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Changes in parental sleep from pregnancy to postpartum: A meta-analytic review of actigraphy studies

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ABSTRACT

Sleep changes in new parents are widely observed but there is no extant meta-analysis of changes to sleep parameters in this group. We completed a meta-analysis of changes in actigraphy-measured parent sleep between pregnancy and the end of the first year of a child's life. A search of six databases was completed. Following review using predetermined inclusion and exclusion criteria, 16 papers were left for review. Data were extracted, analysed and each paper was reviewed for methodological quality. Where possible, subgroup analysis was completed based on time since birth and location of the study, and meta-regression of parent age. Parents' total sleep time and sleep efficiency were shown to decrease following the birth of a child, with wake after sleep onset increasing. This change was most notably observed in the first four weeks after birth. Up to 16 weeks post-birth, differences were still apparent, but sleep parameters were beginning to return to pre-birth levels. New parents experience a significant change in multiple sleep parameters following the birth of a child. Future data collection, using best practice actigraphy measurement, reporting a broader range of variables and including fathers, as well as mothers, is warranted.

Parenthood precipitates physiological, psychological and social changes. New parents need to respond to these changes, adapt routines and meet new challenges independently and interpersonally. Parents of newborn infants typically report fragmented sleep, with sleep bouts lasting around 0.5–2 h [1]. Even after this time, most babies continue to wake regularly [2] up to the age of 6–9 months [3]. By 10 months, parents typically report longer sleep periods, with parents of toddlers 23–34 months old reporting sleep periods of around 8–12 h [1]. Short sleep periods, greater sleep fragmentation, and the need for night-time feeding in the first months of life mean that new parents are at risk of sleep disruption and sleep deprivation. There is a growing body of evidence that looks at sleep loss in parents and carers.

While poor sleep is often seen as an inevitable consequence of parenthood, its impact is likely substantial. Multiple studies connect postpartum sleep disturbances with poorer mental health outcomes [4–7], reduced sensitivity towards infants [8], stress and lower observed positive parenting [9]. Enduring postnatal depression can have an impact on child outcomes and has been evidenced to affect behavioural problems in children [10,11], as well as cognitive development in the early years [12,13]. Although there are other mediating factors that are likely to contribute to postnatal depression, the evidence suggests that understanding the role of sleep is of great importance. Poor sleep also likely precipitates poor performance cognitively and socially in new parents. Sleep deprivation negatively affects a broad range of cognitive processes in the general population [14], whilst sleep deprivation has also been linked to poorer social performance, lower social motivation and increased social isolation [15,16]. Studies measuring the impact of sleep deprivation on cognition and social performance in new parents are limited and require further attention.

Abbreviations: PSG, polysomnography; QEM, quality effects model; REM, random effects model; SE, sleep efficiency; SMD, standardised mean difference; SOL, sleep onset latency; TST, total sleep time; WASO, wake after sleep onset.

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1. Possible causes of poor sleep in new parents

As well as being a critical time for the potential impact of sleep deprivation, there are multiple good reasons why many new parents experience problems with their sleep. Sleep disturbances may have an onset during pregnancy. Sleep disorders such as restless leg syndrome, insomnia and, sleep disordered breathing are common during pregnancy [17]. New mothers experience physiological and anatomical changes, which return the body to the non-pregnant state [18]. Physiological changes linked to diuresis, menstruation and haemoglobin continue in the days following childbirth and last to at least 12 months after childbirth [18]. Environmental factors that arise through the natural process of having a new child in the home affect all those in a caring role. Newborn babies spend an average of 63.8% of their time sleeping, with periods of being awake during the day and the night [19]. Parental sleep quality and quantity is likely to be directly influenced by the quality and quantity of infants' sleep [20], with parents being required to fulfil the needs of the infant during day-time and night-time waking. Night-time feeding is associated with poorer sleep outcomes [21], with the need to feed after sleep onset negatively affecting sleep duration in the early months of life [22]. The transition from pregnancy to parenthood comes with psychosocial changes. Changes may occur at all levels of family life from parental roles at home to the stress of returning to work [23]. Parents have to cope with the demands and distress of their infant, often expressed through crying, which is expected to increase over the first few weeks of life [24]. The impact of stress on sleep has been demonstrated in the general population, with some studies identifying stress as an important risk factor for poor sleep in parents [25].

2. Measurement of sleep in new parents

As well as negatively impacting sleep in new parents, significant social changes can make it difficult to measure new parent sleep accurately. Subjective measures of sleep provide an inexpensive and relatively unobtrusive means to assess new parent sleep. Sleep diaries require an individual to report on habitual characteristics of their sleep [26–28]. This can include the time they got into bed, the time they fell asleep, any periods of night time wakefulness, the time they woke up and the time they got out of bed [29] and have been used with new parents [7,30–32]. Sleep questionnaires require an individual to report on habitual aspects of their sleep. As with any self-report measure, sleep diaries and sleep questionnaires are limited and potentially subject to user error. They require the participant to make a note of their sleep wake pattern consistently and accurately, which may be made more difficult by the presence of a new-born baby. The ability to estimate sleep accurately can be affected after a period of partial sleep deprivation [33], which may be particularly relevant in research with parents whose sleeping patterns are often irregular.

Polysomnography (PSG), is often considered the gold standard of sleep research [35], but presents substantial difficulties when estimating the sleep of new parents. PSG often relies on one or two nights of data, following habituation. Though crucial for identifying disordered sleep, such a short period of measurement is not necessarily an accurate measure of habitual sleep patterns [36]. Measuring sleep over short periods may be particularly problematic in new parents, whose sleep is likely to be highly variable [30,37]. Further, practical and ethical issues may prevent reproducing home sleep conditions for new parents in a sleep laboratory.

