THE IMPACT OF SLEEP DEPRIVATION ON EMOTION RECOGNITION IN NEW PARENTS

By

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A THESIS SUBMITTED TO THE UNIVERSITY OF BIRMINGHAM FOR THE DEGREE OF DOCTOR OF CLINICAL PSYCHOLOGY

Department of Clinical Psychology

Centre for Applied Psychology

The University of Birmingham

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Declaration of disruption to planned research at submission of thesis

This form should be completed at the point of submission and included in the e-mail to the research Student Administration Team along with all the other forms required at submission.

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Submission date	06/09/2021

Summary of **planned** research (this is research activity that was planned but has not taken place due to disruption caused by COVID-19)	The project initially planned to use a within subjects' design, recruiting parents who were in the third trimester of pregnancy. It was initially planned that participants would take part in testing during the third trimester and once again following the birth of their child, within 3 months of their birth. Parents were going to be asked to record their sleep using an actigraphy device as well as a sleep diary. Parents were going to be asked to take part in an emotion recognition task as well as a test of vigilance at each time point. This was due to take place either in the participants home or, at the university campus. Participants were going to be tested on their accuracy of emotion recognition as well as their speed of emotion recognition. Twenty-four control participants were also due to be recruited. For control participants, there were to be two testing dates three months apart. Control participants were going to complete a test of vigilance as well as a neutral recognition task. Ethical approval was given for this project on 13/06/2019, with recruitment due to start by 01/05/2020. An amendment was made to the protocol prior to the COVID 19 pandemic and was accepted on 27/09/2019.

Summary of **research undertaken** to mitigate disruption	Due to the potential risks posed to pregnant participants and new-born children, the study was changed to be conducted remotely. Health and safety clearance was not possible for face-to-face testing under University of Birmingham Covid-19 restrictions. As a result, amendments to the procedure were submitted to the ethics committee for approval. Initial changes included approval to meet with participants over Zoom to administer the emotion recognition task, widening of the recruitment area to allow participants across the UK to be included and change in the protocol to a between subjects' design. Further adaptations also had to be made including making the consent form available online and obtaining equipment to ensure that the research materials could be posted to the participants. Submission for approval of this new procedure was submitted on 08/07/2020, with final approval granted on 01/09/2020. Another amendment was submitted on 24/09/2020 and approved on 24/09/2020. Subsequent to ethical approval of this new protocol, the research team were alerted to the need the include an equipment cleaning protocol into the procedure. Further amendments were submitted to the ethics committee which added further delay to beginning recruitment – these were submitted on 02/12/2020 and approved on 11/01/2021. The cleaning protocol required items to be packaged and quarantined for 72 hours prior to being sent to participants, which again, caused some delay in the turnaround of equipment. Delays in approval of the procedure regarding ethical and health and safety clearance meant that it was not possible to pilot the procedure prior to commencement. With this in mind, a cautious approach was taken to early recruitment and testing, beginning with a single participant. It was not possible to ask participants to use a public post office (due to Covid risk) and the first Ōura ring sent was lost in the post on return to the University (perhaps due to Royal Mail procedures, or adapted University processing of post during the pandemic.) Following this, a PO BOX was set up so rings could be returned to the home of a member of the research team. This caused some delay waiting for this to be confirmed and active. The remaining two rings were then posted to participants and a 3rd ring was sourced following a delay. Data collection then commenced as planned. Due to posting the rings, there was some delay in the turnaround. Although participants were only recording sleep for 7 nights, with the delay in the postal service at the time due to the pandemic, as well as the need to adhere to the cleaning protocol, the delay between data collection being complete and the ring being put in the post, turnaround of equipment ranged between 2 and 4 weeks. Towards the end of data collection, the PO BOX that was set up was coming to an end and due to expire. Royal Mail were contacted to change the initial 6month PO BOX to a 1 month PO BOX, but this could only be done by post causing some delay. Royal Mail were then chased, and I was informed that it could take up to 30 days for the direct debit to be set up and for the PO BOX to be active once again on the new plan. Whilst this was happening three rings were then 'stuck' with participants and not available for data collection. During this time, I was informed by one of the participants that they had tested positive for COVID which meant they had to quarantine. This meant that they could not return the ring and when it was returned,

	it had to remain in quarantine before being opened and cleaned as per the cleaning protocol. In sum, recruitment and testing were substantially impacted by the Covid-19 pandemic. Amendments to the protocol, achieving ethical approval and health and safety clearance meant I tested the first participant on [date], a full X months after this likely would have occurred without the pandemic. Although we were able to test 2-4 participants at one time, amendments to the protocol to include for postal return and cleaning procedures meant the average turnaround time between participants was X days, when this would have been 10 days without these delays. Whilst it is impossible to know how the project would have progressed without the pandemic, it is reasonable to assume the final sample size would have been substantially higher than that ultimately achieved. Testing remotely over Zoom meant use of an emotion recognition procedure that was less sensitive than that initially planned. Whilst it would have been possible to programme an "online" remote version of the paradigm, to capture response times as well as accuracy, this would likely have resulted in further delays.

How has your submitted work met the requirements for the research degree? Regulations of the University of Birmingham. (Section 7.4.1 c for masters by research; 7.4.1 c and d for MPhils and 7.4.1 c, d and e for doctoral research degrees)	This work demonstrates my knowledge of the research related to this topic and the literature in which this study is grounded. It demonstrates my ability to design a research method suitable for testing the initial hypothesis and my ability to adapt this in the face of adversity. The investigation has been conducted independently. The research demonstrates my ability to understand and utilise methods of data analysis based on alternate statistical models to produce meaningful outcomes despite the data having limited power. The information presented in the empirical paper demonstrates my ability to put forward an argument for further research and the research in which hypothesis are grounded. It also demonstrates my ability to reflect on the process of conducting such research and offer guidance for others interested in conducting research in a similar manner. This is an original and novel piece of work using wearable technology with a population in which the potential outcomes of such research would be beneficial.
Other relevant information (If any of your supervisory team wishes to make a supporting statement, they can do so here)	

Thesis overview

This thesis is presented in two volumes. Volume one contains the research project and volume two contains clinical practice reports completed as part of clinical placements.

Volume one consists of two papers: a meta-analysis and an empirical study. It also contains a public dissemination document providing a summary of both papers. The aim of the research papers was to address existing gaps in the literature related to the experience of sleep and sleep loss in new parents and, its potential impact on social and emotional abilities.

The meta-analysis found that new parents experience an increase in time spent awake during the night following the initial sleep onset. It also identified that total sleep time and sleep efficiency decrease following the birth of a child. Most notably, this change is much more significant in the first four weeks after birth and does not return to pre-birth levels even 16 weeks after birth. Cultural differences were also found in these parameters. The meta-analysis also identified variation in the methodological quality of papers, particularly, the way actigraphy is used to measure sleep.

The empirical study used a between participants design to measure sleep and emotion recognition in new parents. Although underpowered, the pilot study did identify similar patterns of sleep loss to the meta-analysis with new parents experiencing higher levels of wake after sleep onset and lower sleep efficiency. No differences were found in parents' ability to recognise emotions in infants. This study demonstrates that research of this type is feasible with this population and offers some recommendations for future research in this area.

For Mopsy

Those that she loved and, those that she would have loved

x

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I would like to start by thanking the course team for their support throughout this process. Gary Law for checking in and keeping me on track. My supervisor Andy Surtees for all those reads, re-reads and continuous reassurance. Thank you to those who have supported with the research papers, Abby Howes for taking the time to support with the meta-analysis and Belle Vickers-Graver for providing your support for the meta-analysis and running of the research study. I would like to thank my fellow trainees for their support. In particular, Hannah Plaisted and Tom Watson for providing the humour and always being on call.

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Thank you to my friends and family who have checked in with me along the way. Particularly my dad with whom I had many much needed calls with on the way home from placement. I would also like to acknowledge my thesis soundtrack. Particularly Slipknot and Machine Head for helping me to find the zone. I would also like to acknowledge my indoor trousers for providing comfort when it was needed most working at home.

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Volume one

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Meta-analysis: The impact of childbirth on the sleep of new parents: a meta-analytic review of the literature using actigraphy

Abstract

Purpose

A significant amount of research has measured sleep parameters in new parents. However, there is no meta-analysis which synthesises the data for this population.

Method

A search of six databases was completed using search criteria specifically for within subject designs that utilised actigraphy to measure sleep. Following review using predetermined inclusion and exclusion criteria, 14 papers were left for review. Data were extracted, analysed and each paper was reviewed for methodological quality. Subgroup analysis were also completed for some of the data.

