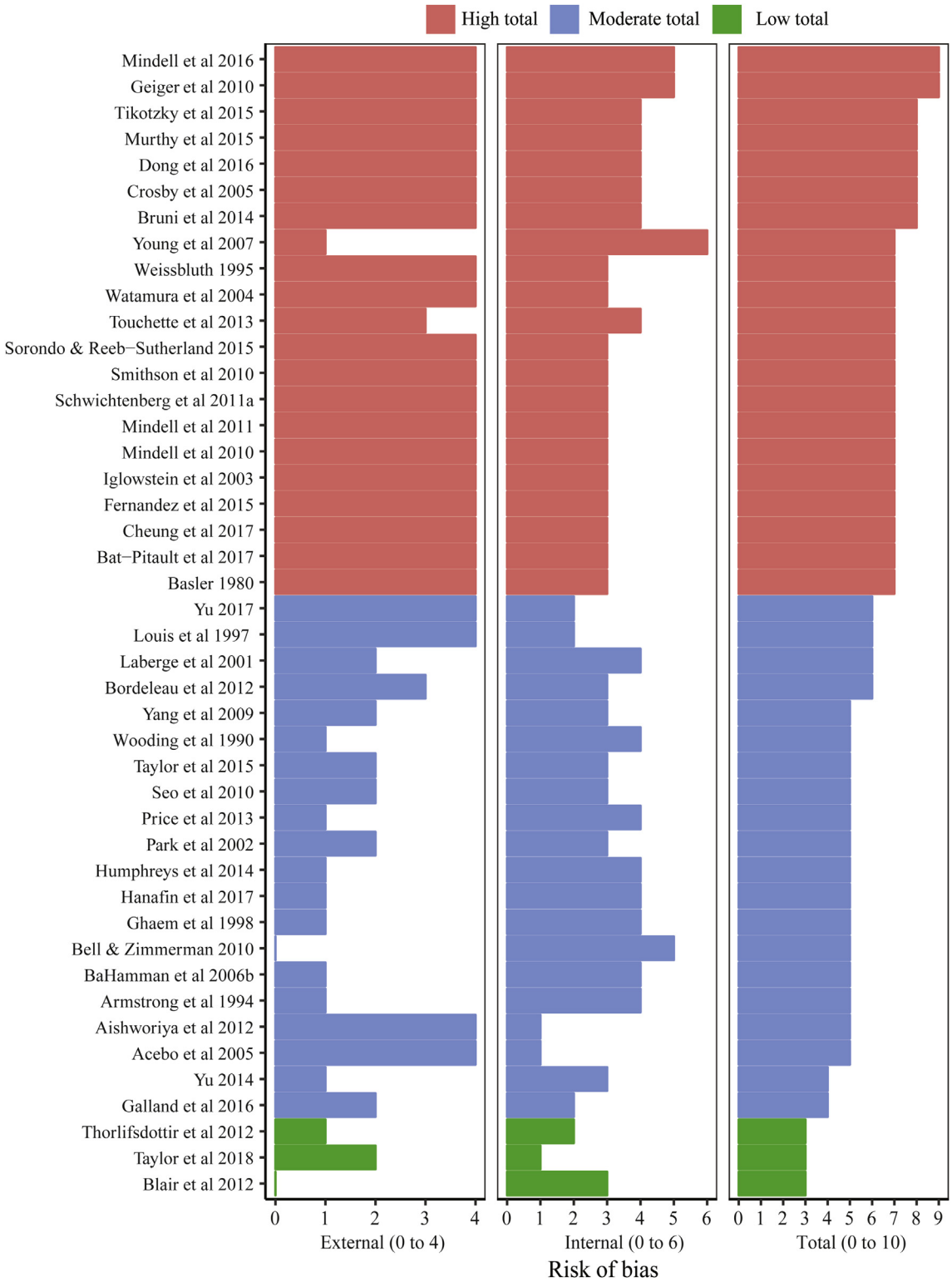

Fig. 2. Risk of bias scores, including internal and external validity, across napping studies. Note. Red = high risk (≥7); Blue = moderate risk (4–6); Green = low risk (≤3). External validity scores range 0–4; internal validity scores range 0–6; total range 0–10. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

validity biases included risks associated with the use of convenience or purposive sampling or absence of sufficient data to assess the sampling frame. Internal validity biases stemmed from use of subjective, undefined or poorly validated measurement approaches. Only three studies were assessed to have low risk of bias [1,37,38].