In measurement of sleep in new parents, actigraphy may provide a crucial combination of objective sleep measurement with minimal disruption. Actigraphy requires participants to wear a small device on their wrist, finger, ankle or waist over a period of days to weeks [38] and estimates sleep/wake periods from movement data. Actigraphy-recorded sleep data are highly concordant with polysomnography [39], with low participant burden [40]. Given the variability of night-to-night sleep in new parents [37], being able to record multiple nights of sleep over a period of days to weeks is of benefit. The growing number of actigraphy studies in new parents presents a vital data set for estimating sleep loss in new parents, however, results have varied, and even contradicted one another [7,41,42]. The current meta-analysis synthesises data on this topic to provide a weighted average of differences.

3. Possible moderators of sleep in new parents

Though some of the variance in estimates of changes in sleep in new parents across studies reflects random variability, some of this variance also likely reflects meaningful difference across samples tested. One factor that likely affects estimates is the country in which data are collected: new parent experiences are not consistent worldwide, so changes in sleep are also unlikely to be. Sleep is governed by cultural logics, values, beliefs and practices [43] and this is likely to play a role in how parents from differing cultures sleep. Sleep routines, environments and, co-sleeping habits vary widely across different cultures, which all may impact parents' experience of sleep [44]. The current meta-analysis will test the impact of study location on parent sleep. Generally, infant sleep becomes more stable as children get older [45], so we predict that parent sleep will improve as their baby ages. We will test this by analysing how sleep changes vary as an effect of the time postpartum at which sleep was measured. As adults age, their average total sleep time decreases [46]. It is hypothesised that the age of the parent may have an impact on their sleep. It is widely acknowledged that fathers are underrepresented in research involving parents [45,47], the influence of parental gender will be reviewed.

4. Rationale

Sleep is an essential part of everyday life that serves a multitude of functions. New parents are at particular risk of sleep disturbance. Actigraphy is being increasingly favoured as a way of gaining detailed measurements of sleep in new parents without the need for a laboratory setting. There is not clear agreement on how parent sleep changes following the birth of a new child. This meta-analysis will synthesise the current literature comparing actigraphy-recorded sleep parameters in parents before and after the birth of their child. With actigraphy being used more regularly in research, the methodological quality of the studies within this area will be reviewed. We will also look at factors in the literature that may correlate to variance in sleep changes, such as the age of the baby when sleep is recorded, the age and gender of the parent and the location of the study.

5. Method

The review was not prospectively registered, but a retrospective registration is available from https://doi.org/10.17605/OSF.IO/HSDN4.

5.1. Identifying primary studies

5.1.1. Search of electronic databases

A systematic search of the literature was carried out in October 2021. Six databases were searched: APA Psychinfo (1967), OVID Medline (R) (1946), Embase (1974), Web of Science (core collection, 1900), Pubmed and CINAHL plus. No additional restrictions were made on any databases. All databases were searched from their

earliest record. Duplicates that were identified from OVID databases (Psychinfo, Medline and Embase) were removed using the deduplicate function at the point of searching. Further duplicates were checked and removed manually using Zotero referencing software. Search terms focussed on simple free text terms for parents (Matern* OR Patern* OR Parent* OR Mother OR Father) and Actigraphy (Actigra*), combined using the AND operator. Search terms for parent/carer were informed by a previous review conducted by Haddad et al. [48]. The review explored factors associated with sleep in parents of pre-term infants within the first year of life. Like this review, Haddad et al. [48] looked at sleep quality and quantity to measure sleep. The single truncated search term for actigraphy was based on the initial focus of identifying papers making use of research-grade actigraphy devices. Truncation was used to ensure a broad search of the literature was conducted. Whilst this was likely to return papers using actigraphy for other purposes (e.g. studies of movement), this represents an over-inclusive strategy to ensure appropriate papers were returned. Given the growth of the use of commercial wearables in research, an additional set of search terms (device* OR wearable* OR accelerometer OR accelerometers OR mobile application* OR mobile app* OR smartphone app* OR ambulatory OR portable) were substituted for actigra* and combined with the parent terms in a separate search. This returned only one additional paper; for full details of this additional search, see Supplementary Materials (Fig. S1).

5.1.2. Inclusion criteria

Studies were considered eligible for inclusion if they met the criteria outlined in Table 1.

5.2. Data extraction and quality ratings

The first author screened all the papers. The second author screened a random sample of 20% of papers, using the same inclusion/exclusion criteria to confirm the reliability of selection processes. As part of this process, there was a need to clarify the wording of the inclusion/exclusion criteria to ensure that papers included used a within subjects design. Following a clarification of wording, there were no disagreements about papers to be included in the meta-analysis.

Full texts of the papers included for analysis were obtained and data relating to methods, participants, interventions, and outcomes, extracted by a single author. All sleep data recorded through actigraphy were extracted for review and logged in an excel spreadsheet. The three most commonly reported sleep parameters were total sleep time (TST), wake after sleep onset (WASO) and, sleep efficiency (SE). Due to limited papers reporting sleep onset latency (1) and fragmentation (3), these were not included in the final analysis. All papers used a within participants design, so means and standard deviations from all recorded time points before and after birth were extracted.

5.2.1. Risk of bias assessment

A set of quality criteria were developed to assess risk of bias. The quality criteria were adapted from existing frameworks including: Downs and Black [49], The Cochrane Collaboration Risk of Bias Tool [50] and the Risk of Bias Assessment Tool for Nonrandomised Studies [51]. The framework assessed risk of bias in five domains: Selection bias, detection bias, statistical bias, reporting bias and generalisability. Inter-rater reliability was calculated using Cohen's Kappa, k [52]. Of the papers reviewed, 35% were chosen for cross validation by a second rater. Following the second rating, inter-rater reliability was calculated as $k = 0.58$, indicating 'moderate' agreement between raters [52]. Following a review of ratings with the second rater, it was identified that the criteria for selection bias were unclear and subject to interpretation. Following a review of the criteria and a re-rating of five papers, a Cohen's Kappa of $k = 0.88$ was achieved indicating a high level of inter-rater reliability.