Results

Parents' Total Sleep Time and Sleep Efficiency were shown to decrease following the birth of a child, with an increase in time spent awake after the onset of sleep identified. 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. This study also identified possible cultural differences in the data.

Discussion

The results indicated that new parents experience a significant change in multiple sleep parameters following the birth of a child. This change was most significant in the immediate weeks after birth. Given what we know about the impact of sleep on cognitive and emotional processes in an adult population, further work needs to be completed to understand the impact this change in sleep has on new parents.

Introduction

Sleep is a “reversible state of minimal interaction and decreased responsiveness with the environment” (Chervin et al., 1997). Although a state of reduced responsiveness, sleep is a time of significant neurological and physiological activity (De Beritto., 2020). Sleep has a multitude of functions, affecting learning and memory, restorative functions, macromolecular synthesis and neural detoxification (Landolt & Dijk, 2019). There is a wealth of literature that explores the effects of sleep loss on the general population and research that provides normative data for sleep in children (Galland et al., 2018) and adults (Jonasdottir et al., 2021). When born, babies enter into a free running sleep rhythm over 25 hours, which aligns to a 24 hour cycle at around 4 weeks old (Shimada et al., 1999). Even after this time, most babies continue to wake regularly (Ball, 2020), with sleeping through the night being achieved typically around 6-9 months (Henderson et al., 2011). Given this mismatch in circadian cycle, and the need for night-time feeding, we would expect parents to be particularly at risk of sleep disruption and sleep deprivation. There is a growing body of evidence that looks at sleep loss in parents and carers. However, there is currently no meta-analysis of the change in sleep new parents experience.

Impact of poor sleep on new parents

The impact of sleep deprivation in the general population has been well documented. A meta-analysis of 70 studies showed that even short term sleep deprivation negatively affects a broad range of cognitive processes (Lim & Dinges, 2010). Sleep disturbances during pregnancy and postpartum are likely to have an impact on the health and wellbeing of both mother and child (Lawson et al., 2015). In pregnancy, maternal sleep disturbances have been linked with poor birth outcomes (Felder et al., 2017; Okun, Schetter, et al., 2011) and a higher

risk of emergency delivery (Paine et al., 2020). Research has been conducted into the effects of sleep disturbances on the mental health of mothers. Multiple studies connect postpartum sleep disturbances with poorer mental health outcomes (González-Mesa et al., 2019; Lawson et al., 2015; Okun, Luther et al., 2011; Park et al., 2013). The implications of postpartum depression have been well documented. Enduring postnatal depression can have an impact on child outcomes and has been evidenced to effect behavioural problems in children (Netsi et al., 2018; Prenoveau et al., 2017), as well as cognitive development in the early years (González et al., 2017; Liu et al., 2017). 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.

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. In the postpartum period, mothers experience physiological and anatomical changes, which return the body to the non-pregnant state (Chauhan & Tadi, 2020). Physiological changes linked to diuresis, menstruation and haemoglobin continue in the days following childbirth and last to at least 12 months after childbirth (Chauhan & Tadi, 2020), prompting further disruption to sleep. Badr & Zauszniewski (2017) reported through meta-analysis that physiologic illness, low ferritin level, low haemoglobin level, also demonstrated a significant effect in relation to postpartum fatigue and tiredness.

Physiological factors are internal factors that are only experienced by a biological mother of a new baby. Environmental factors that arise through the natural process of having a new child will affect all those in a caring role in the home. New born babies spend an average

of 63.8% of their time sleeping, with periods of being awake during the day and the night (Sadeh et al., 1996). Parental sleep quality and quantity is likely to be directly influenced by the quality and quantity of infants' sleep (Meltzer & Mindell, 2007), with parents being required to fulfil the needs of the infant during day-time and night-time waking. There are numerous factors affecting sleep that are specific to the role of being a parent. Responding to an infant's need to feed day and night is one such role. Night-time feeding is associated with poorer sleep outcomes (Kendall-Tackett et al., 2011). More specifically, the need to feed after sleep onset negatively affects sleep duration in the early months of life (Touchette et al., 2005).

The transition from pregnancy to parenthood comes with some significant changes. By the time parents return home from the place of birth, they immediately have parental roles to undertake. Changes may occur at all levels of family life such as new parental roles at home and the stress of returning to work (Grice et al., 2011). Having a new baby can also impact on marital life, personal wellbeing and stress (Miller & Sollie, 1980). Parental characteristics such as personality, mental health status, and cognitions will likely indirectly impact on infant sleep through parenting practices (Sadeh et al., 2010). Parents must cope with the distress of their infant. This is typically expressed through crying, which is expected to increase over the first few weeks of life (Cabana et al., 2021). In a review of the literature, Oldbury & Adams (2015) identified a common theme of infant crying evoking emotions of anger, frustration, guilt and, shame. Many of the studies reviewed by Oldbury & Adams (2015) also identified that when feeling tired themselves, parents felt most at risk of a negative emotional response towards their child. 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 (McQuillan et al., 2019).

How the sleep of new parents is measured

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 (Buysse et al., 1989; Johns, 1991; Douglass et al., 1994). 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 (Ibáñez et al., 2018) and have been used with new parents (Gay et al., 2004; Tsai et al., 2011; Park et al., 2013; Sharkey et al., 2013). 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 (Goulart et al., 2014), which may be particularly relevant in research with parents whose sleeping patterns are often irregular.

Polysomnography is often considered the gold standard of sleep research (Azimi et al., 2019). It is a useful diagnostic tool for several sleep conditions. However, it typically relies on a single night of data, which is not always an accurate measure of habitual sleep patterns (Newell et al., 2012). People typically undergo a habituation night when sleep is recorded in this way however, sleep measured using polysomnography is subject to the 'first night effect'. When this happens sleep parameters are not representative of a 'normal' sleep, and this can last through 4 nights of recording (Le Bon et al., 2001). This effect is caused by many factors specific to the sleep lab setting such as discomfort caused by electrodes, limitation of

movement, psychological consequences of being under scrutiny and the change of environment (Le Bon et al., 2001). New parents sleep tends to be broken and irregular (Bei et al., 2012; Gay et al., 2004), which means short periods of sleep measurement may not be an accurate measurement of sleep. Due to this variance and increased sleep deprivation, new parents are at risk of experiencing rapid eye movement (REM) rebound. Data produced from a single night of sleep recording may not produce an accurate picture of this effect. It may be the case that these factors contribute to the presence of very little literature examining new parents sleep in the laboratory setting. Whilst polysomnography is considered the gold standard for measuring sleep disorders, it is unlikely that is the best option for measuring habitual patterns of sleep.

Actigraphy is an alternative method of collecting sleep data electronically, requiring the user to wear a small device on their wrist, finger, ankle or waist relatively unobtrusively over a period of days to weeks (Smith et al., 2018). Actigraphy can provide the user with objective data related to sleep that is concordant with polysomnography (de Zambotti et al., 2019). However, actigraphy differs to polysomnography, as it does not provide information on sleep architecture (Smith et al., 2018). It is a portable, non-invasive method of objective recording that can be used in the home and requires little user input to record sleep (Chinoy et al., 2020), with the participant needing to do little more that ensure the device is charged, thus reducing participant burden (Martin & Hakim, 2011). Although actigraphy is more expensive than traditional paper diaries, it offers objective sleep measurement at a fraction of the cost of polysomnography (Chinoy et al., 2020). This is especially important in the case of new parents in sleep research who are adjusting to new roles and responsibilities. Given the variability of night to night sleep in new parents (Bei et al., 2012), being able to record multiple nights of sleep over a period of days to weeks is of benefit. It is for this reason that

between 1991 and 2009 the rate of growth of the use of actigraphy in research exceeded the relative growth of PSG use (Sadeh, 2011). Numerous studies have demonstrated the value of actigraphy in the estimation of sleep (de Zambotti et al., 2019; Kosmadopoulos et al., 2014; Quante et al., 2018). Given the benefits of being able to objectively record sleep over several nights and, its relatively unobtrusive nature, actigraphy is particularly suited to measuring sleep in new parents. It is likely that these factors contribute to its use in the measurement of parents sleep over the last 20 years. The current meta-analysis focuses on actigraphy-measured sleep in new parents before and after the arrival of their child.

