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CLINICAL REVIEW

Cross-cultural disparities of subjective sleep parameters and their age-related trends over the first three years of human life: A systematic review and meta-analysis

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SUMMARY

Changes in nighttime sleep consolidation and daytime discontinuation have been observed in early life. Yet information about societal or cultural factors remains scant for implementing sleep recommendations. We aimed to provide pooled estimates of subjective sleep duration, number of nightwakings and sleep timing; to describe their age-related trends; and to determine potential cross-cultural disparities between predominantly-Asian (PA) and predominantly-Caucasian (PC) regions during the first three years of life. We performed this review according to the PRISMA guidelines. Overall, 102 studies with 167,886 children aged 0–3 y from 26 different countries/regions were included. Compared to PC regions, PA toddlers had shorter sleep duration and more frequent nightwakings. When PC regions were further divided into Pacific Rim and Europe, differences were much more evident between PA and Pacific Rim for all nighttime sleep parameters. Trends of nighttime sleep duration and bedtime for PC regions showed rapid changes over the first 3–6 mo before stabilizing to a plateau, whereas a different change was found for PA regions. In conclusion, an apparent cross-cultural disparity of the subjective sleep parameters already exists in early childhood. Improved operationalization of sleep parameters and more objective evidence are needed to establish cultural-sensitive recommendations this early in life.

Introduction

In recent years, sleep has attracted a growing attention as a vital part of public health [1]. Accumulating evidence indicates that sleep is most clearly associated with children's physical, mental, and neurobehavioral development as well as other family members' well-being [2,3]. Particularly, early childhood life is acknowledged to be a critical period in the normative transition of sleep-wake patterns [4] as characterized by nighttime sleep consolidation and daytime sleep discontinuation. Despite being a major concern for parents and physicians, early sleep problems which could persist into later life [5] are often poorly understood and managed [6,7]. The apparently important role of sleep in children's optimal development and the paucity of knowledge about sleep patterns in early childhood call for a better understanding of its normative values, developmental changes as well as its determining factors [3].

Sleep can be characterized along multiple dimensions, such as sleep quantity, quality and timing [8]. Sleep quantity, especially total sleep duration (TSD) in early life, has received much more attention from parents and sleep researchers [9]. However, sleep

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Abbreviations

CI	confidence interval
DSD	daytime sleep duration
ES	effect size
K	numbers of the included observation data
n	sample size
Ns	number of included studies
NSD	nighttime sleep duration
NSF	National Sleep Foundation
NW	number of nightwaking
PA	predominantly-Asian countries/regions
PC	predominantly-Caucasian countries
QI	Downs & Black quality index
SD	standard deviation
SE	standard error
TIB	time in bed
TSD	total sleep duration

quality (e.g., number of nightwaking, NW) and timing (e.g., bedtime) may be just as important, if not more important, than sleep quantity in predicting future health [10,11]. Furthermore, researchers have suggested that when implementing sleep recommendations, not only the sleep parameters, but individual, societal and cultural factors should all be taken into account [10–12].

Two meta-analyses [13,14] have demonstrated that adolescents from Asian countries had significantly shorter time in bed (TIB, a proxy of sleep time [15]) and later bedtimes compared to American and European youth, which may partially be due to cultural factors, such as homework ethic, time of starting school, etc. However, in early childhood, other cultural practices may influence children's sleep, e.g., parenting behaviors [16]. A large cross-cultural internet-based survey [17] indicated that children aged 0–36 mo who were from predominantly-Asian regions (PA) had significantly shorter TSDs than those of predominantly-Caucasian regions (PC), and this difference was mainly attributed to nighttime sleep duration (NSD) rather than daytime sleep duration (DSD). Two reviews [4,9] systematically summarized and compared cultural disparities in sleep behavior in early life. One systematic review conducted by Galland et al. [9] showed that within the age group of 0–12 y, children of PA had significantly shorter TSDs. However, it is unclear whether this difference could be ascribed to children of younger and/or older age specifically, and whether the difference is due to nighttime or daytime sleep discrepancies. The other one conducted by Dias et al. [4] indicated different sleep values across countries in the first 12 mo of life, though difference in sleep values did not differ between studies as a function of the country where the study was conducted. The emerging evidence of potential cultural disparities in early life [4,9,17] makes it timely to conduct a systematic review and meta-analysis on these issues.

Although sleep in early life develops rapidly, its age-related trends have not been systematically studied [18]. Most studies present age-related changes using averages or percentiles across several age points, and the few longitudinal studies depicting fitted curvilinear trajectories in early life showed inconsistent findings. For NSD, two studies [18,19] reported a nonlinear increase from 3 to 24 mo and from 6 to 48 mo; Another study [20] suggested that NSD increased in the first year, followed by a decrease until adolescence; An increase in NSD from three months onwards until stabilization around 6–12 mo has also been reported [21]. Due to different study designs, age groups and sample sizes examined, it is difficult to draw conclusions about the overall trends of sleep in early life and to compare if these developmental changes differ between regions.

Therefore, we aimed to 1) provide a global estimation of six subjective sleep parameters: TSD, NSD, DSD, NW, bedtime and waketime; 2) determine the cross-cultural disparities of these sleep parameters between regions; 3) depict sleep trends in early life; 4) investigate differences in age-related sleep trends between regions; and finally 5) conduct a meta-regression to explore underlying moderators of sleep parameters in the first three years of life.

Methods

This systematic review and meta-analysis was conducted according to the 2015 Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines [22]. The protocol was registered with PROSPERO (registration number: CRD42017076289).

Data sources and searches

The searches (Table S1) were performed on Pubmed, Embase and Web of Science electronic databases. All database searches were updated on 31 December 2018 (no lower date limit) using the following search terms (combined with free term and MeSH term): “sleep”, “baby or babies or neonate* or newborn* or infant* or toddler* or preschool*”, and “questionnaire* or scale* or diary or log or interview or survey or actigraph* or actiwatch or actimeter or accelerometer” with filters for the English language and the journal article without review publication type. To expand our search, online professional journals on sleep as well as reference lists of retrieved studies and three prior reviews [4,9,23] were searched to identify more relevant articles.

Inclusion and exclusion criteria

The inclusion/exclusion criteria (Table S2) of the literature was adapted from prior reviews assessing sleep patterns in children [4,9,13,23]. Briefly, studies were included if they were: 1) investigating non-clinic samples age ranged 0–3 y; 2) observational studies (longitudinal, cross-sectional or case-control design) with a minimum sample size of 40 [13]; 3) describing the sample characteristics in detail (e.g., sample size, sex, recruitment criteria, etc.); 4) reporting one or more of the following sleep parameters with a measure of central tendency and variance: TSD, NSD, DSD, NW, bedtime and waketime; 5) original articles in peer-reviewed journals. Exclusion criteria were: 1) non-normative samples; 2) age range of the samples surpassed our upper limit or was too big without providing age subgroup datasets; 3) experimental designs such as intervention studies or clinical trials; 4) selection bias, i.e., study population had special request; 5) case reports and case-series; 6) the work was published as a commentary, abstract or dissertation only; 7) If more than one report from the same sample were published, we included only one with data best meeting the inclusion/exclusion criteria. If different papers reported the same sample but with different sleep parameters across age-bands, we extracted data to generate a (more) complete dataset for the sample.

In general, most studies relied on subjective report of sleep parameters, e.g., via sleep diaries, questionnaires or interviews [3]. As for objective assessment, actigraphy is often used to estimate sleep-wake behavior in children's natural environment [24]. However, a recent systematic review and meta-analysis establishing normal actigraphic sleep values in children aged 0–18 y [23] indicated that due to the paucity of data collected via actigraphic

recordings in this age-range and the lack of uniformity in actigraphy brands, scoring rules and algorithms, it was too difficult to integrate data from infants into relevant age-categories. Our search strategy led to the same conclusion and we could not conduct the cultural analysis. Only two studies in PA regions applied actigraphy measurements [25,26]: one from Japan, in which children aged 19 mo, using Micro-mini RC (Ambulatory Monitoring Inc., Ardsley, NY) attached to the waist (the scoring rule: unknown) [25]; the other one from Taiwan, in which children aged three months, using Actiwatch-2 (Phillips-Respironics Co., Murrysville, PA, USA) attached to the ankle (the scoring rule: high sensitivity-80 counts) [26]. Therefore we only focused on the subjective sleep parameters in our current meta-analysis.