5.2.2. Overall methodological bias

Methodological bias was mixed within the studies. Table 2 displays the ratings for each of the areas of bias by study with an overall quality index. To calculate the quality index, each level of risk is attributed a score; 2 for low risk, 1 for medium and 0 for high risk. The total for each study was then calculated as a percentage of the total possible score which would be 10 for a study with 5 scores of 'low'. The higher the percentage in the overall quality index, the lower the risk of bias.

5.3. Summary

Risk of bias varied across studies. There were six papers that did not report high risk in any domain [7,55,58–61]. There was particularly high-risk of bias across the domains of detection bias and generalisability, with four papers being appraised as high risk for detection bias and generalisability. Particularly in the domain of detection bias, there was variability in the way that actigraphy was reportedly used with multiple methods reported across papers. It was often unclear how different sleep parameters were being calculated and used as few papers specifically reported definitions of these. It is also clear from the data that sample sizes in this area of research are generally small. Given the variability in ratings of potential bias and small sample sizes, caution was taken when interpreting the results of this analysis.

5.4. Data analysis

Analysis was completed for three sleep parameters: TST, WASO and SE, where data were available across 16 papers. Not all studies reported information on all parameters of sleep. These papers were omitted from parts of the analysis where data were not available, so the sample size varied. Standardised mean difference (SMD) was used to calculate the size of the effect for each study and represented as Hedges' g [63]. Heterogeneity of included studies was assessed using Higgins' I^2. Higgins [64] suggests acceptable levels of

Table 1
Inclusion and exclusion criteria.

Inclusion criteria	Exclusion criteria
Reporting primary data on parent/carer sleep	Papers written in any language other than English
Reported sleep data within pregnancy and postpartum data within 12 months following childbirth.	Reviews, editorials, conference abstracts
Measurement of sleep includes any sleep measurement recorded through actigraphy.	Qualitative methodology
A within participants design is used.	Non-human subjects
All populations to be included.	Intervention studies
Published peer review journal article.	
Paper is published at any time.	

Table 2
Risk of bias ratings for papers included in the review adapted from Refs. [49–51].

	Selection bias	Detection bias	Statistical bias	Reporting bias	Generalisability	Overall quality index
Bei Bei et al[37] (2012)	High	Medium	Low	Low	Medium	60%
Calcagni et al[53] (2012)	Low	High	Medium	Medium	Medium	50%
Coo et al[54] (2014)	Medium	High	Medium	Low	Medium	40%
Gay et al[30] (2004)	Medium	High	Low	Low	Medium	60%
Gordon et al[55] (2021)	Low	Medium	Medium	Low	Medium	70%
Krawczak et al[41] (2016)	Medium	High	Medium	Low	Medium	50%
Matsumoto et al[56] (2003)	High	Medium	Low	High	High	30%
Park et al[7] (2013)	Medium	Medium	Low	Low	Medium	70%
Saarikko et al[57] (2020)	Medium	High	Medium	Low	High	40%
Shao-Yu et al[60] (2014)	Medium	Low	Medium	Medium	Low	70%
Sharkey et al[58] (2016a)	Low	Low	Medium	Medium	Medium	70%
Sharkey et al[59] (2016b)	Medium	Low	Low	Low	Medium	80%
Sharkey et al[34] (2013)	Low	Low	Medium	Low	High	70%
Signal et al[42] (2007)	High	Medium	High	Low	High	40%
Volkovic et al[61] (2015)	Low	Medium	Medium	Medium	Medium	60%
Wulff[62] (2000)	Medium	Low	Medium	Low	High	50%

heterogeneity in the data, with values above 75% considered to represent high levels of heterogeneity. Values above this would suggest that the effect sizes analysed are not measuring the same population effect. For each analysis, Quantile Quantile plots were examined to assesses the normality of data for fixed and random effects models created (see Supplementary Materials, Fig. S2). In each case the random effects model (REM) was chosen and the restricted estimator of maximum likelihood employed to estimate variance of the true effect (tau^2). The impact of influential studies was assessed using a "leave-one-out" analysis, in which the REM was calculated with each study systematically left out of the analysis. This was used to calculate the change in weighted average effect size and the study's influence on the overall effect. Studies identified as discrepant and influential were reviewed, but only removed if elevated risk of bias was identified. Details of this process are included in the Supplementary Materials (Tables S1 and S2). To assess further for impact of risk of bias, a quality effects model (QEM) was calculated using the total score from the risk of bias ratings reported in the method of this paper. The discrepancy between the REM and QEM was analysed to understand likely impact of methodological quality on the estimate of the effect.

Funnel plots were created to identify possible evidence of publication bias. Where evidence was apparent, a trim and fill procedure was employed to correct for this. Rosenthal's [65] failsafe number was used to estimate the number of unpublished studies required to reduce the effect to a level of non-significance ($p > .05$).

Subgroup analysis and meta-regression were conducted where more than 10 studies were identified. Subgroup analyses were planned to examine the impact of the age of the baby at measurement post-birth, the location of the study and the inclusion of only fathers, only mothers or a mixed sample. Consistent with the body of literature in this area, it was observed that only two studies had male participants (therefore this analysis was not conducted for any of the parameters). Meta-regression was planned to examine the impact of the average age of parents at testing.

Final data used for the analysis and relevant analysis files are available from https://osf.io/ac6fp/.

6. Results

The results of the systematic search are presented in Fig. 1. Sixteen studies reported a total of 772 participants (693 female).