Current understanding of sleep loss in new parents

Despite using a similar methodology, there continues to be variability in the estimation of sleep change following childbirth when measured using actigraphy. Many studies agree that there is a decrease in the total time that parents sleep following the birth of a child (Bei et al., 2012; Matsumoto et al., 2003; Signal et al., 2007). However, some studies suggest that the total sleep loss is less significant (Gay et al., 2004; Krawczak et al., 2016), and some suggest there is no overall loss of sleep (Park et al., 2013). It is a similar picture when considering the time parents are awake during the night after going to sleep. Many studies agree that parents spend more time awake during the night (Calcagni et al., 2012; Matsumoto et al., 2003; Park et al., 2013), with others suggesting that sleep is less disturbed by night time awakenings (Bei et al., 2012; Krawczak et al., 2016). There may be many reasons for differences in the data for which further, more detailed analysis would be required. Meta-analysis is one tool that can be used to explore these data further.

Factors affecting sleep in new parents

One reason for varying estimates for changes in sleep faced by new parents is that the new parent experience is genuinely not homogenous worldwide across all parents. Sleep is governed by "cultural logics, values, beliefs and practices" (Airhihenbuwa et al., 2016) and this is likely to play a role in how parents from differing cultures sleep. In a study of nearly 5000 mothers in the U.S., Kendall–tackett et al. (2010) highlighted that, although bedsharing was common among all demographics, mothers from African American, American Indian, Caucasian and, lower income families were more likely to bedshare with their child, which may have a greater impact on their sleep. Sleep routines, environments and, co-sleeping habits vary widely across different cultures (Owens, 2004).

Generally, infant sleep improves as a child grows (Tikotzky et al., 2015), so we should predict that parent sleep will improve as their baby ages. However, as adults age we would expect the length of their total sleep time to decrease (Li et al., 2018) across the lifespan (Ohayon et al., 2004). 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 (Macfadyen et al., 2011; Tikotzky et al., 2015). It is beyond the scope of this analysis to ascertain why this may be the case. However, the influence of parental gender will be reviewed in this analysis. The parents' approach to sleep is also going to have an impact on the child's ability to develop regular sleeping patterns and may be influenced by culture (Kendall–tackett et al., 2010). The influence of cultural differences in relation to geographical location will also be reviewed

Rationale

Sleep is an essential part of everyday life that serves a multitude of functions. New parents are a group who are at particular risk of sleep disturbance. The way in which researchers measure sleep has continued to develop. With more objective measures of sleep being available, actigraphy is being increasingly favoured as a way of gaining detailed measurements of sleep in new parents without the need for a laboratory setting.

Many studies have been conducted that measure the impact having a new child has on new parents' sleep. However, there does not appear to be an agreement on how sleep is affected, with results varying. Meta-analysis was used to conduct a review of these data as meta-analysis aim to provide a single summary estimate of the effect. By pooling data from multiple studies, meta-analysis can answer questions about the data that cannot be answered by individual studies. Meta-analysis can also be used to correct for apparent bias and heterogeneity in the data.

This meta-analysis will summarise the current literature reviewing the impact having a new-born child has on parental sleep as recorded using actigraphy. With actigraphy being used more regularly in research the methodological quality of the studies within this area will be reviewed. It will also look at factors in the literature that may have a correlational link to variance in sleep such as the time point at which sleep is recorded, location of the study, age, and gender.

Method

Identifying primary studies

Search of Electronic Databases

A systematic search of the literature was carried out in March 2020. 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. The aim of the search was to obtain a comprehensive overview of the effect that having a new-born child has on parental sleep, as measured by actigraphy. The search was open to any study reporting sleep parameters recorded using actigraphy.

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 can be found in Table 1.

Table 1

Meta-analysis search terms

Construct	Free Text Search Terms
Parent/carer	Matern* OR Patern* OR Parent* OR Mother OR Father
Actigraphy	"Actigra*"

Search terms for parents were based on a previous review conducted by Haddad et al. (2019). The review looked to explore factors associated with sleep in parents of pre-term

infants within the first year of life. Like this review, Haddad et al. looked at sleep quality and quantity to measure sleep. Truncation was used to ensure a broad search of the literature was conducted.

Inclusion criteria

Studies were considered eligible for inclusion if they met the criteria outlined in Table 2.

Table 2

Inclusion and exclusion criteria

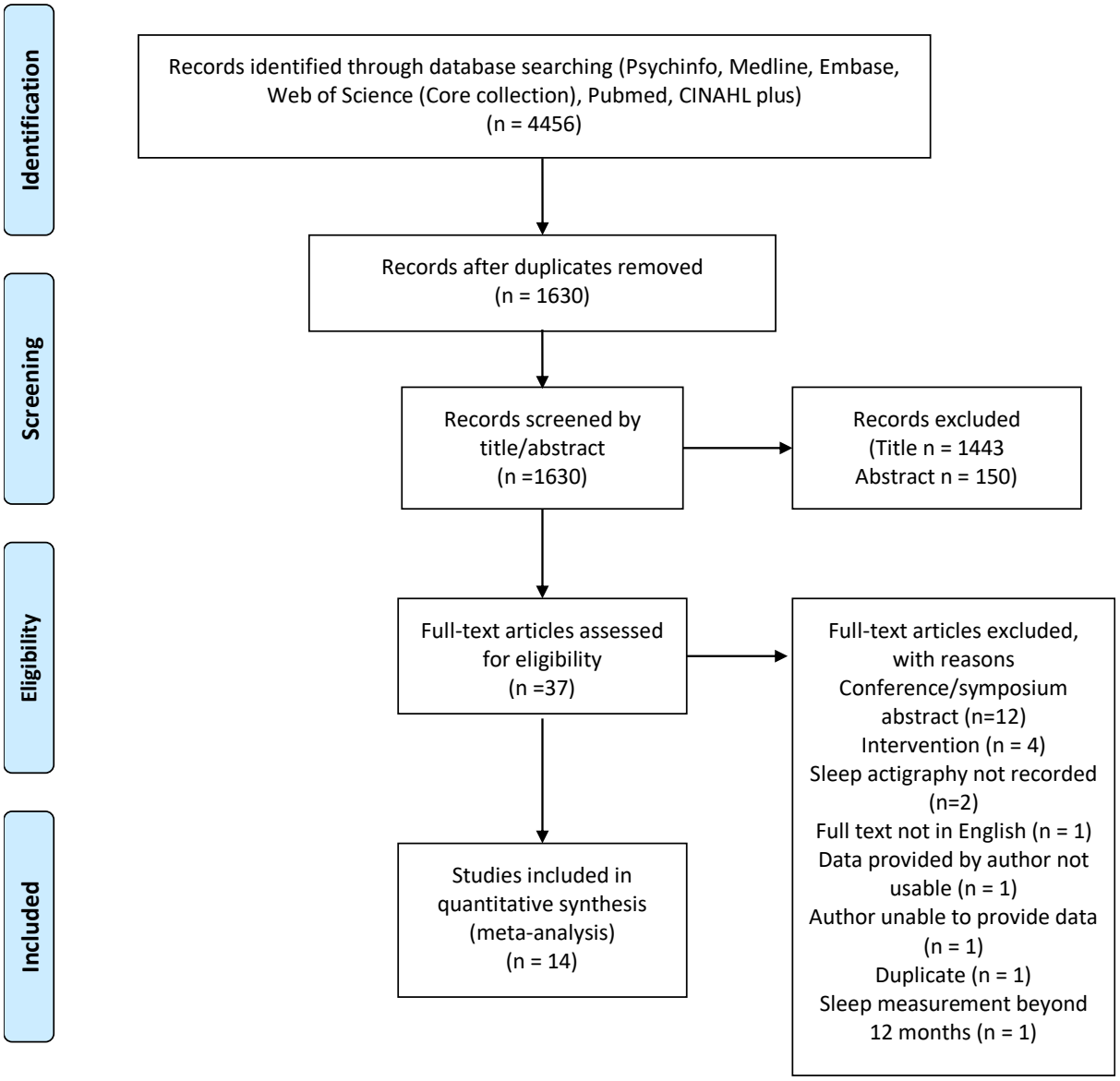
Inclusion criteria	Exclusion criteria
Reporting primary data on parent/carer sleep	Papers written in any language other than English
Reported sleep data within pregnancy and postpartum data within 12 months following childbirth.	Reviews, editorials, conference abstracts
Measurement of sleep includes 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.

The results of the systematic search are presented in Figure 1. The search yielded 4456 papers. Once duplicates were removed, 1630 articles remained. The remaining articles were screened by title and abstract using the exclusion criteria in Table 2. Of the 1630 articles, 1443 were screened out from title alone with 150 screened out after reviewing the abstract. Thirty-seven full texts were reviewed against the inclusion/ exclusion criteria. Twenty-three articles did not meet the inclusion/exclusion criteria and reasons for this are detailed in Figure 1. Fourteen articles satisfied criteria for the meta-analysis. A summary of these papers can be found in Appendix 1.