Sampling and design

Identified studies were conducted across European (n = 13), North American (n = 15), Asian (n = 22), and Australasian (n = 10) continents (Fig. 3). Two studies did not report the study location, so we assumed they were conducted in the country of the authors.

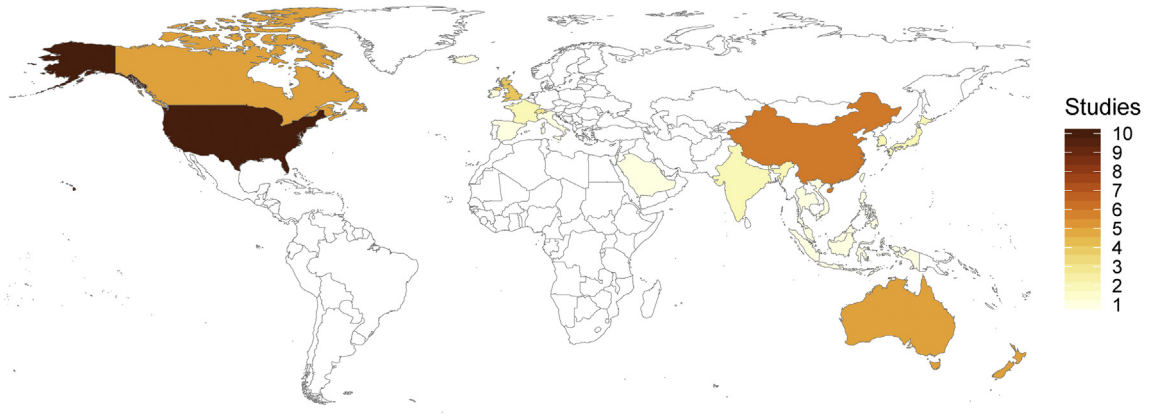

Fig. 3. Napping studies that met inclusion criteria across geographical region.

Napping data was primarily derived from parent report, including parent survey and sleep diaries. Only four studies report napping using objective measurement [38–41]. Louis et al. [40] report duration data based on polysomnography measurement of $N = 15$ children in France across 24-h periods at 3, 6, 9 12 and to 24 mo of age. Three studies, all conducted in New Zealand, report napping data based on accelerometry [38,39,41].

Napping prevalence

Napping prevalence rates by age for each study is provided in Table S2. Considerable heterogeneity in measurement of napping across studies was present, thus precluding meta-analysis. Four key approaches to measurement of prevalence were used. Frequency measurement was the most common approach ($n = 10$), and included reports of 1)*'regular'* [41,43,53] or *'frequent'* [72] napping that was undefined, 2) napping across multiple frequency descriptors (e.g., *'never, sometimes, everyday'* [36], or 3) frequency of naps per day [60,70] or week [18]. Only two studies specifically defined regular napping, but varied in definition as that occurring *'more than once per week'* [57] and *'at least 3 times per week'* [45]. Presence/Absence of napping ($n = 5$) included measurement descriptors such as the number of children *'having daytime sleep'* [54], *'who slept during the day'* [36] or *'any naps'* [42], but did not account for daily variation in napping behaviours. Five studies based napping prevalence on measurement of duration of napping, providing prevalence across duration categories (e.g., *'up to 60 min'* [55]). Only one study reported specifically on *'napping cessation'* [69]. This study, based on a sample of $N = 172$ children aged six months to seven years, from the United States of America (USA), focused on parent reports of whether children had ceased (stopped) napping naturally or whether the parent did not allow napping.

Napping cessation

Eleven studies were used to estimate cessation of napping by age [1,36,37,42,44,46,55,64,68,69,73]. These 11 studies provided a total of 73 data-points for meta-analyses (Fig. 4). Results indicate that prior to two years of age, cessation of napping is rare (<2.5%). By the time children are aged three, 33% of children have ceased napping. The largest rates of cessation occur for children across the preschool period, with 57% ceasing to nap by age 36–48 mo and 80% by 48–60 mo. The preschool period also had the largest variation in cessation prevalence rates across studies, with rates ranging from 4.8% to 65% at 36 mo (three years), 26.5%–78.2% at 48 mo (four years) and 36.9%–96% at 60 mo (five years). Beyond 60 mo of age, 94% of children had ceased napping. Exclusion of high risk studies provided slightly lower estimates of cessation (Table S3).