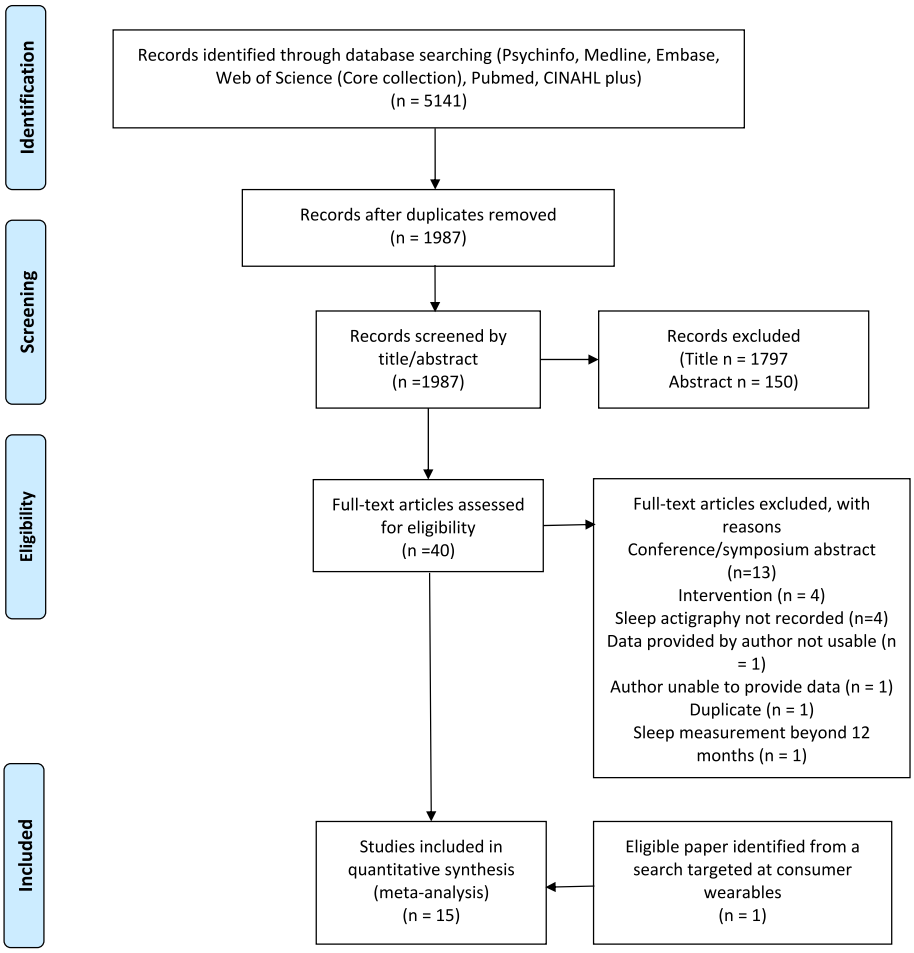

Fig. 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses [76] style diagram showing the results of the systematic search and the application of the exclusion criteria.

The average age of women in the studies reviewed was 30.2 years (SD = 4.27), the average age of men was 34.9 years (SD = 6.0). A summary of studies included in analysis can be found below in Table 3. The studies used multiple methods to recruit participants. Reporting of participant characteristics varied between studies as outlined in the risk of bias assessment. Many of the studies reported results from multiparous and nulliparous mothers. Measurement of sleep was conducted at varying time points in the literature for each of the variables studied. Studies were conducted in various locations including Australia and New Zealand, Canada, the United States of America, Germany, Finland, Israel, Japan, and Taiwan. Recruitment strategies included adverts in the local community (7), women's health clinics (5), antenatal clinics (3), childbirth education classes (3), and midwives (2).

6.1. Total sleep time (TST)

A REM was calculated using the generic inverse variance method and returned a weighted average standardised mean difference of *SMD* = 0.62, $z = 6.29$, $p = .001$, 95%CI = 0.43–0.82; Fig. 2. A positive effect indicates a reduction in parent TST following birth. A treatment effect of this magnitude would be considered a moderate effect. Weighted by sample size, this meant new parents slept for on average 43 min less per night following the birth of their child. An acceptable level of heterogeneity in the primary studies was observed (Higgins' $I^2 = 61\%$, $tau^2 = 0.086$, $p < .01$). The QEM reported an effect of *SMD* = 0.57, 95% CI = 0.38–0.78, an 8% change on the REM estimate. No significant difference was observed between studies that were appraised as low risk, compared to those appraised as any risk (i.e., either medium or high risk), as seen in Supplementary Materials (Table S3). Visual analysis of the funnel plot (Fig. S3) indicated no clear evidence of publication bias, with studies well-distributed throughout. Rosenthal's Failsafe procedure suggested that 630 studies would be required to reduce the observed standardised mean difference to non-significance.

6.2. Subgroup analyses and meta regression

6.2.1. Age of baby at measurement

Some studies measured sleep at a single time point before and after birth, while others recording at multiple time points. Studies were placed into three categories based on the age of the baby at post-partum data collection: 0–4 weeks (N = 13), 4–8 weeks (N = 8), and 8–16 (N = 5) weeks. There was a significant difference observed between groups (Table 4). As recording of sleep became further from birth, the observed effect decreased. Notably, though, even when measured between eight-sixteen weeks, parent TST was still shorter than antenatally.

6.2.2. Study location

A range of effect sizes was observed between continents, with Australia and New Zealand demonstrating a large effect of 0.99 and

Table 3
Summary of papers included in analysis.