Study selection

Relevant studies were screened at multiple stages by two researchers (Q.M.L. and R.Y.J.) independently, as described in Fig. 1. All references were managed by reference manager software. After removal of duplicate records, the initial stage of screening was performed on the titles and abstracts. Applying the inclusion/exclusion criteria mentioned above, we decided through an iterative process whether articles were to be included for full text review and to confirm their eligibility for inclusion. Disagreements at all stages were resolved by discussion, and if agreement was not possible, a third researcher (G.H.W.) made the final decision.

Quality assessment

We used the same approach, the modified Downs & Black quality index (QI), for quality assessment as the previous systematic review [9] on sleep patterns of children aged 0–12 y, in order to increase comparability with the existing reviews. The Downs & Black assessment tool have 11 of 27 items suitable for non-randomized or observational studies [9,27] to assess the risk of bias and precision (Table S3). Two authors, Q.M.L. and S.M.D., independently evaluated each article on their quality in five domains, i.e., reporting (original item 2, 3, 5, 7 and 9), external validity (original item 11 and 12), bias (original item 16 and 20), confounding (original item 26), and power (original item 27) [9]. Higher points on the QI reflected better quality (maximum 12) with a score of eight or more implying good, five to eight implying moderate, and less than five implying poor quality of evidence [9]. The two researchers resolved any discrepancies and consulted a third researcher (Y.R.J.) in case of remaining disagreement.

Data collection process

Data items were extracted and double-checked by Q.M.L. using a predefined data extraction form, which included the publication details, study design, sample characteristics and data results. The corresponding author(s) were contacted when clarifications were needed. The co-author Y.R.J. performed a final check and any disagreement was resolved by discussion.

Age was extracted as the average in each study. Where an age-range rather than a mean age was reported, the midpoint was retained. All age-data were converted into months. When the data for males and females or other subgroups was presented separately, we combined the data to have one estimate per study. When the standard deviation (SD) or 95% confidence interval (CI) was printed, it was converted to standard error (SE). When sleep data provided in both measurements, i.e., sleep diary and questionnaire (or interview), we only analyzed the sleep diary data, considering that measurement of questionnaire usually requires recollection of the past few weeks or months child sleep patterns that might lead to a high bias. When the year of data-collection of the study was different (or absent) from the year of publication, we calculated the conducted year of a study, in a way similar to a prior review [28].

Outcome measures

Our primary outcome measures were six subjective sleep parameters reported by parents: 1) sleep quantity: TSD, NSD and DSD; 2) sleep quality: NW and 3) sleep timing: bedtime and waketime.

Table S4 showed the diversity in operationalization of the nighttime sleep parameters. Nighttime sleep quantity was either reported directly as mean values by parents (n = 29, 44.6%) or calculated indirectly as TIB (n = 19, 29.2%) from parents report of "bedtime" and "waketime" by researchers, or calculated TIB with excluding sleep latency and/or nightwaking time (n = 3, 4.6%). Ten studies estimated sleep time using sleep-wake log (i.e., diary), six of which had no details information or definition. The remaining four studies using questionnaire also had no clear definition. It is important to note that there is no standardized method to estimate nighttime sleep values using subjective tools, and there has been a mixed use of the above two definitions (i.e., parent reported mean NSD and researchers calculated TIB) [15]. In this study, we combined these together, and additionally, we also evaluated the differences between them when possible. The bedtime parameter-can also be interpreted in multiple ways. For example, some studies used the term "bedtime" or "lights off time" while others used "fall asleep time" or "sleep onset time". The waketime parameter could be phrased as "wake up time", "sleep offset time", "rise time" or "get up time". Given the limited data available, we chose to include the nighttime sleep parameters based on all above definitions.

Notably, newborns tend to have 0.5–2 h shorter sleep periods throughout the day and the consolidation of infant circadian rhythm is not established before three months [4,15], which makes it hard to define newborns bedtime at night and waketime in morning. Therefore, while the sleep timing data was extracted in all age categories, we only summarized it in children >3 mo.

Data synthesis and analysis

Meta-analysis was performed on six subjective sleep parameters. These parameters were categorized in age-bands according to the National Sleep Foundation (NSF) recommendation [29]: newborns (0–3 mo), infants (4–11 mo) and toddlers (12–36 mo). Cultural disparities among regions were operationalized based on geographical positions [17–19] (Table 1). We calculated modified QI and graphically summarized the combined risk of bias for each quality domain. Publication bias was evaluated by funnel plot. For the meta-analysis, random-effect models [30] were chosen because a posteriori result showed high heterogeneity for all sleep variables, similar with a prior study [23]. The percentage of observed total variation across studies due to real heterogeneity rather than chance was evaluated using the I^2 statistic test, with the thresholds of 25%, 50%, and 75% being considered low, moderate, and high heterogeneity, respectively. All analyses were performed using the Stata MP 13.0 software (Stata Corp, College Station, TX, USA). A double-sided P value of <0.05 was considered as statistically significant.

To generate the normative values, a weighted estimated mean and 95% CI were calculated at each age-band using mean and SE for each study, including both longitudinal and cross-sectional studies. For longitudinal data, specifically, only the first time assessment was used to avoid bias from an individual study contributing more than once to a dataset [9]. To compare differences between PA and PC studies, the forest plots with the Cohen's *d* effect size (ES) were presented, with 0.2, 0.5 and 0.8 being defined as the cutoffs for

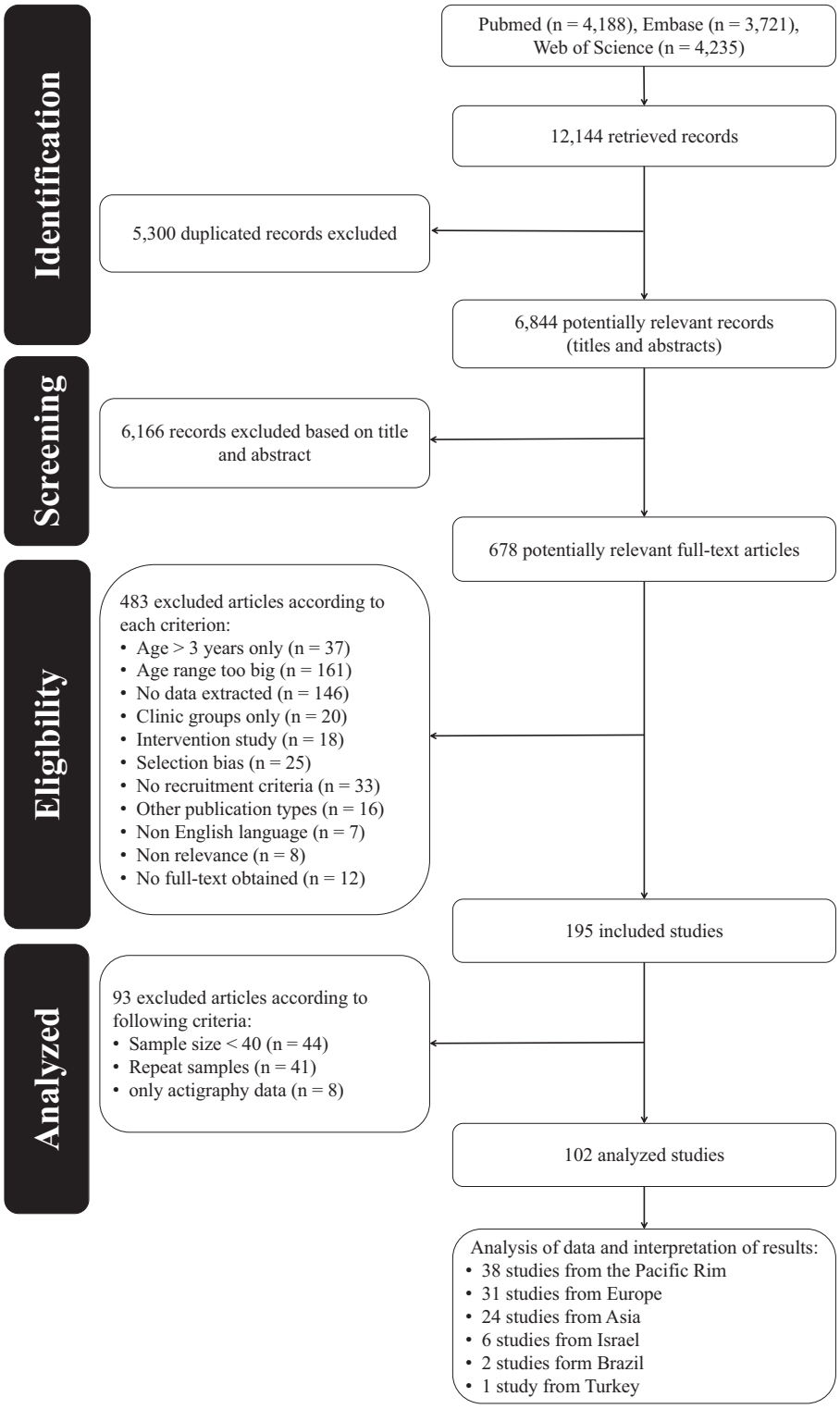


Fig. 1. Search strategy and results.