Geographical variations geographical areas

In general, there were not enough studies to make continental comparisons for most age groups (Table S4). However, for children 12–24 mo, European countries tended to have higher cessation rates than Australasia. Additionally, for children 24–36 mo, European countries tended to have higher cessation rates than North America.

Napping duration patterns

The most commonly reported napping characteristic was nap duration ($n = 28$ studies, Table S5). Many studies, however, reported mean duration inclusive of children who did not nap ($n = 13$) or did not clearly define the sample used to calculate duration ($n = 9$), did not include the standard deviation [42] or used a categorical measure of duration [1] and therefore could not be included in meta-analyses. Estimates were therefore based on a meta-analysis of four eligible studies [36,46,64,69]. On average, the duration of daytime naps for children was 3.1 h in infants below 12 mo, 2.3 h between age 1–2 y, 1.9 h between 2 and 3 y, 1.7 h between 3 and 4 y, 1.5 h between 4 and 5 y, and 1.1 h for children who napped beyond age five (Fig. 5, Table S6).

Napping frequency and timing

Napping frequency was reported by nine studies and showed a reduction in naps per day as children aged (Fig. S7). Studies reporting the proportion of children napping per frequency indicate a dramatic reduction in polyphasic sleep (≥2 naps/day) at 12–18 mo of age [36]. However, polyphasic sleep was still present for a small number (17.1%) of children at 30 mo [60] and was reported up to 72 mo of age (0.84%) [36].

Studies examining changes in weekly distribution of napping were limited. Two studies [18,46], provided data on children's pattern of napping across the week, with a gradual reduction in the number of days napping per week by age (Table S2). Armstrong et al. [44] also report some evidence of graduated transition to monophasic sleep, reporting children napping *every day*, *most days*, *some days* or *never*, although, the specific definition of each category were not defined. Yu et al. [73] report less prevalence of napping on weekends, when compared to weekdays.