Author	Study location	N	Mean age (SD)	Sample Gender	Ethnicity	Time point of sleep recording	Sleep variables measured	Wearable used
Bei et al. [37] (2012)	Australia	24	30.5 (SD = 5.3)	Female	–	3rd trimester, 39 weeks prepartum, 6 days postpartum	TST, WASO, SE%	Actiwatch-64, Mini Mitter, OR, USA
Coo Calcagni et al. [53] (2012)	Australia	68	30.4 (SD = 5.4)	Female	64% Australian 36% Other	38 weeks prepartum, 1 week postpartum	TST, WASO, SE%, Sleep fragmentation	Actiwatch-64 and Actiwatch-2 Mini Mitter Company, Inc., Bern, OR
Coo et al. [54] (2014)	Australia	29	31.1 (SD = 3.82)	Female	–	3rd trimester, 15 days, 10–12 weeks postpartum	TST, WASO, SE%, Sleep fragmentation	Actiwatch®-2, Mini Mitter, Bend, OR
Gay et al. [30] (2004)	USA	144	33.4 (SD = 5.9)	Female Male	Caucasian (68%) Asian (13%) Hispanic (12%) African American (3%) Mixed other (4%)	3rd trimester, 0–4 weeks postpartum	TST, WASO	Ambulatory Monitoring, Inc., Ardsley, NY
Gordon et al. [55] (2021)	USA	96	28.2 (SD = 4.9)	Female	White (71%) Latina (10%) Multi-racial (10%) Black (6%) Asian (2%)	3rd trimester, 2, 6 & 16 weeks postpartum	TST, SE%	Micro Motionlogger Watch, AMI, Ardsley, NY
Krawczak et al. [41] (2016)	Canada	33	31.2 (SD = 3.9)	Female	–	3rd trimester, 6–12 weeks postpartum	TST, WASO, SE%, SOL	Actiwatch 2
Matsumoto et al. [56] (2003)	Japan	10	29.5 (SD = 2.2)	Female	–	3rd trimester, 0–4, 4–8, 8–12 weeks postpartum	TST, WASO, SE%	Ambulatory Monitoring Inc., Ardsley, NY, USA
Park et al. [7] (2013)	USA	25	28.4 (SD = 4.4)	Female	Caucasian (64%)	3rd trimester, 2, 6, 10 & 14 weeks postpartum	TST, WASO, SE%, Sleep fragmentation	Actiwatch-64, Mini Mitter Company, USA
Saarikko et al. [57] (2020)	Finland	20	26 (SD = 5)	Female	–	2nd trimester, 3rd trimester, 1 month postpartum	TST, WASO	Garmin Vivosmart
Sharkey et al. [58],2016a	USA	21	29.5 (SD = 4.7)	Female	–	3rd trimester, 2, 6 & 16 weeks postpartum	TST, SE%	Actiwatch-64, Mini Mitter Company, USA
Sharkey et al. [59],2016b	USA	30	28.3 (SD = 5.1)	Female	–	3rd trimester, 2, 6 & 16 weeks postpartum	TST, SE%	Octagonal Basic or Micro Motionlogger Watch, AMI, Ardsley, NY
Sharkey et al. [34] (2013)	USA	12	26.9 (SD = 5)	Female	–	3rd trimester, 6 weeks postpartum	TST	Octagonal Basic or Micro Motionlogger Watch, AMI, Ardsley, NY
Signal et al. [42] (2007)	New Zealand	19	34[a]	Female	–	2nd trimester, 39 weeks prepartum, 1 & 6 weeks postpartum	TST, WASO, SE%	Mini Mitter, Bend, OR, USA
Tsai et al. [60] (2014)	Taiwan	124	31.76 (SD = 4.4)	Female	–	3rd trimester, 0–4 weeks postpartum	TST, SE%	Actiwatch-2, Philips-Respironics, Bend, OR, USA
Volkovich et al. [61] (2015)	Israel	153	28.9 (SD = 2.9)	Female	–	2nd trimester, 12 & 24 weeks postpartum	TST, WASO	micro motion logger sleep watch
Wulff & Siegmund [62] (2000)	Germany	14	33.2 (SD = 5.6)	Female Male	–	37 weeks prepartum, 1–3 weeks postpartum	TST	Actiwatch (Cambridge Neurotechnology, CNT, UK)

TST = Total sleep time; SE% = Sleep efficiency; WASO = Wake after sleep onset; SOL = Sleep onset latency.
[a] SD not reported.

USA and Canada representing a much smaller effect size of 0.38. Further analysis was completed to identify if there were any differences between the studies in the western hemisphere compared to the eastern hemisphere. Hemispheres were defined by the prime meridian as a way of grouping multiple studies to observe an effect. Studies in the eastern hemisphere demonstrated a much larger effect than the western hemisphere. The difference between these effects was statistically significant.

6.2.3. Age

A meta-regression was conducted to assess whether the average participant age reported by studies was systematically related to the TST reported by the primary studies. Results of the meta-regression indicated no relationship between age and the observed effect ($R^2 = 0.023$, $\beta = 0.053$, $p = .24$).

6.3. Sleep efficiency (SE)

The REM was calculated using the generic inverse variance method, to return a weighted average standardised mean difference of $SMD = 1.26$, $z = 7.72$, $p < .0001$, 95%CI = 0.94–1.59; Fig. 3. A positive effect in this instance indicates a reduction in the SE following birth. A treatment effect of this magnitude would be considered a large effect. A high level of heterogeneity was observed, Higgins' $I^2 = 75\%$, $tau^2 = 0.2071$, $p < .01$. Two studies, Sharkey et al. [59] and Park et al. [7] were identified as potentially influential and discrepant from the rest of the literature. The analysis concluded that if Sharkey [59] were removed, it would have little observable difference on the effect still producing a significant outcome. If Park et al.'s [7] data were removed, the outcome of the effect would remain significant, however, the