small, medium and large effect, respectively. Since the age-related changes might follow a non-linear trend, the fractional polynomials weighed by sample size was used to determine the best fitting shape (based on R^2 values). In cases of insufficient number of longitudinal studies, we also included cross-sectional studies, which was similar with previous studies [9,23]. We also performed more refined regional analyses (post-hoc analysis) both for the normative values and their age-related trends, if possible. That is, PC regions were further divided into the European and Pacific Rim regions.

We executed a meta-regression for the following moderators when available for >10 observation datasets. These moderators

Table 1
Description of the included studies.

Region	Country/region	Study[a]	n	Male %	Age			Sleep variables	Measure	Design	QI
					Newborns (0–3 mo)	Infants (4–11 mo)	Toddlers (12–36 mo)				
Asia	mainland China	Wu R et al., 2018 [81]	375	52.3	–	–	3 yrs	TSD, NSD, DSD, BT, WT	Q	X	9
Asia	mainland China	Sun W et al., 2018 [82]	1102	53.8	–	2–11 mo	12–30 mo	TSD, NSD, DSD, NW	Q	X	8
Asia	mainland China	Sun W et al., 2016 [41]	42	50.0	–	6 mo	–	TSD, NSD, DSD, NW	Q	L-x	5
Asia	mainland China	Xiao-Na H et al., 2009 [74]	14,883	52.5	≤1, 2, 3 mo	4, 5, 6, 7, 8, 9, 10, 11 mo	12, 18, 24, 36 mo	TSD, NSD, DSD	Q	X	10
Asia	India	Murthy CL et al., 2015 [83]	368	66.7	–	–	12–36 mo	TSD, NSD, DSD	Q	X	10
Asia	Japan	Iwata S et al., 2017 [65]	1075		1 mo	–	–	NSD, DSD	Q	X	10
Asia	Japan	Chen H et al., 2017 [84]	62,623	51.7	–	–	18 mo	NSD	Q	X	11
Asia	Japan	Nakagawa M et al., 2016 [25]	50	64.0	–	–	19 mo	BT	D	X	8
Asia	Japan	Iemura A et al., 2016 [85]	300	–	–	–	18 mo	TSD, NSD, DSD, BT, WT	D	X	8
Asia	Japan	Kitamura S et al., 2015 [86]	425	48.0	–	–	2 yrs	NSD, DSD, BT, WT	Q	X	9
Asia	Japan	Yamazaki A. 2007 [50]	101	–	4–5 wks	–	–	TSD	D	L-x	7
Asia	Japan	Fukumizu M et al., 2005 [87]	174	–	–	–	18–21 mo	NSD, DSD, BT	Q	X	8
Asia	Japan	Fukuda K et al., 2002 [88]	150	51.9	–	–	3 yrs	TIB, BT, WT	Q	X	9
Asia	Korea	Lee K. 2000 [89]	188	51.6	11–222 d	–	–	TSD	D	X	9
Asia	Nepal	Shrestha D et al., 2015 [90]	553	52.4	–	6–12 mo	13-24, 25–36 mo	TSD, NSD, DSD, NW	Q	X	8
Asia	Singapore	Sensaki S et al., 2018 [91]	376	49.7	–	–	12 mo	TSD, NSD, DSD, NW	Q	L-x	8
Asia	Singapore	Zhou Y et al., 2015 [79]	899	52.8	3 mo	6, 9 mo	12, 18, 24 mo	TSD	Q	L	8
Asia	Singapore	Aishworiya R et al., 2012 [92]	96	50.5	–	–	2, 3 yrs	TSD, NSD, DSD	Q	X	8
Asia	Taiwan	Tsai S-Y et al., 2018 [26]	219	47.5	–	6 mo	–	TSD, NSD, DSD, BT, WT, NW	Q	X	9
Asia	Taiwan	Huang YS et al., 2014 [46]	68	50.0	–	6 mo	–	NSD, DSD	Q	X	7
Asia	Thailand	Chonchaiya W et al., 2017 [93]	208	–	–	6 mo	12 mo	TSD, NSD, DSD	Q	L	9
Asia	Thailand	Vijakkhana N et al., 2015 [61]	208	49.0	–	6 mo	12 mo	NSD	D	L	10
Asia	Thailand	Anuntaseree W et al., 2012 [75]	3937	49.7	–	–	1 yrs	NSD, DSD, NW	Iv, D	L-x	9
Asia	Thailand	Anuntaseree W et al., 2008 [94]	3127	50.4	3 mo	–	–	NW	Q	L-x	11
Europe	Denmark	Klingenberg L et al., 2013 [95]	311	47.6		9 mo	18, 36 mo	TSD, NSD	Q	L	8
Europe	Finland	Morales-Munoz I et al., 2018 [68]	1221	–	3 mo	–	–	NSD, DSD	Q	L-x	10
Europe	France	Plancoulaine S et al., 2018 [96]	1205	53.2	–	–	2, 3 yrs	NSD, DSD	Q	L	10
Europe	France	Plancoulaine S et al., 2015 [97]	1028	53.1	–	–	3 yrs	TSD, NSD, DSD, BT, WT	Q	L-x	9
Europe	Italy	Bruni O et al., 2014 [21]	704	50.7	3 mo	6, 9 mo	12 mo	TSD, NSD, DSD, BT, WT, NW	Q	L	11
Europe	Italy	Brescianini S et al., 2011 [33]	333	53.3	–	–	18 mo	NSD, DSD	Q	L-x	8
Europe	Italy	Fazzi E et al., 2008 [49]	50	54.0	–	–	10–39 mo	TSD, NSD, DSD, NW	Q	X	7
Europe	Italy	Ottaviano S et al., 1996 [98]	2889	52.7	1–5 mo	6–12 mo	13–24 mo	TSD, NSD, DSD, BT, WT	Q	X	9
Europe	Netherlands	Kocevska D et al., 2016 [99]	3465	49.2	–	–	2, 3 yrs	TSD	Q	L	10
Europe	Netherlands	Netsi E et al., 2015 [100]	2241	48.5	–	–	24 mo	TSD	Q	L-x	11
Europe	Netherlands	Kupers LK et al., 2015 [101]	2475	49.9	–	4 mo	–	TSD	Q	L-x	9
Europe	Netherlands	Tollenaar MS et al., 2012 [102]	163	55.2	4, 7 wks	–	–	NSD, NW	D	L	9
Europe	Netherlands	Meijer AM et al., 2007 [103]	107	51.4	2, 7 wks	–	1 yrs	NW	Q	L	8
Europe	Norway	Garthus-Niegel S et al., 2018 [69]	1480	52.0	8 wks	–	2 yrs	TSD, NSD, DSD, NW	Q	L	11
Europe	Norway	Hysing M et al., 2016 [104]	2012	51.6	–	–	2 yrs	NSD	Q	L-x	9
Europe	Portugal	Figueiredo B et al., 2017 [66]	163	54.6	2 wks, 3 mo	6 mo	–	TSD, NSD, DSD, NW	D	L	9
Europe	Russia	Kelmanson IA. 2008 [105]	114	43.9	2 mo	8 mo	–	TSD	Q	L	8
Europe	Russia	Kelmanson IA et al., 2002 [106]	112	45.5	2 mo	–	–	TSD, DSD	Q	X	9
Europe	Sweden	Ekstedt M et al., 2017 [107]	46	37.0	–	–	1 yrs	TSD, NSD, DSD, BT, WT	D	L-x	9
Europe	Sweden	Klackenberg G. 1968 [39]	212	57.5	–	6, 9 mo	12, 18, 24, 30, 36 mo	TSD, NSD, DSD	Q	L	8
Europe	Switzerland	Iglowstein I et al., 2003 [20]	493	52.9	3 mo	6, 9 mo	12, 18, 24, 36 mo	TSD, TIB, DSD; BT, WT	Q	L	9
Europe	UK	St James-Roberts I et al., 2017 [108]	101	–	3 mo	6 mo	–	NW	D	L	8
Europe	UK	Baird J et al., 2016 [109]	587	51.4	–	–	3 yrs	TSD, NSD	Q	L-x	8
Europe	UK	McDonald L et al., 2014 [32]	1702	48.6	–	–	14–27 mo	NSD, DSD, WT, WT	Q	L-x	10
Europe	UK	Kaley F et al., 2012 [110]	74	55.4	4–10 wks	–	–	TSD, NSD, DSD, NW	D	X	9
Europe	UK	Blair PS et al., 2012 [80]	11,478	51.6	–	6 mo	18, 30 mo	TSD, NSD, DSD, BT, WT	Q	L	11
Europe	UK	O'Connor TG et al., 2007 [111]	11,490	51.3	–	6 mo	18, 30 mo	TSD, NW	Q	L	10
Europe	UK	Darlington AS et al., 2006 [112]	75	57.0	8 wks	–	–	TSD	D	X	8
Europe	UK	Harrison Y. 2004 [113]	56	46.4	6, 9, 12 wks	–	–	TSD	D	L	8
Europe	UK	St. James-Roberts I et al., 1997 [51]	45	–	6 wks	–	–	TSD	D	X	7