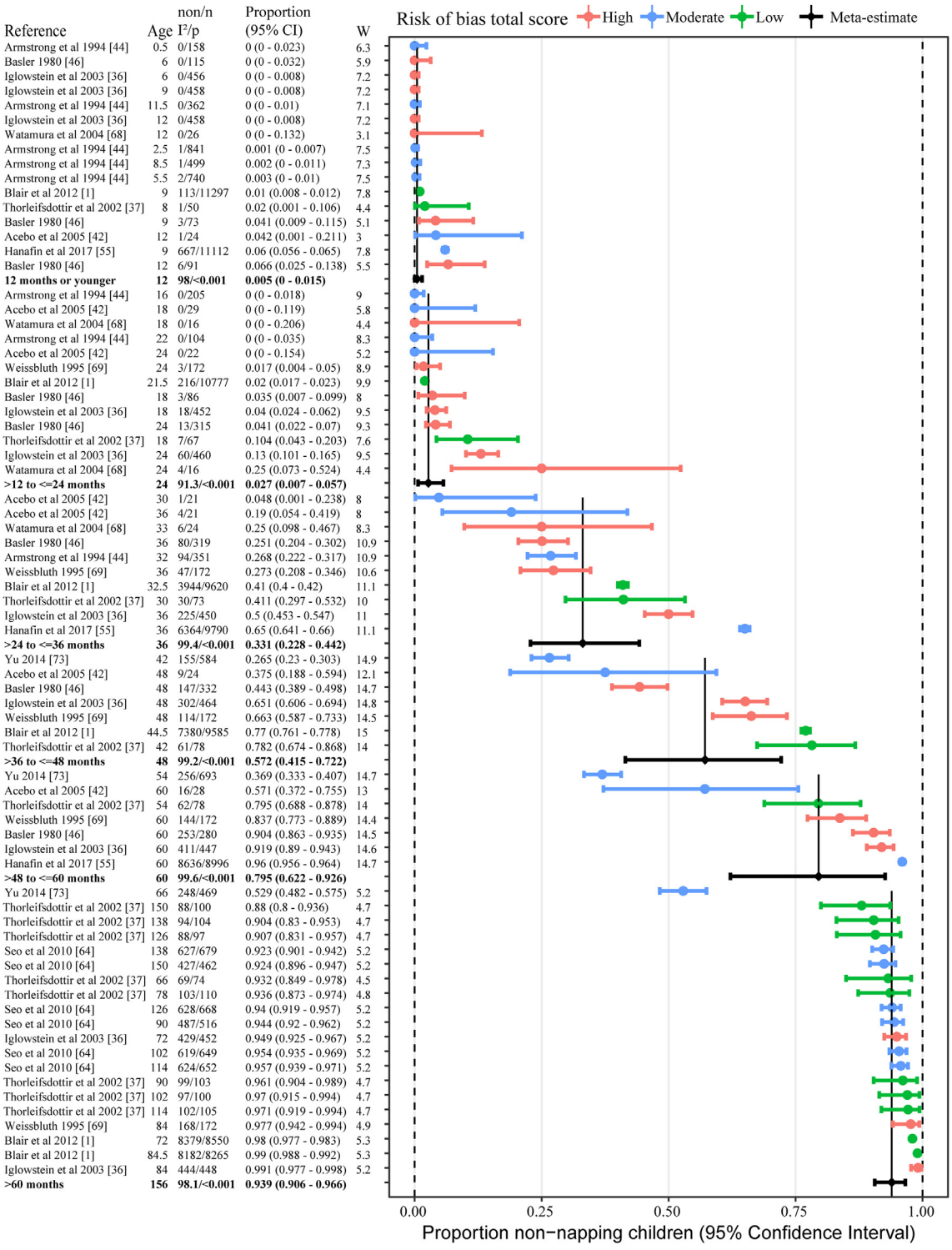

Fig. 4. Random effects meta-analysis of napping cessation by age groupings. Individual studies are ordered by proportion napping and then median age of sample range within each age grouping. Age = median of age range (months), non = number children not napping, n = number children, I^2 = 0–100 indictor of heterogeneity between studies (only for random effect rows), p = p-value for I^2 and if less than 0.05 means significant heterogeneity (only for random effect rows), and W = weighting in random effects analysis.

Only one study [59] reports on the timing of naps by age. This paper analyzes parent report data collected across an 18-mo period via a free digital phone sleep diary application in the USA. Data includes reports for 841 unique children (birth −36 mo) and includes 156,989 recorded sleep periods. Mapping of napping patterns against time of day, show both high individual variation in nap timing, and also distinct changes across age. A bimodal napping pattern emerged from 8 to 12 mo of age with naps clustering around 09:30 and 14:00 h, and from 13 to 34 mo, the timing of naps converged towards the middle of the day and then gradually shift later in the afternoon (mid-point of approximately 14:00).