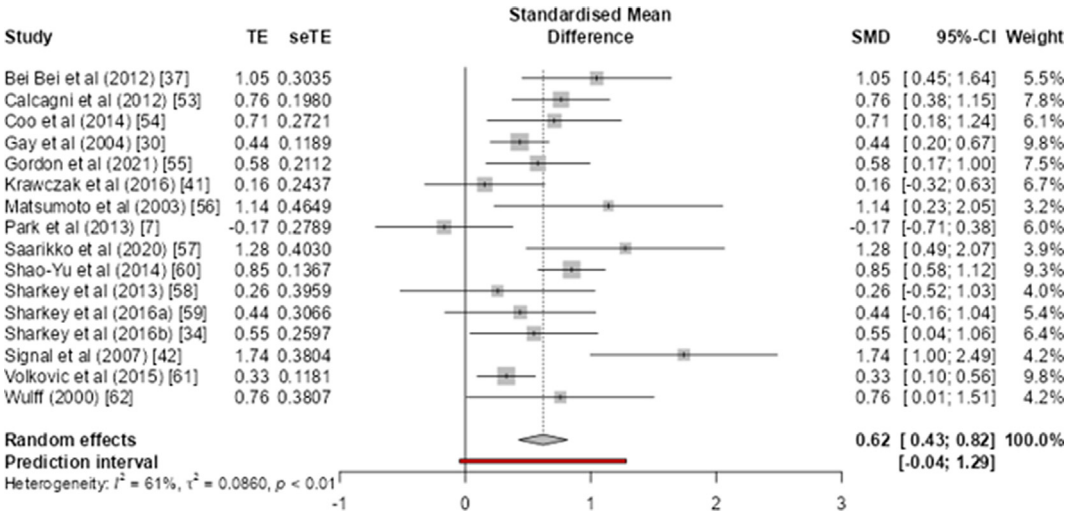

Fig. 2. Forest plot of standardised mean difference in total sleep time.

Table 4
Results of sub group analyses for total sleep time.

	Level	SMD	95% CI	K	X^2	p
Time point sleep is recorded	0–4 weeks	0.72	[0.50; 0.93]	13		
	4–8 weeks	0.30	[0.11; 0.50]	8		
	8–16 weeks	0.25	[0.08; 0.42]	6	9.23	<0.01
Study location	Australia and New Zealand	0.99	[0.60; 1.37]	4		
	USA and Canada	0.38	[0.22; 0.54]	7		
	Japan and Taiwan	0.87	[0.62; 1.13]	2		
	Israel	0.33	[0.10; 0.56]	1		
	Finland	1.28	[.49; 2.07]	1	22.44	<0.01
Hemisphere	Eastern hemisphere	0.86	[0.60; 1.13]	9		
	Western hemisphere	0.38	[0.22; 0.54]	7	9.30	<0.01

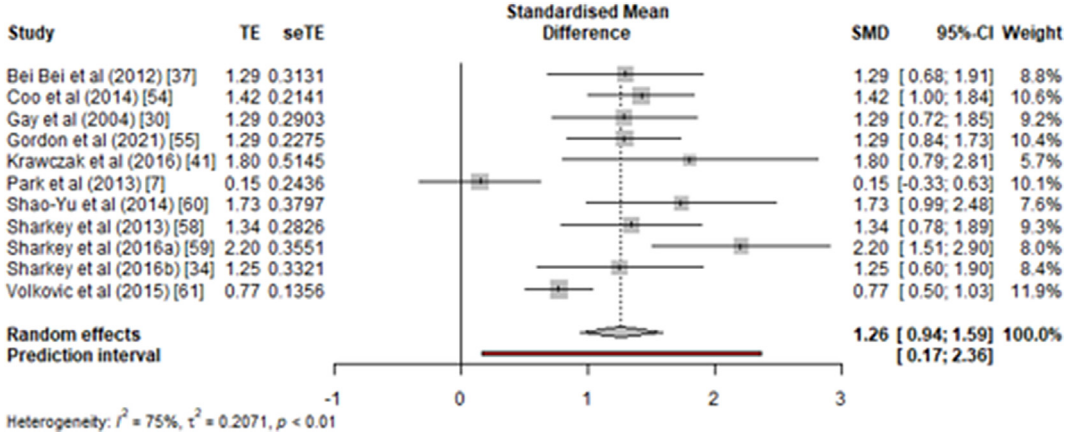

Fig. 3. Forest plot of standardised mean difference for sleep efficiency.

heterogeneity of the data would fall to 61% (see supplementary materials Table S1). A review of both studies identified that their methodologies did not differ greatly from those used in other papers included for analysis and so both were included in the final analysis. The QEM reported an effect of *SMD* = 1.25, 95% CI = 0.89–1.61. When the methodological quality of the literature was taken into consideration, no substantial change in the overall effect was observed. No significant difference was observed between studies that were appraised as low risk, compared to those appraised as any risk, as seen in Supplementary Materials (Table S4), suggesting methodological quality had little impact on the observed effect. Visual analysis of the funnel plot indicated possible evidence of publication bias, with studies poorly distributed through the funnel plot (Fig. 4). The effect of publication bias was simulated using a trim and fill procedure [66] and yielded a corrected random effects model of *SMD* = 1.08, *95% CI* = 0.75–1.41. The corrected REM evidences a 14.3% reduction relative to the uncorrected estimate. Rosenthal's Failsafe procedure suggested that 910 studies would be required to reduce the observed standardised mean difference to non-significance.