Figure 1

PRISMA diagram showing the results of the systematic search and the application of the exclusion criteria



Data extraction and Quality ratings

All papers were screened by the author. The reliability of selection processes was validated by a second rater using a 20% random sample and the same inclusion/exclusion criteria. There was a need to clarify the wording of the 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. These papers were quality-rated, and data relating to methods, participants, interventions, and outcomes, extracted. All sleep data recorded through actigraphy were extracted for review. Due to limited papers reporting sleep onset latency (1) and fragmentation (3), these were not included in the final analysis. Analysis of data from a sample of this size would likely not produce a reliable representation of the effect having a child would have on latency of sleep and fragmentation. However, it was possible to review the three most reported sleep parameters; Total Sleep Time (TST), Wake After Sleep Onset (WASO) and, Sleep Efficiency (SE). Data relating to TST, WASO and sleep efficiency were extracted. All papers used a within participants design so means and standard deviations from all recorded time points before and after birth were extracted.

Risk of Bias Assessment

A set of quality criteria were developed to assess any risk of bias within this literature. The quality criteria were adapted from existing frameworks including: (Downs & Black, 1998), The Cochrane Collaboration Risk of Bias Tool (Higgins et al., 2011) and the Risk of Bias Assessment Tool for Nonrandomised Studies (Kim et al., 2013). The framework assessed risk of bias in five domains: Selection bias, detection bias, statistical bias, reporting bias and generalisability (see Table 3). The criteria for detection bias was adapted from a review of actigraphy studies conducted by Berger et al. (2008). The inclusion criteria specified that all papers included in analysis would be a within subjects' design. This means that the design of studies included for analysis are homogenous. For the risk of bias analysis,

therefore, no weighting was placed on the study design when assessing methodological quality. Each domain was rated as either Low, Medium, or High risk.

Table 3

Risk of bias assessment framework

Risk of Bias	Definition	Low risk of Bias	Medium risk of bias	High risk of bias
Selection Bias	Selection bias in epidemiological studies occurs when there is a systematic difference between the characteristics of those selected for the study and those who are not. Randomisation cannot be applied to observational studies or within-subject intervention designs as it might be in other designs such as randomised control trials. For this reason, studies must make some attempt to ensure some randomisation in the recruitment procedure to reduce the effects of selection bias.	The characteristics of the study population are clearly described and without evidence of bias. The source population is well described, and the study reports the characteristics of the sample The recruitment method is clearly reported, and participants are recruited from multiple sources.	The characteristics of the study population are not clearly reported. The recruitment process/ sampling method of individuals are unclear. Participants were selected from only one source, but selection of participants is seemingly random.	Participants are selected from a single source, this includes multiple sources of the same type, and does not allow for random selection e.g., participants are recruited from a clinic waiting list or, recruitment procedure is not described. The characteristics of the study population are not reported.

Risk of Bias	Definition	Low risk of Bias	Medium risk of bias	High risk of bias
Detection bias	Detection bias refers to whether the design of the study is optimised to detect the effect in question. In the case of sleep data, is the instrument being used to measure sleep being used in a way which is concordant with measuring sleep accurately. For detection bias, studies will be reviewed on a set criteria for measuring actigraphy and the ability of the paper to describe the method in which actigraphy was applied.	5-6 of the below criteria are met. 1. 7+ nights of actigraphy recorded 2. Actigraph is worn on the non-dominant wrist. 3. Recording of sleep includes a sleep diary. 4. Includes definition for the reported actigraphy variables. 5. Explicit reporting of how the data were cleaned using the sleep diary. 6. Actigraph reported as being worn continuously.	3-4 of the following criteria are met. 1. 7+ nights of actigraphy recorded 2. Actigraph is worn on the non-dominant wrist. 3. Recording of sleep includes a sleep diary. 4. Includes definition for the reported actigraphy variables. 5. Explicit reporting of how the data was cleaned using the sleep diary. 6. Actigraph reported as being worn continuously.	<3 of the following criteria is met. 1. 7+ nights of actigraphy recorded 2. Actigraph is worn on the non-dominant wrist. 3. Recording of sleep includes a sleep diary. 4. Includes definition for the reported actigraphy variables. 5. Explicit reporting of how the data was cleaned using the sleep diary. 6. Actigraph reported as being worn continuously.
Statistical Bias	Bias resulting from the (inappropriate) statistical treatment of the data. Studies are also at risk of statistical bias through attrition which must be considered	Appropriate statistical testing was used and reported in the paper. Attrition rate – data loss is reported or	Unclear what statistical test was used, or data is only partly described Attrition rate – data loss is not reported	Statistics were not reported. Inappropriate statistical test was used and not appropriate for the study design.

Risk of Bias	Definition	Low risk of Bias	Medium risk of bias	High risk of bias
	when interpreting data.	calculable and attrition is at an acceptable level for within subject designs (<10%)	at analysis and is therefore unclear. Attrition rate is reported as >10%	Attrition rate – data loss is not reported or reported at analysis at an unacceptable level (>20%)
Reporting Bias	Reporting bias refers to systematic differences between reported and unreported findings. Within a published report those analyses with statistically significant differences between groups are more likely to be reported than non-significant differences. This is also related to the extent to which results and graphically represented or reported in the narrative of the paper.	Reported all results of measures as outlined in the method.	Not all descriptive and/or summary statistics are presented. There is a description (narrative) in the results but do not record statistics. Data is reported graphically without numerical data.	Not reported full outcome measures that are stated in the method section/ reported only a subsample of results/only significant results.
Generalisability	Generalisability describes the extent to which research findings can be applied to settings other than that in which they	Sufficient sample for generalisation and representative of target population.	Sufficient sample for generalisation (20+) but with some idiosyncratic features.	Small sample with or without idiosyncratic feature.

Risk of Bias	Definition	Low risk of Bias	Medium risk of bias	High risk of bias
	were originally tested. This will be affected by the size of the sample and the heterogeneity of study participants.	A sample size justification, estimate and power analysis was provided. The sample size is adequate to detect an effect (30+)	A sample size justification, estimate and power analysis were not provided	High percentage (over 80%) of sample is represented by one demographic e.g., women in a study containing men and women. The sample size is not adequate to detect an effect (<20)

Inter-rater reliability was calculated using Cohens Kappa, k (Cohen, 1960). 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 (Cohen, 1960). 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 5 papers, a Cohens Kappa of *k* = 0.88 was achieved indicating a high level of inter-rater reliability.

Overall methodological Bias

Methodological bias was mixed within the studies. Table 4 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. Quality ratings for each of the assessed areas of bias are summarised.

Table 4

Quality framework applied to assess risk of bias

	Selection bias	Detection bias	Statistical bias	Reporting bias	Generalisability	Overall quality index
Bei Bei et al. (2012)	High	Medium	Low	Low	Medium	60%
Calcagni et al. (2012)	Low	High	Medium	Medium	Medium	50%
Coo et al. (2014)	Medium	High	Medium	Low	Medium	40%
Gay et al. (2004)	Medium	High	Low	Low	Medium	60%
Matsumoto et al. (2003)	High	Medium	Low	High	High	30%
Krawczak et al. (2016)	Medium	High	Medium	Low	Medium	50%
Park et al. (2013)	Medium	Medium	Low	Low	Medium	70%
Sharkey et al. (2016a)	Low	Low	Medium	Medium	Medium	70%
Sharkey et al. (2016b)	Medium	Low	Low	Low	Medium	80%
Sharkey et al. (2013)	Low	Low	Medium	Low	High	70%
Signal et al. (2007)	High	Medium	High	Low	High	40%
Shao-Yu et al. (2014)	Medium	Low	Medium	Medium	Low	70%
Volkovic et al. (2015)	Low	Medium	Medium	Medium	Medium	60%
Wulff (2000)	Medium	Low	Medium	Low	High	50%

Selection Bias. There was variability in the ratings under selection bias. Most studies were rated medium or high risk with only four being rated as having a low potential risk of selection bias. Overall, studies did not perform well for selection bias. Studies rated as low risk of bias selected participants from multiple sources providing details about participant characteristics related to participant age, education level, socioeconomic status, and parity. Those rated as high risk reported limited details about participant characteristics (Matsumoto et al, 2003; Signal et al., 2007) and recruitment source (Matsumoto et al., 2003). Many studies recruited participants from a single source (Gay et al., 2004; Sharkey et al., 2016 (b); Signal et al., 2007; Shao-Yu et al., 2014; Wulff, 2000). Although the recruitment source was included in many of the reviewed papers, several studies did not describe their recruitment process and details on how attempts were made to randomise recruitment as much as possible (Bei Bei et al., 2012; Gay et al., 2004; Krawczak et al., 2016; Park et al., 2013, Sharkey et al., 2016b; Wulff, 2000).