(*continued on next page*)

Table 1 (*continued*)

Region	Country/region	Study[a]	n	Male %	Age			Sleep variables	Measure	Design	QI
					Newborns (0–3 mo)	Infants (4–11 mo)	Toddlers (12–36 mo)				
Europe	UK	St James-Roberts I et al., 1996 [52]	217	49.8	2, 6, 12 wks	40 wks	–	TSD	D	L	7
Pacific Rim	Australia	Wilson J et al., 2017 [114]	402	–	8 wks	–	–	TSD	Iv	X	9
Pacific Rim	Australia	McGeorge K et al., 2015 [44]	55	52.7	–	4–7 mo	–	TSD	D	X	6
Pacific Rim	Australia	Price AM et al., 2014 [115]	2625	51.2	–	4-6, 7–9, 10–12 mo	13-15, 28–33, 34–39 mo	TSD, DSD, BT, WT, NW	D	L	9
Pacific Rim	Australia	Johnson N et al., 2014 [116]	81	54.0	–	7 mo	18 mo	NSD	Q	L	9
Pacific Rim	Australia	Piteo AM et al., 2013 [72]	111	48.0	–	–	12 mo	NSD, DSD, NW	Q	L-x	8
Pacific Rim	Australia	Hiscock H et al., 2001 [117]	738	54.1	–	6–12 mo	–	DSD, BT	Q	X	8
Pacific Rim	Canada	Smithson L et al., 2018 [118]	822	51.6	3 mo	6, 9 mo	12, 15, 18, 21, 24 mo	NSD	Q	L	8
Pacific Rim	Canada	Costanian C et al., 2018 [119]	3675	50.4	–	–	1–2 yrs	NSD	Q	X	11
Pacific Rim	Canada	Plumptre L et al., 2017 [76]	597	54.6	–	–	12–36 mo	TSD	Q	L-x	9
Pacific Rim	Canada	Bouvette-Turcot AA et al., 2015 [45]	209	54.1	–	6 mo	12, 18, 24, 36 mo	TSD	Q	L	6
Pacific Rim	Canada	Simard V et al., 2013 [47]	55	54.5	–	–	2 yrs	NSD, NW	D	L-x	7
Pacific Rim	Canada	Bordeleau S et al., 2012 [73]	55	40.0	–	–	1 yrs	TSD, NSD	D	L-x	8
Pacific Rim	Canada	Bernier A et al., 2010 [120]	60	40.0	–	–	–	TSD, NW	D	L	8
Pacific Rim	Canada	Touchette E et al., 2009 [121]	2057	51.2	–	–	29 mo	NSD	Q	X	10
Pacific Rim	New Zealand	Taylor BJ et al., 2017 [122]	209	46.9	–	19, 27 wks	12, 24 mo	NSD	Q	L	9
Pacific Rim	New Zealand	Galland BC et al., 2017 [123]	209	46.9	–	6 mo		TSD, NSD, NW	D	L-x	9
Pacific Rim	New Zealand	Galland B et al., 2016 [124]	100	60.0	–	6 mo	12, 24 mo	TSD, NSD, DSD, BT, WT, NW	D	X	8
Pacific Rim	USA	Voltaire ST et al., 2018 [125]	167	–	1, 3 mo	6, 9 mo	–	NW	Q	L	8
Pacific Rim	USA	Mindell JA et al., 2017 [126]	117	41.0	–	6 mo	12, 18 mo	TSD, BT, NW	Q	L	8
Pacific Rim	USA	Thomas KA et al., 2016 [40]	42	54.8	–	32 wks		TSD	Q	L-x	5
Pacific Rim	USA	Schwichtenberg AJ et al., 2016 [42]	42	64.3	–	–	24, 36 mo	NSD, DSD, BT, WT, NW	D	L-x	6
Pacific Rim	USA	Paul IM et al., 2016 [71]	279	49.6	2, 8 wks	16, 40 wks	–	TSD, NSD, DSD	Q	L	10
Pacific Rim	USA	Butler R et al., 2016 [127]	104	51.9	–	7–11 mo	–	NSD, DSD, BT, WT; NW	Q	L-x	9
Pacific Rim	USA	Burnham MM et al., 2016 [78]	3050	51.8	–	–	2 yrs	DSD	Iv	L-x	10
Pacific Rim	USA	Sorondo BM et al., 2015 [43]	40	52.5	–	5, 9 mo	12 mo	NSD, DSD, NW	Q	L	7
Pacific Rim	USA	Molfese VJ et al., 2015 [128]	64	63.0	–	–	30–31 mo	TSD, TIB, BT, WT	D	L-x	8
Pacific Rim	USA	Cespedes EM et al., 2014 [129]	1864	51.4	–	6 mo	12, 24, 36 mo	TSD	Q	L	9
Pacific Rim	USA	Mindell JA et al., 2012 [130]	92	39.1	–	3-12, 6–15 mo	9–18 mo	NSD, NW	Q	L	8
Pacific Rim	USA	Byars KC et al., 2012 [5]	359	45.1	–	6 mo	12, 24, 36 mo	TSD, NSD, DSD	Q	L	9
Pacific Rim	USA	Hayes MJ et al., 2011 [131]	120	52.0	–	–	16 mo	TSD, DSD	Q	L-x	9
Pacific Rim	USA	Shope TR et al., 2010 [48]	49	51.0	1–12 wks	–	–	TSD	Q	X	7
Pacific Rim	USA	DeLeon CW et al., 2007 [132]	41	63.4	–	9 mo	–	TSD, NSD, DSD, NW	D	X	9
Pacific Rim	USA	Montgomery-Downs HE et al., 2006 [133]	944	52.9	<1, 1, 2 mo	4, 6, 9 mo	12, 15, 18, 24 mo	TSD, NSD, DSD, NW	Q	X	9
Pacific Rim	USA	Acebo C et al., 2005 [134]	169	49.7	–	–	12, 18, 24, 30, 36 mo	NSD, BT, WT	D	X	9
Pacific Rim	USA	Weissbluth M et al., 1984 [36]	107	43.0	–	4–8 mo	–	TSD, NW	Q	X	9
Pacific Rim	USA	Weissbluth M. 1984 [37]	60	43.3	–	–	3 yrs	TSD, NSD, DSD	Q	X	9
Pacific Rim	USA	Jacklin CN et al., 1980 [38]	141	–	–	6 mo	12, 18, 26, 36 mo	TSD	D	L	7
Pacific Rim	USA–Canada	Sadeh A et al., 2009 [67]	5006	51.9	0–2 mo	3-5, 6–8, 9–11 mo	12-17, 18–23, 24–36 mo	TSD, NSD, DSD, NW	Q	X	10
Other	Israel	Volkovich E et al., 2018 [135]	188	–	3 mo	6 mo	12, 18 mo	NW	D	L	10
Other	Israel	Hairston IS et al., 2016 [136]	152	42.0		5–8 mo	–	TIB, DSD, BT, WT, NW	Q	L-x	8
Other	Israel	Volkovich E et al., 2015 [137]	153	58.4	3 mo	6 mo	–	DSD, NW	D	L	10
Other	Israel	Tikotzky L et al., 2009 [138]	85	60.0	1 mo	6 mo	12 mo	TSD, DSD, BT, NW	Q, D	L	9
Other	Israel	Scher A. 2001 [34]	94	51.0	–	–	12 mo	BT, NW	Q	L-x	8
Other	Israel	Scher A.1991 [35]	118	46.6	3 mo	6, 9 mo	12 mo	NSD, DSD, NW	Q	L	7
Other	Brazil	Balaban R et al., 2018 [70]	157	43.3	–	5–13 mo	–	TSD, NSD, DSD, NW	Q	X	10
Other	Brazil	Netsi E et al., 2017 [77]	3842	52.0	3 mo	–	12, 24 mo	TSD, NSD, DSD, BT, WT, NW	Q	L	12
Other	Turkey	Kondolot M et al., 2009 [139]	187	56.1	1–6 mo	–	–	NSD, DSD	Q	X	9