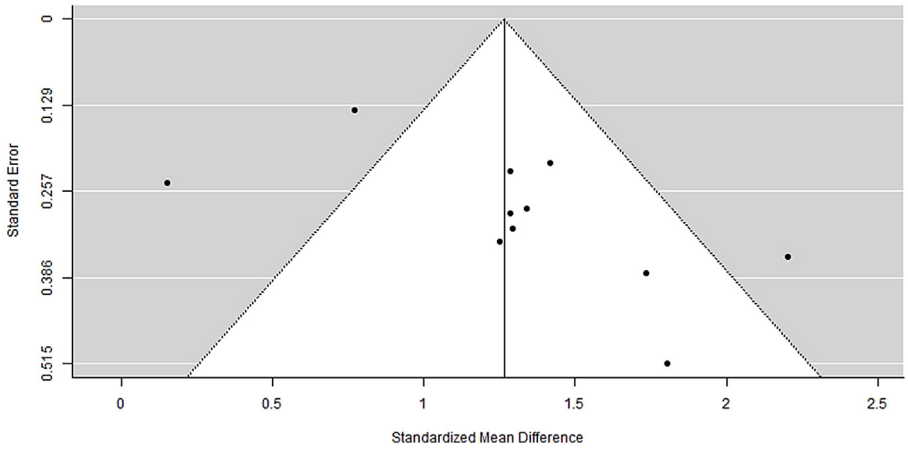

Fig. 4. Funnel plot showing publication bias for sleep efficiency.

Table 5
Results of sub group analyses for sleep efficiency.

	Level	SMD	95% CI	K	X^2	p
Age of baby	0–4 weeks	1.43	[1.24; 1.63]	9		
	4–8 weeks	0.68	[0.29; 1.07]	8		
	8–16 weeks	0.38	[-0.05; 0.81]	5	25.63	<0.01
Study location	Australia and New Zealand	1.38	[1.03; 1.72]	2		
	USA and Canada	1.29	[0.80; 1.77]	8		
	Japan and Taiwan	1.73	[0.99; 2.48]	1		
	Israel	0.77	[0.50; 1.03]	1	11.77	<0.01
Hemisphere	Eastern hemisphere	1.24	[0.79; 1.69]	4		
	Western hemisphere	1.29	[0.80; 1.77]	7	0.02	*0.89*

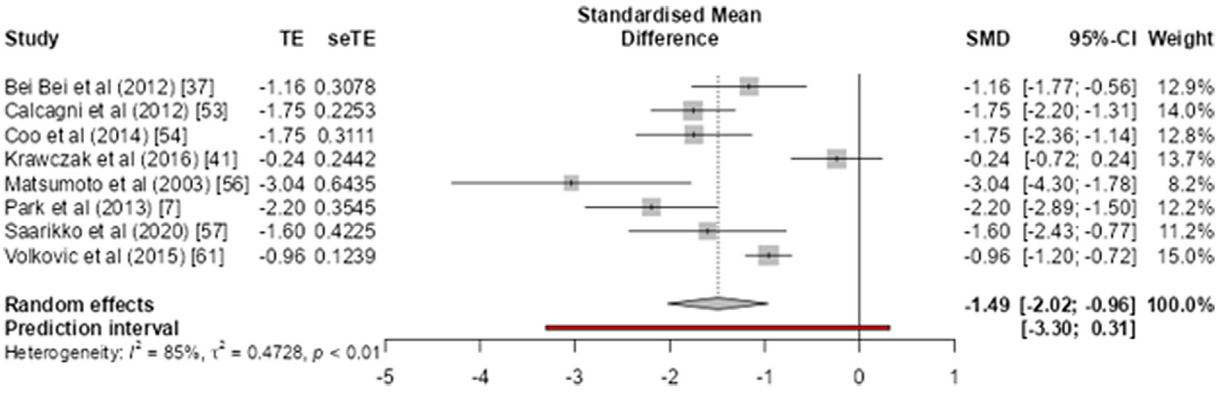

Fig. 5. Forest plot of standardised mean difference for wake after sleep onset.

6.4. Subgroup analyses and meta regression

As with TST, there was a significant difference observed between groups based on the age of the baby at sleep recording, $X^2 = 25.63$, $p < .01$, see Table 5. As recording of sleep became further from birth, the observed effect decreased, with measurement at 8–16 weeks not evidencing a significant effect. Analysis by study location showed a significant effect of country of measurement, $X^2 = 11.77$, $p < .01$, but not of hemisphere, $X^2 = 0.02$, $p = .89$.

6.4.1. Age

A meta-regression was conducted to assess whether the average participant age reported by studies was systematically related to the sleep efficiency reported by the primary studies. Results of the meta-regression indicated a non-significant relationship between age and the observed effect ($R^2 = 0.0071$, $\beta = 0.088$, $p = .312$).

6.5. Wake after sleep onset (WASO)

The REM was calculated using the generic inverse variance method, to return a weighted average standardised mean difference of $SMD = -1.49$; $z = -5.52$; $p < .0001$; 95%CI = −2.02 to −0.96; Fig. 5. A negative effect in this instance indicates an increase in WASO following birth. A treatment effect of this magnitude would be considered a large effect. A high level of heterogeneity was observed, Higgins' $I^2 = 85\%$, $tau^2 = 0.47$, $p < .01$. Two studies, Krawczak et al. [41] and Matsumoto et al. [56] were identified as potentially influential studies, discrepant from the rest

of the literature. The analysis concluded that if either of these studies were removed, heterogeneity would continue to be above an acceptable level, but the analysis would produce a significant effect (see Table S2). The small sample size included in the analysis of WASO is likely to be a contributing factor to the high level of heterogeneity in the observed effect. A review of both papers identified no methodological reasons that they should not be included in the analysis. The QEM reported an effect of $SMD = -1.46$; 95% CI $= -2.00$ to -0.92. When the methodological quality of the literature was taken into consideration, little change in the overall effect was observed. A significant difference was observed between studies that were appraised as low risk, compared to those appraised as any risk in the domain of statistical bias, with low risk studies reporting larger effect sizes, as seen in Supplementary Materials (Table S5). This suggests methodological quality may have some impact on the overall observed effect, though the small number of overall studies for comparison may limit this interpretation. Visual analysis of the funnel plot (Supplementary materials, Fig. S4) indicated no clear evidence of publication bias, with studies well distributed throughout. Rosenthal's Failsafe procedure suggested that 602 studies would be required to reduce the observed standardised mean difference to non-significance. Subgroup analysis and meta-regression were not conducted due to the small number of studies.