Detection bias. Ratings for detection bias varied with five studies being rated as low, five rated as medium and four being rated as high. This suggests inconsistency in the way that actigraphy data were recorded and reported across studies. Studies were evaluated based on their description of the use of actigraphy to measure sleep data. There was variation as to how the studies were able to describe the use of actigraphy. Variation in reporting limits the conclusions that can be drawn from the studies as sleep data may have been collected using varied methodologies. One of the most consistent variables reported was the length of time actigraphy was collected for. Only two studies reported that data were collected for less than seven days (Gay et al., 2004; Volkovic et al., 2015). Only four studies reported that participants were not required to record their sleep in a diary alongside actigraphy (Bei Bei et al., 2012; Calcagni et al., 2012; Coo et al., 2014; Krawczak et al., 2016). Of those that did use diaries, many did not report how this was used to support actigraphy data (Gay et al., 2004; Matsumto et al., 2003; Park et al., 2013; Sharkey et al., 2016a; Sharkey et al., 2016b; Sharkey et al., 2013; Wulff 2000).

Statistical bias. Studies did not perform well when reviewed for statistical bias. Few studies were rated as having a high potential risk of bias however, most studies rated as having a medium risk of bias. Five studies were rated as having a low potential for risk of bias. Appraisal for statistical bias again demonstrates variability between studies. Only one study was rated as having a high risk of bias (Signal et al., 2007) having a high attrition rate of 24%. In three of the studies appraised as medium risk, the attrition rate was either not reported or, was not calculable from the information in the paper (Sharkey et al., 2016a; Sharkey et al., 2013; Wulff 2000). For many papers reviewed, the statistical procedure was well defined and was deemed appropriate for the data collected.

Reporting Bias. The studies reviewed appeared to perform well when rated for reporting bias. Most studies were rated as low risk of bias with only 5 studies being rated as either medium or high risk of bias. Studies performed most consistently within this domain. The full reporting within the studies was generally good with most papers reporting means and standard deviations of data outlined from the method. Only one paper was reported as high risk (Matsumoto et al., 2003), due to not reporting all data collected as outlined in the method. Papers that were appraised as medium risk of bias reported a subscale of raw data or only used a descriptive approach for raw data (Calcagni et al., 2012; Sharkey et al., 2016a; Shao-Yu et al., 2015; Volkovic et al., 2015).

Generalisability. Most studies were rated as either medium or high risk of bias when rated for generalisability. Only one study was rated as low risk of bias. The consistency of medium and high ratings suggests some issues when generalising research findings in this field and is consistent with the variability of ratings in other domains. The risk to generalisability was high, with only one paper being regarded as low risk (Shao-Yu et al., 2014). This paper was regarded low risk as the paper followed guidelines for minimum participants required for factor analysis. Throughout the literature there was a lack of reporting on a priori power analysis which meant that most papers were appraised as either medium or high risk. In addition to this, sample sizes were small throughout the literature meaning that it would be difficult to generalise outcomes.

Summary. The risk of bias varied across studies. There were five papers that did not report high risk in any domain (Park et al., 2013; Sharkey et al., 2016a; Sharkey et al., 2016b; Shao-Yu et al., 2014; Volkovic et al., 2015). 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 five for 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 will need to be taken when interpreting the results of this analysis.

Results

There were 14 studies reporting a total of 706 participants, 627 female and 79 were male. The average age of women in the studies reviewed was 30.4 (SD = 4.2), the average age of men was 34.9 (SD = 6.0). The studies included 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. Studies were conducted in various locations around the world including Australia and New Zealand, Canada and the United States of America, Germany, Israel, Japan, and Taiwan. All studies, except one (Matsumoto et al., 2003), reported their recruitment location, with some using multiple locations. This included adverts in the local community (6), women's health clinics (4), antenatal clinics (3), childbirth education classes (3), and midwives (1).

Analysis procedures were undertaken in line with protocol developed at the University of Birmingham's Centre for Applied Psychology. Analysis was completed for three sleep parameters, TST, WASO and SE, where data were available across 14 papers. Not all studies reported information on all parameters of sleep, so the sample size varied across parameters. For the analysis of TST, subgroup analysis and meta-regression were conducted. For sleep efficiency, subgroup analysis was conducted. Fewer data were available for WASO, so subgroup analysis was not completed for this parameter.

Standardised mean difference (SMD) was used to calculate the size of the effect for each study and is represented as Hedges' g (Hedges & Olkin, 1985). Heterogeneity of included studies was assessed using I^2. This estimates the percentage of variation of effect sizes that can be attributed to heterogeneity. Higgins (2003) suggests acceptable levels of 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 this meta-analysis, values below 75% were considered acceptable heterogeneity.

Total sleep time

Selection of the meta-analytic model

The distribution of primary study effects is shown using the fixed effects model and random effects model in Figure *2* and Figure 3. The variance of the true effect (tau^2) was calculated using the restricted maximum likelihood estimator (REML) method.

Figure 2

QQ plot of the distribution of the effect using the restricted maximum-likelihood estimator method within the primary studies using the fixed effects model

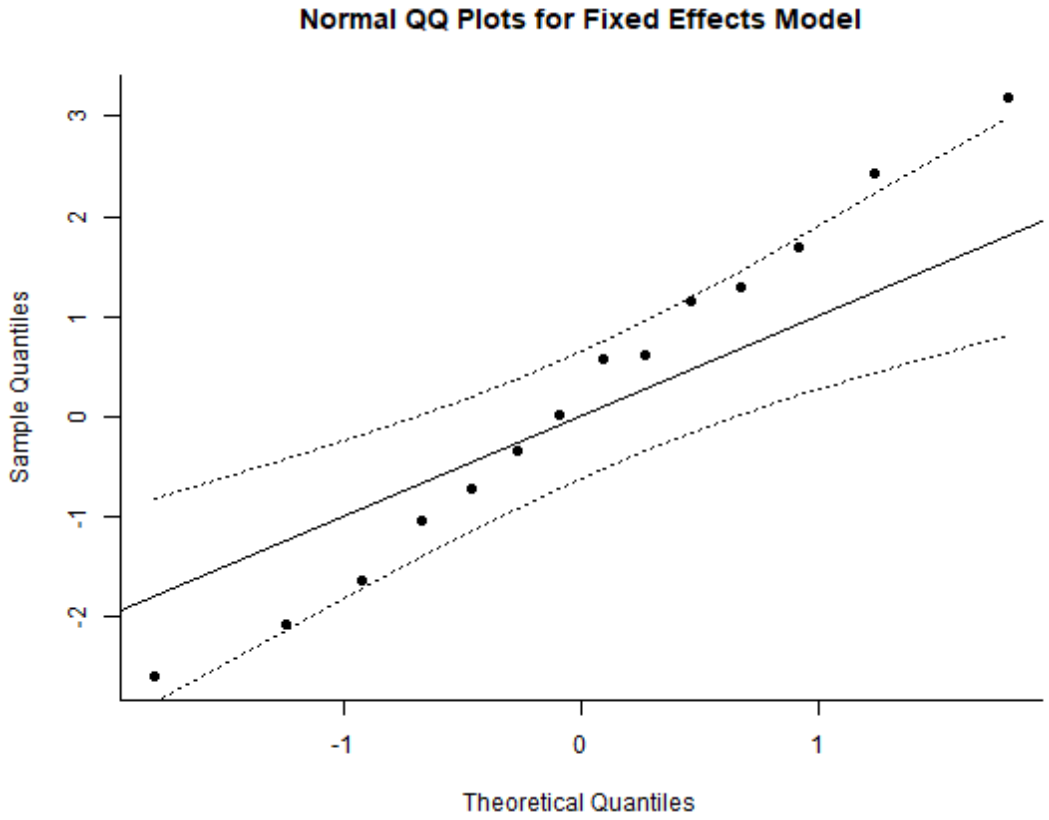
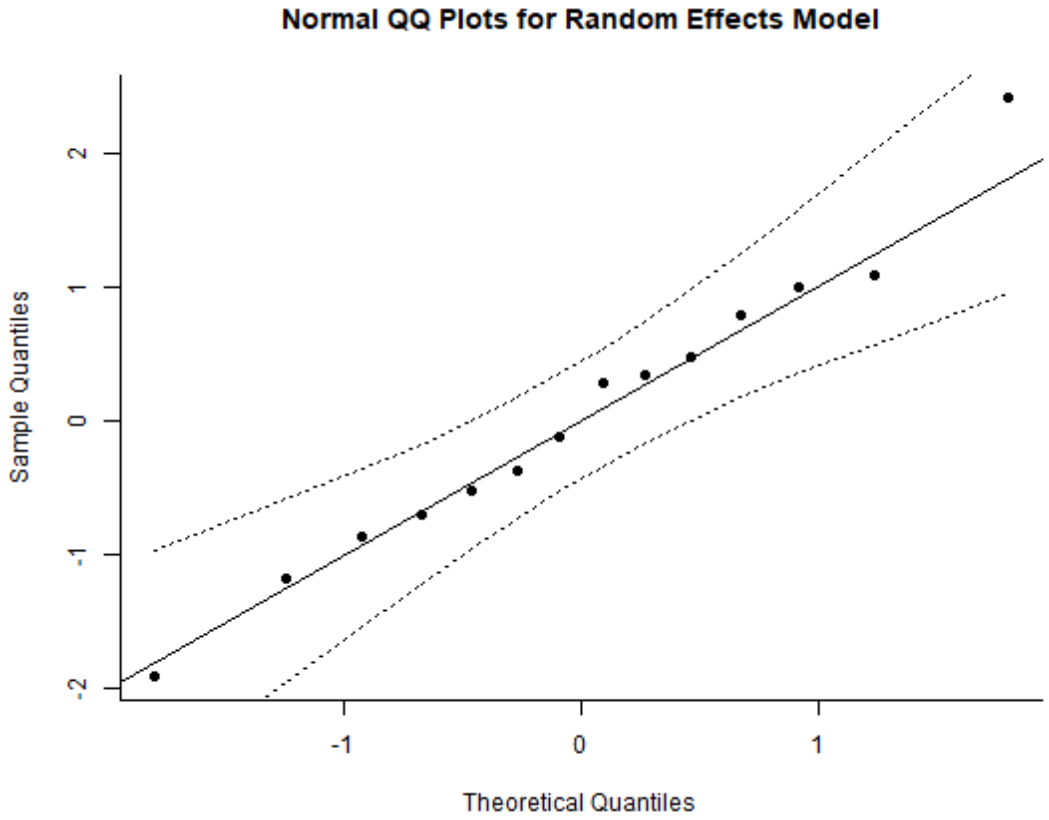