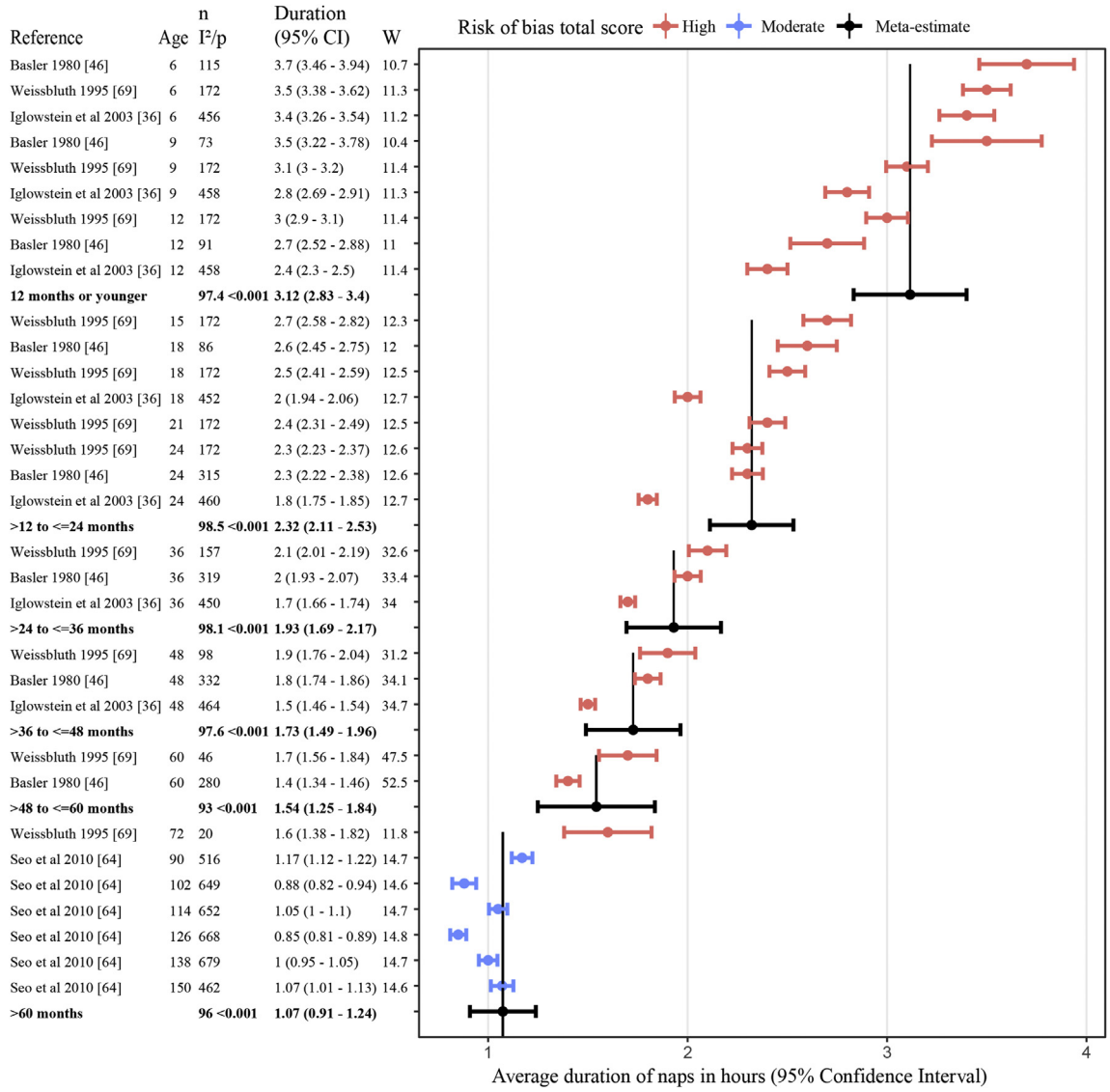

Fig. 5. Random effects meta-analysis of napping duration by age groupings. Individual studies are ordered by napping duration and then median age of sample range within each age grouping. Age = median of age range (months), n = number children, I^2 = 0–100 indictor of heterogeneity between studies (only for random effect rows), p = p-value for I^2 and if less than 0.05 means significant heterogeneity (only for random effect rows), and W = weighting in random effects analysis.

Napping patterns in clinical populations

Napping patterns in clinical populations were reported by four studies; including gastro-oesophageal reflux disease (GORD) [54], autism spectrum disorder (ASD) [56], pre-term birth [63] and Rett syndrome [72] (Table S8). Clinical studies focused on pre-term birth and autism describe napping patterns that are consistent with non-clinical samples. Infants and children with GORD showed significantly higher rates of napping (63%) compared to population norms (31%) in children beyond 24-mo only, likely reflecting compensation for disrupted night-time sleep [54]. Finally, children with Rett syndrome were reported to have high overall frequency of napping (70% in children 8–12 y) relative to non-clinical population norms and mutation specific variations in napping patterns [72].

Discussion

The aim of this review was to examine global evidence regarding napping patterns in childhood and, through meta-analysis, to describe patterns of napping cessation and duration observed in children aged 0–12 y. In total, 44 papers were identified and reviewed; the majority was of low to moderate quality. The extant literature describes a universal pattern of decline in napping prevalence, duration and frequency across childhood. For most children, this transition is completed within the first five years of life. Three distinct phases in the transition to napping cessation are evident. First, prior to 24 mo of age, napping is common, with rates of cessation less than 2.5%. Beyond this phase, acceleration in cessation rates is evidenced, alongside a notable widening of variation in prevalence across studies and global regions. Finally, beyond five years of age, consistent with school entry in most nations, the majority of children have ceased napping and continuation of napping is uncommon (8%).

Behavioural genetic studies of napping provide data that underpins the three distinct patterns described. These studies suggest that in the first two years of life genetics make a significant contribution to nap patterns, whereas beyond this period there is an increasing shared environment explanation for variations in napping patterns [15–17]. That our sample captures populations from different global regions and cultures, almost certainly increases the

variability, reflecting ecological effects. The current data provides initial data to inform future research and efforts to establish reference values for typical napping patterns and those that are atypical. Clinical samples, whilst limited in number, suggest that napping may be associated with disruption of night sleep, as in the case of GORD [54], or specific genetic disorders [72]. However, the extent to which napping in the absence of clinical diagnoses is a marker of disorder warrants further investigation.