BT, bedtime involves parental reported bedtime, lights off time, sleep onset time and fall asleep time together; D, diary; DSD, daytime sleep duration; Iv, interview; L, longitudinal study design; L-x, sub-sample of the longitudinal study design; n, sample size; NSD, nighttime sleep duration; NW, number of nightwaking; PR, the Pacific Rim; Q, questionnaire; QI: the Downs & Black quality index (QI) score; TSD, total sleep duration; WT, waketime in morning involves parental reported wake up time, sleep offset time, rise time and get up time together; X, cross-sectional study design.

[a] References start from number 81 onwards are listed in the supplement.

included child age (continuous), regions (PA/PC), year of study conducted (before/after 1990s [31]), sleep measurements (questionnaires/diary), study design (cross-sectional/longitudinal) and the modified QI score (<8 score/≥8 score). For NSD specifically, the estimating method (reported NSD/calculated TIB) was also considered as a potential moderator. Moderator analysis by age-bands was pursued when possible.

Lastly, we performed a sensitivity analysis by omitting studies conducted years before 1990s and studies with quality assessment less eight score to examine the robustness of the cross-cultural disparities, respectively. Furthermore, we also conducted the cross-cultural analyses by different definition for NSD, bedtime and waketime parameters.

Results

Study characteristics

The search terms from all databases yielded 12,144 hits. The selection process was shown in Fig. 1. A total of 102 observational studies (n = 167,886; 51.3% male) with 35 reporting on newborns, 51 on infants and 67 on toddlers were analyzed in our meta-analysis (Table 1). From these, 63 studies reported on TSD (n = 76,848), 65 on NSD (n = 132,416), 54 on DSD (n = 65,704), 40 on NW (n = 38,293), 26 on bedtime (n = 28,161) and 20 on waketime (n = 26,907). A total of 95 (93.1%) studies collected data from the 1990s and onwards, and seven studies collected data before 1990s; 64 (62.7%) studies had a longitudinal design with 37 (36.3%) studies having more one timepiont follow-up data. 70 (68.6%) studies applied questionnaires, 28 (27.5%) used sleep diaries, two used interview, and one study used both questionnaires and diary, one study used both interview and diary methods to assess sleep. Two twin-based studies [32,33], which were excluded from the later analyses due to the sleep arrangements of families of twin children might differ from that of single child families [5] (Table S2). The range of the sample size was 40–62,623. The average modified QI score was 8.7 (range 5–12), with 87 studies being good, 15 being moderate and no study being poor in quality. Lower QI scores were primarily due to representativeness of the samples (i.e., external validity) (Fig. S1). The funnel plot showed large symmetry for TSD, NSD and bedtime parameters, and asymmetry for DSD, NWs and waketime parameters (Fig. S2).

The studies identified from 26 different countries/regions (Table 1) include eight from Asia (mainland China, India, Japan, Korea, Nepal, Singapore, Taiwan, Thailand; 24 studies, n = 91,547), 11 from Europe (Denmark, Finland, France, Italy, Netherlands, Norway, Portugal, Russia, Sweden, Switzerland, UK; 31 studies, n = 46,649), four from the Pacific Rim (Australia, Canada, New Zealand, USA; 38 studies, n = 24,714), in addition to Brazil (two studies, n = 3999), Israel (six studies, n = 790), and Turkey (one study, n = 187).

Normative estimates and their cultural disparities

Sleep quantity

The pooled mean sleep quantities for TSDs, NSDs and DSDs of children in the first three years, globally, were 12.89 (95% CI: 12.66, 13.12) hours, 9.74 (95% CI: 9.61, 9.88) hours and 3.16 (95% CI: 2.94, 3.38) hours with I^2 being 99.7%, 99.7% and 99.9%, respectively. More details about the age and region subgroup estimates were shown in Table 2 and Table S5. In the cross-cultural analysis, the forest plot indicated that in early life, toddlers in PA regions had shorter TSDs (ES = −0.03, z = 2.44, $P = 0.015$) and NSDs (ES = −0.05, z = 7.30, $P < 0.001$), while PA newborns had longer DSDs (ES = 0.05, z = 2.07, $P = 0.038$) than those in PC regions. No differences of other age subgroups were found between PA and PC regions.

Sleep quality

Overall, the pooled mean NWs were 1.46 (95% CI: 1.21, 1.70) times with I^2 being 99.8% for the first three years (Table 2 and Table S5). The forest plot of the cultural analysis indicated that compared to PC children, PA had more NWs for all age groups, newborns (ES = 0.05, z = 2.09, $P = 0.036$), infants (ES = 0.06, z = 1.76, $P = 0.079$) and toddlers (ES = 0.06, z = 3.81, $P \leq 0.001$), though the difference was border line significant in infants group.

Sleep timing

Children aged 4–36 mo went to bed at 20:43 (95% CI: 20:24, 21:01) and woke up at 7:12 (95% CI: 6:55, 7:29) with I^2 being 99.8% and 99.9%, respectively (Table 2 and Table S5). The forest plot didn't showed difference between PA and PC Children.

When PC regions were further divided into European and Pacific Rim regions, these differences were more significant between PA and Pacific Rim regions. PA children had less TSDs in toddlers and less NSDs in infants and toddlers, more NWs and later bedtimes for all age groups in the first three years, though the difference was border line for the NWs in toddlers (Tables S6–S8).

Age-related trends and their cultural disparities

The trends of the six subjective sleep parameters and their cultural disparities between PA and PC regions were shown in Fig. 2. The equations and plots of the more refined regional analyses were shown in supplement (Table S9; Fig. S3).

Sleep quantity

Age-related trends of the three sleep quantity parameters were best described by power-law models with R^2 being 0.46, 0.29 and 0.85 for TSD, NSD and DSD, respectively. As for TSD, there was a rapid decline over the first three months at approximately 27 min per month, followed by a moderate decrease of one minute per month from 3 mo to 3 y. Cultural analysis suggested that TSD of PA samples were more than that of PC samples before the first three months, but afterward dropped below PC samples, with obvious difference in the middle age group across the first three years of life (Fig. 2A). For NSD, there was a sharp increase over the first three months at approximately 33 min per month, then followed by a moderate increase of three minutes per month thereafter. Cultural analysis found a slight change across different stages in early life, rising at first and going down latter, for PA regions. However, for PC regions, after a sharp decline over the first one month and a rapid increase from one to six months, it reached a plateau stage at 11 h from 24 to 36 mo (Fig. 2B). Similar to the trends for TSD, DSD also decreased with age. DSD of PA regions were at a slight higher stage than that of PC regions, though the age-related changes were similar (Fig. 2C).