Figure 3

QQ plot of the distribution of the effect using the restricted maximum-likelihood estimator method within the primary studies using the random effects model



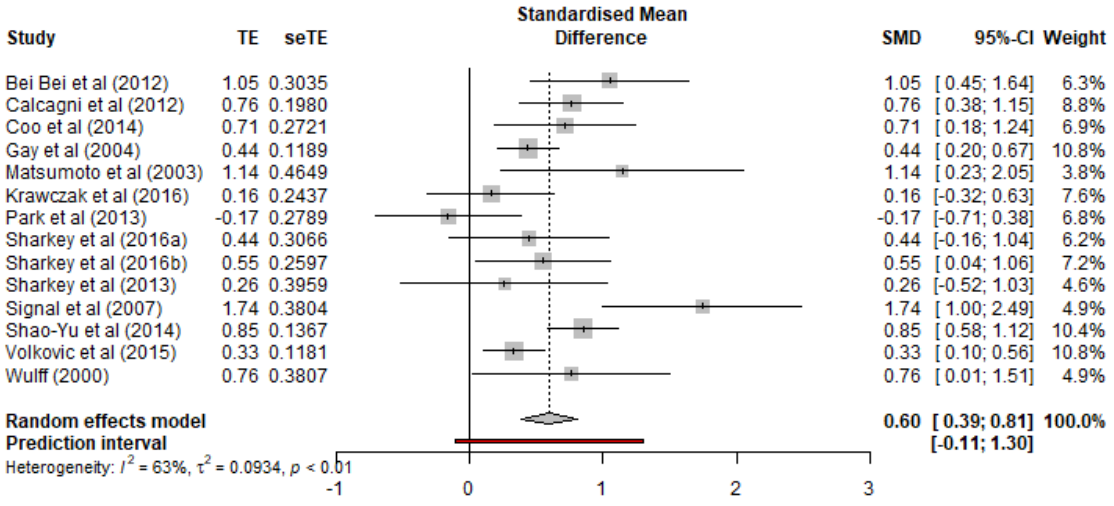
As can be seen from Figure *3* there is no evidence of non-linearity in the distribution of standardised mean difference within the primary studies when using the random effects model. Figure 2 represents the same data as Figure 3 modelled using the fixed effects model. As can be seen, two studies fall outside of the 95% confidence interval. For the random effects model all studies fall within the 95% confidence interval. Therefore, this indicates that the use of the use of the REM is an appropriate method for the calculation of the variation of the true effect.

The omnibus test

The effect described in the primary studies with confidence interval (CI) and weighted average is reported in Figure 4. A random effects model was calculated using the generic inverse variance method. The random effects model suggested a weighted average standardised mean difference of *SMD* = 0.60 (*z* = 5.54, *p* = 0.001) and a 95% confidence interval of between 0.39 to 0.81. A positive effect in this instance indicates a reduction in parent total sleep time following birth. A treatment effect of this magnitude would be considered a moderate effect. This means that overall, from the studies analysed, parents appeared to have less sleep following the birth of their child. Weighted by sample size, this meant new parents slept for on average 38.7 minutes less following the birth of their child. This can be seen from the forest plot in Figure 4.

Figure 4

Forest plot of standardised mean difference



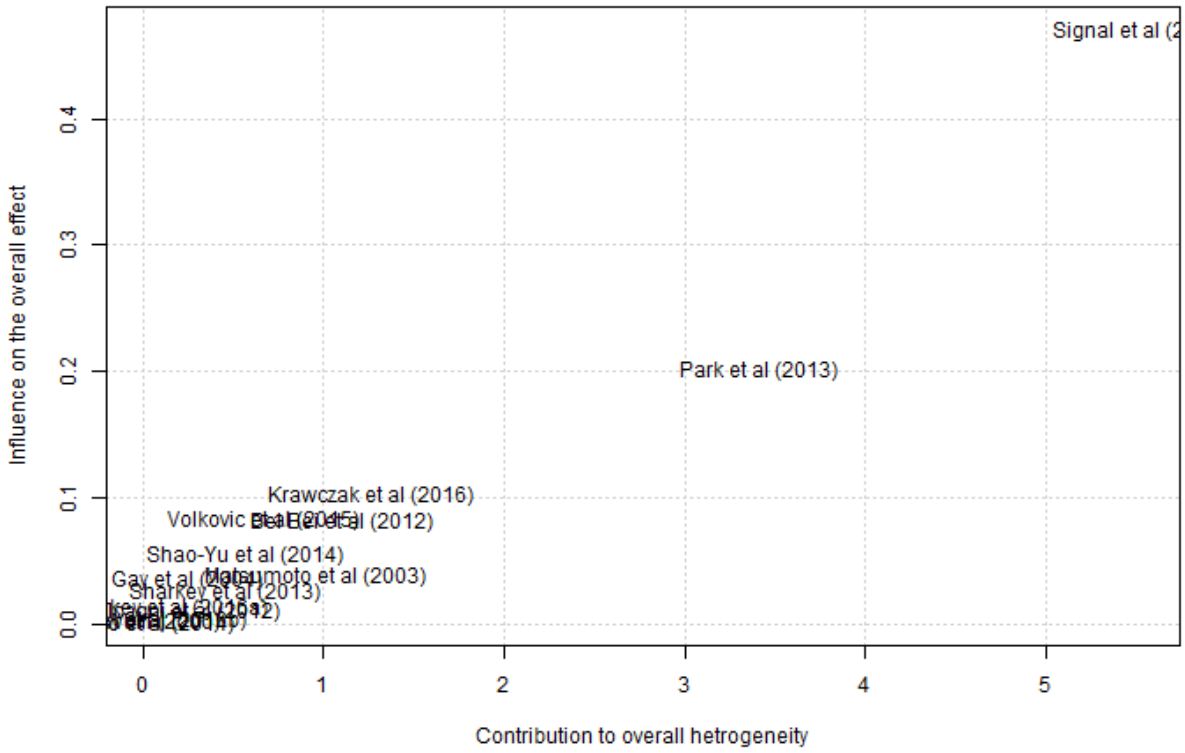
An acceptable level of heterogeneity in the primary studies was observed (Higgin's I^2 = 63%, tau^2 = 0.0934, $p < 0.01$). This suggests an acceptable level of variation in the primary studies, with this body of studies is reporting a coherent and consistent effect size.