Neurophysiological research suggests that the biological drive to nap across the early years of life reflects an interaction between a developing circadian ('body clock') timing and a sleep-wake homeostatic ('sleep drive' accumulation) processes [5–7]. These homeostatic processes appear to attenuate across childhood, such that sleep pressure accumulates more slowly and thus, developing individuals are able to stay awake for longer periods across the day [5,77]. The changes in both the frequency and duration of napping across age are consistent with the dynamics of this process. For example, the current study showed a 50% reduction in napping duration across the first five years of life. The wide variation in napping cessation timing (between 2 and 5 y for most children) may also be indicative of individual variation in such neurophysiological and cognitive processes [6,7].

Limitation and future directions

Considerable issues of external validity were identified across studies. Few applied sampling frames to achieve population representation. Given that there are evident environmental factors that influence napping patterns [15,16], particularly across the preschool years [16], sampling will likely affect prevalence estimates. Almost all longitudinal and multi-point cross-sectional studies of napping have been based on European and USA populations, with limited studies from the Asia–Pacific region and no studies from African or South American Continents. For this reason, current understanding of napping patterns is restricted to specific geographical and cultural populations and cannot be generalized more broadly. Future studies examining the longitudinal patterns of napping across diverse cultural and geographical contexts are necessary.

The use of heterogeneous, un-validated and poorly defined napping measurements is a key limitation. Problems with measurement included a lack of consensus in the definition of napping, imprecise and ill-defined response categories, lack of objective measurement (i.e., reliance on parent report) and aggregation of data in a form that could not be readily interpreted (e.g., inclusion of non-napping children in duration estimates). Studies of napping patterns using objective measurement were rare ($n = 4$) and provide a direction for improvement of measurement in future studies. Such measures would allow for greater understanding of the process of change in napping across time, including nap timing, daily variation in napping patterns, associations with 24-h sleep cycles and the possibility of re-emergent napping (e.g., in circumstances of illness or change in care arrangements).

There is also the potential for individual studies to bias the results. Due to overlapping ages and age ranges of children between studies, studies were allocated to groups based on the median value of the possible total age range (as observed age range was sometimes unavailable). These age allocations will affect the meta-analysis results. Readers are encouraged to be aware of each studies possible age range, the associated confidence interval for each study and how a study may differentially affect meta-analysis estimates.

Finally, the current study focused on reported and observed napping patterns in children 0–12 y. Whilst this data can help to inform us what children "do" in regards to napping, it is important to note that this may vary from what children "should do". There is evidence that napping behaviours are influenced by a number of environment factors, including parent sleep practices [50], child-care attendance [73], social-economic assets [63], parent work patterns [73] and technology use [51] (see Table S7). Sleep behaviours within the population may also change across time [36]. Future studies that account for potential variations in sleep need versus sleep opportunities are a critical next step in informing future establishment of normative reference values for napping in children.

Conclusion

This study examined global evidence to describe napping patterns in children aged 0–12 y. The results suggest three distinct phases of napping development, consistent with changing genetic, biological, and environmental influences on children's sleep. The current study highlights the need for greater consensus and care in both the measurement and reporting of napping in young children, including greater utilization of objective measurement approaches. Future studies should focus on understanding of the underlying mechanisms explaining individual variations and group trends in napping patterns and the extent to which individual patterns of napping may represent a marker of broader social and cognitive development.

Practice points

Napping cessation prevalence rates are useful to:

1. inform understanding of sleep development in pediatric populations;
2. better understand the role of napping in meeting children's 24-h sleep need;
3. inform future efforts to establish reference points to distinguish typical sleep development, from atypical development that may warrant investigation and/or intervention.

Research agenda

Increased studies of napping patterns in children, applying objective and consistent reporting standards, are warranted.

These studies should include:

1. measurement of napping across diverse geographic populations;
2. extend beyond point-prevalence rates to identify:
   i. longitudinal patterns of napping transitions, through the application of objective, ambulatory measurement and a focus on intra- and inter-individual variations;
   ii. social and genetic determinants of napping cessation patterns;
   iii. short- and longer-term developmental consequences of timing of napping cessation;
3. account for potential variations in sleep need, versus sleep opportunities; a critical step in establishing normative reference values for napping in children.

Contributors' statement page

Dr Staton led the systematic review, analyses and writing of the paper. Mr Rankin undertook analysis and contributed to writing of paper. Ms Harding undertook searches, screening and extraction of data, and contributed to analyses and writing. Ms Westwood, Associate Professor Smith, Professor Thorpe and Associate Professor LeBourgeois contributed to synthesis of the studies and reviewed and revised the manuscript. All authors approved the final manuscript as submitted.

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Conflicts of interest

None.

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Appendix A. Supplementary data

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