Sleep quality

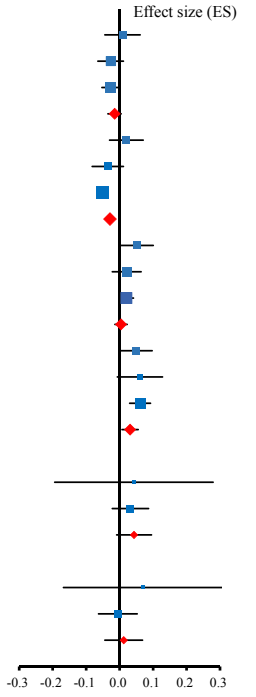
The trend of NW was also best described by a power-law function ($R^2 = 0.30$), with a rapid decline in the first three months and decreasing slightly afterwards. Cultural analysis showed different age-related trends of NWs, namely, PA samples were at a highest level in the first three years compared with PC regions, especially for the early life (Fig. 2D).

Sleep timing

Overall, bedtime gradually delayed 63 min from 4 to 12 mo then advanced 40 min from 12 to 36 mo (Fig. 2E), yet waketime did not change significantly (Fig. 2F). Similar trends of bedtime with age was found for PA and PC samples, but PA stayed at a slight higher level, meaning later bedtime (Fig. 2E). There was no cultural disparity in the waketime parameter (Fig. 2F).

Table 2
Cross-cultural disparities for the six subjective sleep parameters between PA and PC regions (data present as mean and 95% CI).

Sleep and age groups	Global [a]	PA	PC [b]	Effect size [c]	z	P values
TSD: Newborns (0-3 mo)	13.76 (13.29, 14.23)	13.91 (12.94, 14.89)	13.73 (13.16, 14.31)	0.01 (-0.04, 0.06)	0.32	0.749
Infants (4-11mo)	13.05 (12.79, 13.31)	12.66 (12.32, 13.01)	13.24 (12.96, 13.53)	-0.03 (-0.07, 0.01)	1.37	0.171
Toddlers (12-36 mo)	12.27 (12.05, 12.49)	11.81 (11.58, 12.05)	12.47 (12.17, 12.76)	-0.03 (-0.05, -0.01)	2.44	**0.015**
Overall (0-36 mo)	12.89 (12.66, 13.12)	12.61 (12.24, 12.99)	13.03 (12.75, 13.31)	-0.02 (-0.04, 0.00)	1.51	0.130
NSD: Newborns (0-3 mo)	8.65 (8.29, 9.01)	8.83 (8.40, 9.25)	8.52 (8.02, 9.02)	0.02 (-0.03, 0.07)	0.79	0.429
Infants (4-11mo)	9.73 (9.47, 9.99)	9.30 (9.15, 9.46)	9.96 (9.68, 10.24)	-0.04 (-0.08, 0.01)	1.51	0.130
Toddlers (12-36 mo)	10.23 (10.05, 10.40)	9.57 (9.46, 9.69)	10.57 (10.27, 10.87)	-0.05 (-0.07, -0.04)	7.30	**< 0.001**
Overall (0-36 mo)	9.74 (9.61, 9.88)	9.39 (9.27, 9.52)	9.96 (9.71, 10.20)	-0.03 (-0.04, -0.02)	4.47	**< 0.001**
DSD: Newborns (0-3 mo)	5.20 (4.52, 5.88)	6.32 (5.24, 7.41)	4.96 (4.20, 5.72)	0.05 (0.00, 0.10)	2.07	**0.038**
Infants (4-11mo)	3.16 (2.82, 3.49)	3.59 (3.30, 3.88)	3.05 (2.69, 3.42)	0.02 (-0.02, 0.06)	0.95	0.341
Toddlers (12-36 mo)	2.17 (2.01, 2.33)	2.30 (2.10, 2.51)	2.08 (1.93, 2.23)	0.02 (0.00, 0.04)	1.78	0.076
Overall (0-36 mo)	3.16 (2.94, 3.38)	3.23 (2.85, 3.61)	3.13 (2.87, 3.38)	0.00 (-0.01, 0.02)	0.46	0.644
NW: Newborns (0-3 mo)	2.05 (1.63, 2.47)	2.70 (2.66, 2.74)	2.06 (1.53, 2.59)	0.05 (0.00, 0.10)	2.09	**0.036**
Infants (4-11mo)	1.44 (1.30, 1.58)	1.89 (1.35, 2.43)	1.36 (1.23, 1.48)	0.06 (-0.01, 0.13)	1.76	0.079
Toddlers (12-36 mo)	1.14 (0.86, 1.42)	1.86 (1.13, 2.59)	0.95 (0.84, 1.07)	0.06 (0.03, 0.09)	3.81	**< 0.001**
Overall (0-36 mo)	1.46 (1.21, 1.70)	1.96 (1.60, 2.31)	1.35 (1.09, 1.61)	0.03 (0.01, 0.06)	2.53	**0.011**
BT: Newborns (0-3 mo)	-	-	-	-	-	-
Infants (4-11mo)	20:35 (20:06, 21:05)	21:54 (21:35, 22:13)	20:28 (19:58, 20:59)	0.04 (-0.19, 0.28)	0.36	0.722
Toddlers (12-36 mo)	20:45 (20:19, 21:12)	21:20 (21:13, 21:27)	20:30 (20:03, 20:57)	0.03 (-0.02, 0.09)	1.16	0.247
Overall (4-36 mo)	20:43 (20:24, 21:01)	21:23 (21:15, 21:31)	20:29 (20:10, 20:47)	0.04 (-0.01, 0.10)	1.61	0.108
WT: Newborns (0-3 mo)	-	-	-	-	-	-
Infants (4-11mo)	7:04 (6:54, 7:15)	7:49 (7:28, 8:10)	7:00 (6:50, 7:11)	0.07 (-0.17, 0.31)	0.57	0.570
Toddlers (12-36 mo)	7:16 (6:59, 7:34)	7:11 (7:06, 7:16)	7:13 (7:06, 7:21)	-0.01 (-0.06, 0.05)	0.18	0.855
Overall (4-36 mo)	7:12 (6:55, 7:29)	7:14 (7:07, 7:20)	7:07 (7:00, 7:15)	0.01 (-0.04, 0.07)	0.41	0.678



BT, bedtime involves parental reported bedtime, lights off time, sleep onset time and fall asleep time together; DSD, daytime sleep duration; NSD, nighttime sleep duration; NW, number of nightwaking; PA, predominantly-Asian countries/regions; PC, predominantly-Caucasian countries; TSD, total sleep duration; WT, waketime in morning involves parental reported wake up time, sleep offset time, rise time and get up time together.
[a]Data from all countries, including Brazil, Israel, and Turkey.
[b]Including Israel and Turkey, because their cultural norms are generally western.
[c]The forest plot in the right of the Table presents the effect size, i.e., standardized mean difference (mean and 95%CI) of the six sleep values between PA and PC regions, with 0.2, 0.5 and 0.8 being defined as the cutoffs for small, medium and large effect, respectively. Note: the blue squares represent age subgroup comparisons and the red diamonds represent the overall comparisons for children aged 0–36 mo (TSD, NSD, DSD and NW) or 4–36 mo (BT and WT), with the positive indicating more or later sleep values of PA regions and the negative indicating less or earlier sleep values of PA regions.
P value of <0.05 was considered as statistically significant.

In the refined regional analyses, compared to European regions, a different age-related changes of NSD in Pacific Rim were found (Figs. S3A–3F). However, these results need to be interpreted with caution due to limited evidence available, especially for NW, bedtime and waketime age-related trends PA samples (Table S9).

Meta-regression and sensitivity analysis

Meta-regression results (Table S10) also showed that regional differences were most pronounced in infant and toddler childhood, with PA having shorter TSDs and NSDs, higher NW frequency, and later bedtimes. In addition to the child age and country region of the studies, the year in which the study was conducted and the definition of NSD were the two other moderators. TSD and NSD reported in the studies conducted after 1990s was 41 and 50 min shorter than those reported in studies before 1990s, respectively; and TIB calculated from bedtime and waketime by researchers was 22 min longer than mean NSD reported by parents over the first three years.