The impact of influential primary studies

The impact of influential studies was assessed using a "leave-one-out" analysis, in which the random effects model 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 studies overall influence that the study has on the overall effect. The result of this "leave-one-out" analysis is presented on the Baujat plot (Baujat, Pignon, & Hill, 2002) in Figure 5.

Figure 5

Baujat diagnostic plot of sources of heterogeneity. The vertical axis reports the influence of the study on the overall effect and the horizontal axis reports the discrepancy of the study with the rest of the literature.



As seen from Figure 5, Signal et al. (2007) is both discrepant with the bulk of the literature and is influential in terms of the meta-analytic synthesis. It can also be observed that Park et al. (2013) is also somewhat discrepant and influential. The effect of leaving each of these papers out of the analysis can be seen in Table 5. On review of the discrepant papers, there was little clear variation in methodology in comparison to other studies included. This is in part due to the inclusion criteria for this study limiting study designs. It is for this reason that both papers were included in the final analysis. Factors relevant to the studies designs will be discussed in the following sections.

Table 5

Summary of influential studies for total sleep time

	SMD	95%-CI	p-value	tau^2	I^2
Omitting Signal et al. (2007)	0.53	[0.36; 0.71]	<0.0001	0.05	52%
Omitting Park et al. (2013)	0.64	[0.45; 0.83]	<0.0001	0.25	57.7%

The effect of risk of bias in the primary studies

The quality effects model was calculated using the total score from the risk of bias ratings reported in the method of this paper. This score considers the position of study's overall design within the study design hierarchy and the ratings of risk of bias as reported in Table 4.

The quality effects model represents the meta-analysis that would have been obtained had all the papers been of the same methodological quality as the highest rated paper. The quality effect model reported an effect of *SMD* = 0.55 (95% CI 0.33 to 0.76). A summary of the quality effects model for each area of bias can be seen in Table 6. The quality effects model evidenced approximately an 8.3% decrease relative to the uncorrected random effects estimate. When the methodological quality of the literature was taken into consideration, only a small 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 (i.e., either medium or high risk), as seen in Table 6. This suggests that the overall methodological quality of papers in this review has little impact on

the observed effect and none of the risk of bias domains evidenced a significant difference in their estimates of total sleep time.

Table 6

Summary of risk of bias assessment

	Low risk			Any risk				
	SMD	**95% CI**	**K**	**SMD**	**95% CI**	**K**	χ^2	***p***
Selection bias	0.46	[0.20; 0.72]	4	0.67	[0.37; 0.97]	10	1.07	0.30
Detection bias	0.76	[0.42; 1.09]	6	0.49	[0.24; 0.74]	8	1.52	0.22
Statistical bias	0.54	[0.13; 0.96]	5	0.63	[0.38; 0.89]	9	0.14	0.71
Reporting bias	0.58	[0.24; 0.91]	9	0.64	[0.37; 0.92]	5	0.09	0.76
Generalisability	0.85	[0.58; 1.12]	1	0.57	[0.34; 0.80]	13	2.43	0.12

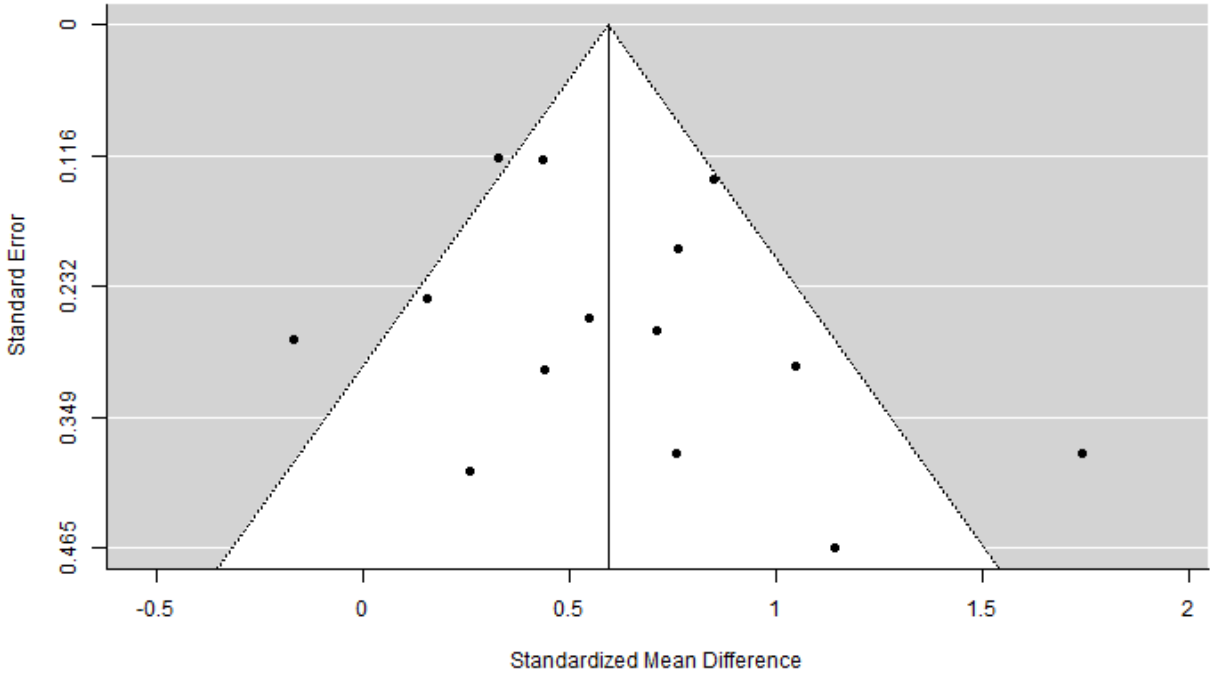
The impact of publication and small study biases

Publication bias is caused by the tendency for statistically significant results to be published and those demonstrating non-significant results to remain unpublished. Small study bias is the tendency for studies with smaller sample sizes to show greater variability in their measurement of an effect. These biases can be identified by a funnel plot which plots the magnitude of the study's estimated effect against the square root of the study's sampling variances. If there is an absence of publication bias, the effects from the studies with small sample sizes which show greater variability will scatter more widely at the bottom

of the plot compared to studies with larger samples at the top which will lie closer to the overall meta-analytic effect, creating a symmetrical funnel shape. If there is an absence of studies in the area of the plot associated with small sample sizes and non-significant results (for this meta-analysis it will be the bottom left-hand corner) then it is likely there is some publication bias leading to an overestimation of the true effect. The funnel plot of standardised mean difference is presented in Figure 6.

Figure 6

Funnel plot of the standardised mean difference. The 95% confidence interval of the expected distribution of standardised mean difference is shown as an inverted "funnel"



Visual analysis of the funnel plot seen in indicates that there is no clear evidence of publication bias with studies well distributed through the funnel plot.

Rosenthal (1979) describes the calculation of a failsafe number. This method calculates the number of unpublished studies required to reduce the effect to a level of non-significance ($p > .05$). This procedure suggests that 462 studies would be required to reduce the observed standardised mean difference = 0.60 to non-significance. This suggests that the observed effect is robust to studies missing due to publication bias. Therefore, no simulation of and adjustment for publication bias and small study effects was undertaken.

However, caution must be taken when interpreting this statistic. The estimate of failsafe N is highly dependent upon the mean intervention effect that is assumed for the unpublished studies (Iyengar & Greenhouse, 1988). The failsafe method assumes that Z scores for unpublished studies will be 0 and not demonstrate the same variance as seen in the observed studies. Failsafe N also makes the assumption that there is no bias present in the unpublished literature (Iyengar & Greenhouse, 1988).

Subgroup analyses and meta regression

A subgroup analysis is a way of breaking down the study sample into subsets of participants based on a shared characteristic. For this analysis, three subgroup analyses were completed.

Time point sleep is recorded

Across the studies there was a difference in the way sleep was measured with some measuring a single time point before and after birth and others recording at multiple time points. Studies were placed into three categories based on their time of recording following birth: 0-4 weeks, 4-8 weeks, and 8-16 weeks. As seen in Table 7, there is a significant difference observed between groups. As studies recording of sleep became further from

birth, the observed effect decreased. The decrease in effect from 0-4 weeks (0.70) to 4-8 weeks (0.28) represents a much larger change than the observed difference between 4-8 weeks and 8-16 weeks (0.25). Notably, though, even when measured between eight and sixteen weeks, parent TST was still shorter than antenatally.