7. Discussion

This meta-analysis shows that the arrival of a baby has an impact on the total amount of sleep, the time spent awake after initial sleep onset and sleep efficiency of new parents. Across studies, TST reduced by 10.8%, WASO increased by 47% and, SE decreased by 12.1%. The decrease in TST and SE was much larger in the first 0–4 weeks following the birth of a child, with smaller effects at 4–8 weeks and 8–16 weeks. There were not enough data to analyse this for WASO. Study results differed across locations. Studies conducted in the eastern hemisphere demonstrated larger effect sizes on TST. Few studies included male parents/carers involved in parental research, as highlighted previously [45,47], so further analysis on these data could not be completed.

7.1. Implications of the review

This review evidenced clearly quantifiable changes to sleep for new parents. Although there are many factors that influence maternal mental health, sleep has been identified as an important factor to consider. Findings of the meta-analysis suggest that there is a reduction in the amount of night-time sleep parents achieve. However, the more substantial change can be observed in the WASO data. Sleep deprivation literature in new parents has focused on the effects of partial sleep deprivation, with little research on the implications of repeated night-time waking over the course of the first few months of life. Night-time waking is associated with increased daytime sleepiness [67] and increased immune response and risk of cardiovascular disease [68,69]. Sleep fragmentation can have clinically significant implications on physical health when compared to sleep deprivation [70]. We do not know the impact of sleep fragmentation on new parents and whether this varies depending on individual differences. For example, future research is needed to clarify how these effects vary with parental gender, cultural logics, values, beliefs and practices. Sub-group analysis suggested total sleep time following the birth of a child is sensitive to national/cultural differences [71]. It should be recognised that this analysis was limited by the few studies analysed in some locations. Further research may examine parents' approach to sleep and the impact of this on sleep between cultures. This review also highlighted that fathers continue to be mostly absent from the literature when it comes to parenting, meaning the impact of poor sleep on them is hard to estimate.

7.2. Limitations of the evidence

Most studies reviewed agreed that the birth of a child decreased parents' TST and SE, and increased WASO. The results must however be interpreted with caution given that baseline data were collected during pregnancy when it is recognised that sleep may already be disturbed. Heterogeneity was also high for SE and WASO in particular. Throughout the literature, there was variability in sleep measurement. This included the length of actigraphy recording, time point at which sleep was recorded pre- and post-birth, variables recorded and reported and, the use or absence of sleep diaries. This is consistent with previous reviews of the actigraphy literature [72,73]. Berger et al. [72] noted variability in the methods of reporting, sampling, processing of data, analysis and a distinct lack of standardised protocols for the use of actigraphy. Sleep diaries can be used alongside actigraphy to increase reliability of the device in the event of device malfunction or, periods of motionless activity being mistakenly recorded as sleep [40]. Many of the studies reviewed did not report the use of sleep diaries to validate actigraphy data. As actigraphy use in research increases, there is a need for practice to be standardised to allow for more accurate comparison of data across studies [72]. Reporting methods varied across the studies reviewed, with not all studies including data for TST, WASO and SE. In addition to this, sleep parameters such as fragmentation, daytime napping and sleep onset latency were less widely reported meaning analysis was not possible. Variance in reporting of sleep parameters meant that sample sizes across each parameter varied. For parameters such as WASO and SE, data analysis was conducted on smaller sample sizes, meaning subgroup analysis was not possible for WASO.

This review focussed on studies using a within participants design, which means the control group for post birth sleep was sleep during pregnancy. However, this period of sleep may not represent 'normal' sleep. TST decreases throughout pregnancy [74] with reported TST being higher before pregnancy when being measured subjectively [54] and objectively [56]. The effects in this review likely represent an under-estimate of the comparative difference between new parent sleep and that of adults in the general population. Further review of the data may look further into the role of sleep loss during pregnancy.

Having a new child is a complex biopsychosocial process. Although factors around age and, location have been explored through regression and subgroup analysis, there are a multitude of factors which may influence sleep which have not been analysed. Inconsistency of demographic reporting in the literature made further analysis difficult. However, It is well documented that maternal mental health [75,76] and, socioeconomic status [77,78] have an influence over sleep and further analysis may explore these factors in relation to childbirth.

8. Conclusion

Sleep deprivation following the birth of a child is experienced by new parents worldwide. This meta-analysis provides clear quantifiable evidence of how much sleep new parents lose. Disturbances in sleep are influenced by factors such as culture and time following the birth of the child. Although not the focus of this study, attention may need to be given to biopsychosocial factors such as gender, socioeconomic status and stress and their influence of parents' sleep.

Practice Points:

New parents are likely to experience significant levels of sleep deprivation.

1. Actigraphy is an effective means to measure sleep in new parents
2. Sleep fragmentation and lowered sleep duration have important implications for new parents
3. Though biggest changes in sleep occur directly after birth, measurable differences remain for at least 16 weeks

Research Agenda:

To understand more about sleep in new parents.

1. We need more data on the sleep of new fathers/non-maternal caregivers
2. Actigraphy protocols need to be more consistently reported
3. The impact of poor sleep in new parents needs to be systematically assessed

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Declaration of competing interest

No conflict of interest was identified by the authors.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.smrv.2022.101719.

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Glossary of terms

Actigraphy: A non-invasive device that is worn to monitor human rest/activity cycles