We excluded seven studies [20,34–39] conducted years before 1990s and 15 studies with quality assessment less than eight scores [35,38,40–52] to conduct the sensitivity analyses, respectively. Furthermore, we also conducted the cross-cultural analyses by different definition for NSD, bedtime and waketime parameters. All results showed that the cultural disparities found were robust (Figs. S4–S7).

Discussion

The present study is the first systematic review and meta-analysis to determine the cross-cultural sleep disparities in only the first three years of human life. There are several important findings. First, newborns, infants, and toddlers globally had TSDs of 13.8, 13.1 and 12.3 h, NSDs of 8.7, 9.7 and 10.2 h, DSDs of 5.2, 3.2 and 2.2 h, and NWs of 2.1, 1.4 and 1.1 times, respectively. Overall, children aged 4–36 mo went to bed at 20:43 and woke up at 7:12. Second, small but significant cultural differences of the subjective sleep parameters existed in early childhood, especially when comparing PA and Pacific Rim regions. PA children had shorter NSDs, woke up more often and went to bed later. Among the PC population, trends of NSD and NWs showed rapid changes over the first three to six months before stabilizing to a plateau. Finally, the magnitude of TIB calculated from bedtime and waketime was greater than the NSD reported by parents.

Normative estimates of sleep early in life

While duration is the most studied sleep parameter [9], growing evidence shows that sleep is a complex psychophysiological phenomenon in which sleep quality and timing are equally important components of optimal sleep health, and both are necessary to provide a context for sleep duration recommendations [10–12]. The present meta-analysis estimated that infants and toddlers

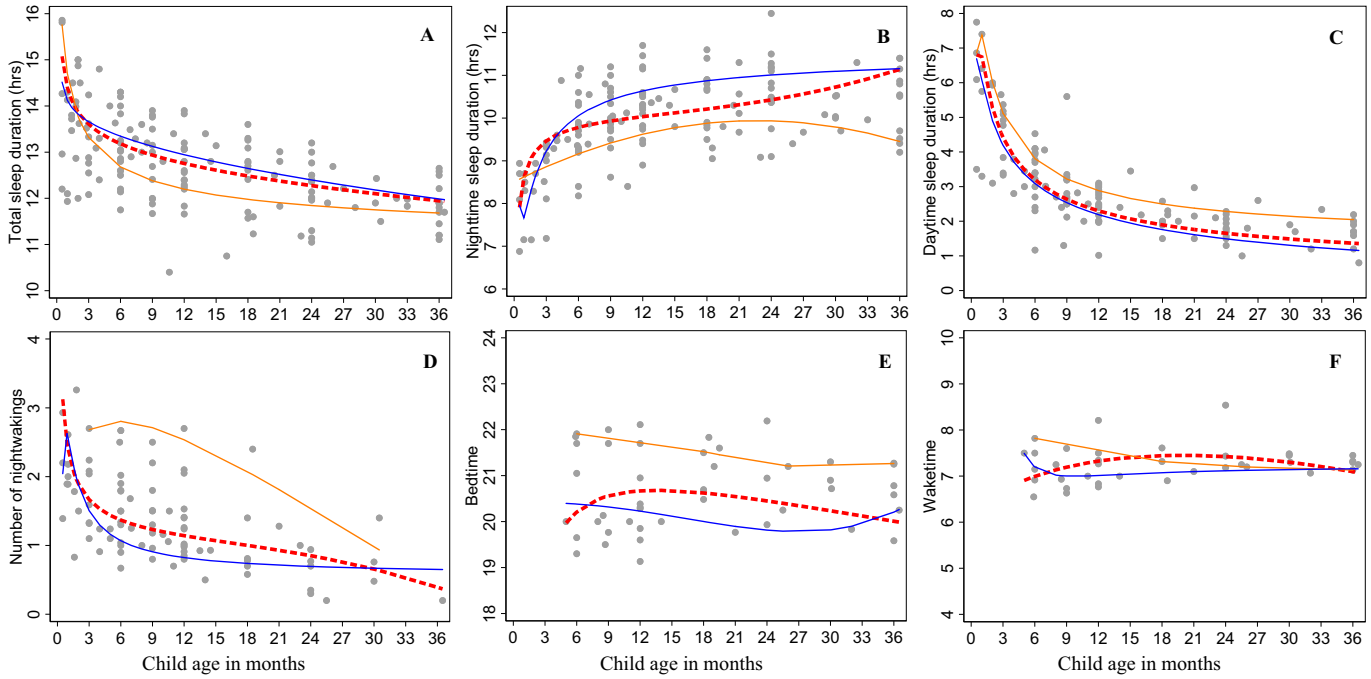


Fig. 2. Cross-cultural disparities of the age-related trends (weighted by sample size) for sleep parameters over the first three years of life. A: Total sleep duration; B: Nighttime sleep duration; C: Daytime sleep duration; D: Number of nightwakings; E: Bedtime involves parental reported bedtime, lights off time, sleep onset time and fall asleep time together; F: Waketime in morning involves parental reported wake up time, sleep offset time, rise time and get-up time together. Note: the orange line represents the development curve fitted for data from PA region samples; the blue line represents the PC region samples; and the red dash curve represents the overall samples.

globally had TSDs within the range of the revised NSF recommendations (12–15 h for infants and 11–14 h for toddlers, respectively) [29]. Meanwhile, an overall TSD of 13.3–14.2 h for newborns is close to the lower range of the revised NSF recommendation (14–17 h) [29]. Notably, the updated recommendation of the American Academy of Sleep Medicine underlines that insufficient evidence supports its association with health outcomes in this age group, and therefore does not report a window of normal variation in duration and patterns of sleep [53]. Future studies should confirm the effect of early life sleep duration on newborn health outcomes, especially with the longitudinal study design.

According to the NSF sleep quality recommendations, one NW per night or less indicated 'good' sleep quality and four or more indicated 'poor' sleep quality for toddlers [54]. Our meta-analysis estimated a NW of 0.9–1.4 times per night for toddlers, which was within this recommended range of 'good' sleep quality. Sleep timings have rarely been studied over the past decades, and thus no recommendation has been published. We found no age-related change for bedtime and waketime from 4 to 36 mo, at about 20:40 and 7:10, respectively. Findings from this meta-analysis may be a useful "rule of thumb" when assessing the "normal" range for sleep parameters over the first three years.

Age-related trends of sleep in early life

The age-related trends of these parameters showed a nonlinear change with rapid change over the first three to six months, followed by a plateau stage or more mild change until three years. While there is no guideline for age-related trends of sleep in the early life, the changes in the sleep parameters, especially those over the first six months as reported in our meta-analysis corroborate with the existing understanding of rapid nighttime sleep consolidation and the establishment of sleep/wake homeostasis as the infant matures [4,9,55]. Physiological studies have also supported these early developmental trends with interaction with changes of body temperature and hormone levels [56]. For example, infants' endogenous melatonin rises to detectable levels at approximately six weeks after the maternally transferred melatonin dissipates, remains low at 12–16 wk, until by six months it stabilizes as part of the individual sleep/wake cycle [56]. Because few studies involved in the first month age, the initiation age-related trends of NSD and NWs should be interpreted with caution.

Cross-cultural disparities of sleep estimates and trajectories early in life

The present review found small but significant cultural disparities in subjective TSD and NSD parameters, though the global estimate of TSD and its estimates in PA and PC subgroups were all within the existing recommendations [29,53]. Specifically, PA children had shorter NSDs and TSDs than PC children in toddlers, which might indicate that PA children were not born with shorter sleep duration. Furthermore, we found that estimates of NWs in PA regions were beyond the NSF recommendations of 'good' sleep quality [54], and children of PA woke up more often and went to bed one more hours later than those of PC regions, especially when compared with those in Pacific Rim regions. Similar cultural disparities were found for the age-related trends of these sleep parameters. Several factors such as inter-ethnic differences [57], intra-ethnic variation, parenting practices, as well as other socio-anthropological factors may contribute to such cultural differences including the development trends of the sleep parameters in early life [58], in which sleep-settling and feeding behaviors may be the most important two cultural factors.

Sleep-settling behaviors

Differences in parental sleep-settling behaviors may play a major role in cultural disparities, which has previously been discussed in a transactional model [16,17]. Since 1993, parental sleep-

settling behaviors, such as parental nighttime involvement and nightly bedtime routine, have been considered to be the most immediate and direct influences on child sleep [16,17,59]. Parental nighttime involvement includes feeding, rocking, holding, or putting a child in bed with parents present at bedtime and during the child's awakenings at night [16,17]. Nightly bedtime routines have been defined as the predictable activities that occur in the hour or so before lights go out and before the child falls asleep [59]. However, in a rapidly evolving society more studies are needed to better describe and understand diverse socio-anthropological sleep settings and habits. Mindell et al. for instance indicated [17,59] that children from PA regions were much more likely to be engaged with their parents, to partake in maladaptive activities (e.g., media-related activities [60]) and were less likely to have a consistent bedtime routine than those from PC regions. These factors could all predict persistent adverse sleep outcomes [15,17,21,57,61], such as later bedtimes, increased NWs as well as shorter NSDs.

Feeding behaviors

Recent animal studies have found that alterations in the timing of food intake influence sleep-wake cycles [62], suggesting that meal timing and feeding regularity might also be potential factors that influence sleep health, independent of energy intake and nutrient quality. Some studies have indicated that PA parents are more likely to arrange a nonscheduled routine for feeding, sleeping and other activities [63], which not only influences circadian rhythm maturation, but could partly contribute to more maladaptive activities, e.g., being exposed to media frequently early in life [64]. For example, many PA parents were more likely to place televisions in their children's bedroom partly as a sleep aid and as part of the child's bedtime routine [57,58].

While sleep-settling and feeding behaviors are likely among the most plausible explanations for the cultural disparities of sleep parameters in young children in PA and PC. The two and other potential confounders have been rarely or inconsistently reported in studies and therefore more research is needed in early childhood across the world.

Potential moderators

Our meta-regression results indicated that apart from child age and different regions, the other two possible moderators were the years in which the study was conducted and the NSD definition.

This study suggested that TSD and NSD from the studies conducted after 1990s were shorter, bedtime were later than in those conducted before, probably due to modern lifestyle changes, e.g., more TV viewing [20]. However, a comprehensive review which focused on objective sleep duration in adults did not find differences for conducted years [28]. One possible reason could be that our study synthesized the sleep values reported by parents only. There might be more variations in sleep estimates reported by parents due to parent knowledge of children's sleep or changes in child rearing policies [6,47]. Future studies should therefore incorporate more objective measurements in examining sleep in early childhood.

Indeed, inconsistency in the definition of NSD has been clearly shown, even when the same instrument is being used. First, despite the acknowledged differences in sleep assessment, a distinction was rarely made between mean NSD reported directly by parents and TIB calculated by researchers. The applied methodology remains to have a great effect on the sleep parameter investigated [21]. Compared to the former, in fact, the TIB was nearly half an hour longer. Moreover, TIB was calculated from "bedtime" (e.g., time of getting into bed, attempting to fall asleep and actual sleep onset time) and "waketime" (e.g., time of getting out of bed, waking up time and actual sleep offset time) that every combination existed. This may be another source of differences [15,21], although we did not found significant difference between different definition both of bedtime and waketime. The need for more uniform operationalization of sleep parameters is obvious. Second, most of the studies (80%) lacked information on the definition of "nighttime", and those who presented this information used different cutoffs (e.g., 20:00–08:00 [65,66], 19:00–08:00 [67], 19:00–07:00 [43,46,68–74], or 18:00–06:00) [75]. The precise determination of nighttime cutoffs, which might be somewhat arbitrary, remains very important. This may not only help in generating (inter)national standards allowing cross-cultural comparisons but may clear up the parents' confusion when reporting publicly on sleep data.

Limitations

Several limitations warrant consideration. First, the normative estimates of six sleep parameters in this review were generated on parental report rather than objective sleep assessment (e.g., actigraphy assessment). More actigraphic studies in the early life are needed. This implies more uniformity in actigraphic brands, scoring rules and algorithms allowing to conduct a meta-analysis in the future. Second, for certain sleep parameters especially in newborns and infants, a limited number of studies could be included due to methodological requirement (Supplementary II). For example, NSD, DSD and NWs in newborns, as well as NWs, bedtime and waketime in infants. Besides, few studies applied longitudinal designs, which prevented us from precisely characterizing the trajectory of the sleep parameters. Third, the majority of studies failed to report different cultural habits, e.g., child rearing practices, feeding practices and family time schedules, etc. [17,59], making it difficult for us to adequately assess their influence. Although virtually most of the studies failed to describe the ethnic composition of the samples [5,32,67,76–80], it is a reasonable assumption that participants in most of these studies were representative of their regions. Therefore, we used regions as a proxy to determine the cross-cultural disparities [13,14,17]. Fourth, the funnel plot showed large asymmetry for DSD, NWs and waketime parameters, potential reasons might be the various age range, sample size and few numerical data available (Table 1). Fifth, we found significant heterogeneity between studies similar to prior reviews [4,9], even after age and region-subgroup analysis were undertaken (may be another reason of the funnel plot asymmetry). The majority of studies were methodologically of good quality and comparable design, which might not be the main reason for the high heterogeneity. Individual sleep needs vary greatly according to the NSF guidelines for each age group [29], which may explain a large part of the heterogeneity. What's more, the other two factors, definition and assessment of sleep parameters should not be ignored. Due to a lack of international guidelines on the operationalization of certain sleep parameters such as "bedtime" and "waketime", they were defined to the best of our ability. Despite the heterogeneities, we still found significant cross-cultural sleep disparities in early life, which was further confirmed by the robustness of our results in the sensitivity analyses. Lastly, the modified Downs & Black assessment tool we used has weaknesses. While there is no standard rule as to the best quality assessment tool, the Downs & Black one is a validated and reliable checklist for assessing the quality of non-randomized and

observational studies [27]. We hope experts working in meta analysis or other field can help to optimize and improve the quality assessment in the future.

Conclusion

This meta-analysis suggested small but significant cultural differences in subjective sleep in early life, especially in infants and toddlers between PA and Pacific Rim regions. PA children had shorter sleep duration, more NWs and later bedtimes; and trends of NSD and bedtime for PC regions showed rapid changes over the first three to six months and stabilized to a plateau afterwards, whereas a different change was found for PA regions. Our findings might help to inform the development and implementation of sleep recommendations in this age group for different cultural backgrounds, and especially useful for clinicians and health professionals to understand that "one size does not fit all". Knowledge of (non-)modifiable correlates is important as it may highlight target groups or behaviors for interventions in order to establish sleep-promoting habits that are globally applicable. More studies in the future with objective measurement of sleep parameters as well as recognition of developmental trajectories are required to help us understand sleep behaviors in early childhood. Future studies should also explore the underlying determinants of sleep and its cultural differences, which would eventually help to inform interventions that lead to improvement of sleep during this critical stage of life.

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Practice points

1 Both the normative estimate of sleep duration and its estimates in predominantly-Asian (PA) and predominantly-Caucasian (PC) subgroup regions were within the existing recommendations.
2 We found significant cross-cultural differences of sleep estimates, especially nighttime parameters, and especially when comparing the PA and the Pacific Rim regions in early life.
3 Infants and toddlers of PA regions had shorter sleep duration, more frequent nightwakings and later bedtimes.
4 Only for the PC samples, age-related trends of nighttime sleep duration and number of nightwakings rapidly changed over the first three to six months and stabilized to a plateau afterwards.
5 Large differences in the definition of sleep parameters existed. Specifically, nighttime sleep duration calculated from bedtime and waketime by researchers was significantly greater than duration reported directly by parents.

Research agenda

1. More studies focusing on sleep parameters beyond (nighttime) sleep duration are needed.
2. More studies of objective sleep measurement and prospective large-scale longitudinal designs focusing on early life are required.
3. Future studies should consider a broad range of cultural/anthropological factors in determining disparities of parenting practices that may influence sleep parameters.
4. Sleep recommendations should be sensitive to diversities in cultural backgrounds.
5. More uniform definitions are needed to generate an international standard for the measurement of sleep parameters suitable for this age range.

Conflicts of interest

The authors do not have any conflicts of interest to disclose.

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Appendix A. Supplementary data

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