Table 7

Results of the time point sub -group analysis

	Level	SMD	95% CI	K	X^2	p
Time point sleep is recorded	0-4 weeks	0.70	[0.46; 0.93]	11		
	4-8 weeks	0.28	[0.05; 0.50]	7		
	8-16 weeks	0.25	[0.08; 0.42]	6	9.48	<0.01

Study location

For this subgroup analysis studies were grouped by location. As can be seen in Table 8 there was not an even distribution of studies across areas. A range of effect sizes was also observed between continents, with Australia and New Zealand demonstrating a large effect of 0.99 and USA and Canada representing a much smaller effect size of 0.34. 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 and effect. As seen in Table 8, studies in the eastern hemisphere demonstrated a much larger effect than the western

hemisphere, which represents a greater level of sleep loss following the birth of a child. The difference between these effects was statistically significant.

Table 8

Subgroup analysis of study location

	Level	SMD	95% CI	K	X^2	p
Study location	Australia and New Zealand	0.99	[0.60; 1.38]	4		
	USA and Canada	0.34	[0.16; 0.52]	6		
	Japan and Taiwan	0.87	[0.62; 1.13]	2		
	Israel	0.32	[0.09; 0.56]	1		
	Germany	0.76	[0.01; 1.51]	1	19.7	p <0.01
Hemisphere	Eastern hemisphere	0.83	[0.55;1.11]	8		
	Western hemisphere	0.34	[0.16; 0.52]	6	8.30	p<0.01

Gender differences

A subgroup analysis on gender was planned as a part of this analysis. Consistent with the body of literature in this area, it was observed that only two studies had male participants. Conducting an analysis on so few studies would not be meaningful, or a reliable reflection on the experience of males caring for new babies.

Age

A meta-regression was conducted to assess whether the average participant age reported by studies was systematically related to the total sleep time reported by the primary studies. The results of the meta-regression can be seen in Table 9.

Table 9

Meta regression using the mean age of participants

	Coefficient	SE	Z	P
Age	0.1038	0.05	2.08	<0.05

Results of the meta-regression indicated a positive relationship between age and the observed effect. Even though the coefficient was small, it indicated that as age increased, so did the size of the effect. The data suggest those studies with, on average, older participants observed a larger reduction in sleep following the birth of a child.

Sleep efficiency

Selection of the meta-analytic model

Ten studies were included for the analysis of sleep efficiency data. The variance in the observed effect was calculated using the REML method. When the data were modelled using the random effects model and fixed effects model, the random effects model was the most appropriate method to estimate the variance in the true effect.

Figure 7

QQ plot of the distribution of the effect using the restricted maximum-likelihood estimator method within the primary studies using the random effects model

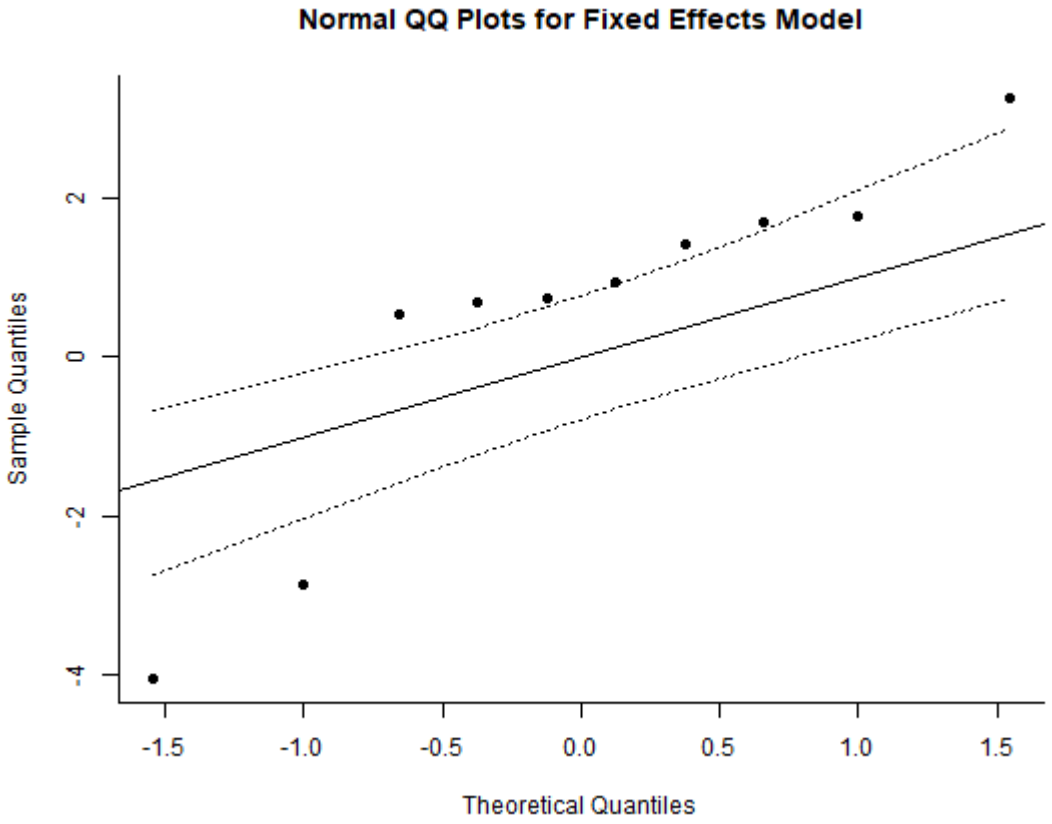
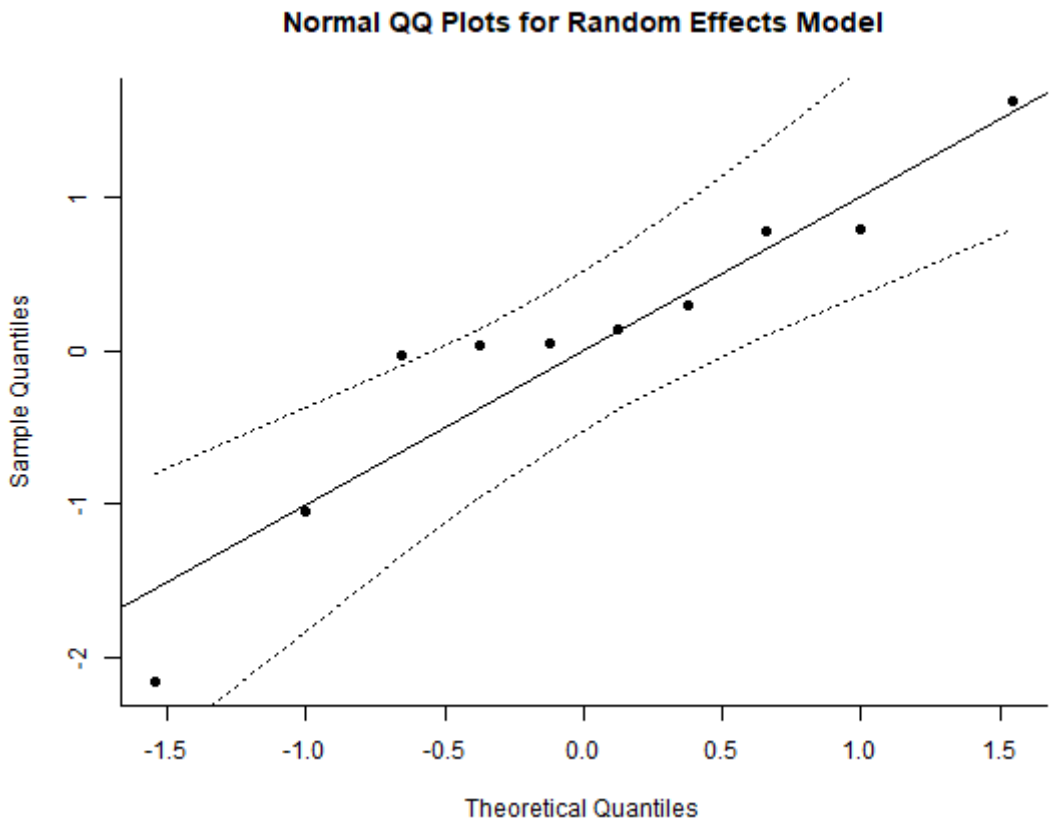


Figure 8

QQ plot of the distribution of the effect using the restricted maximum-likelihood estimator method within the primary studies using the random effects model



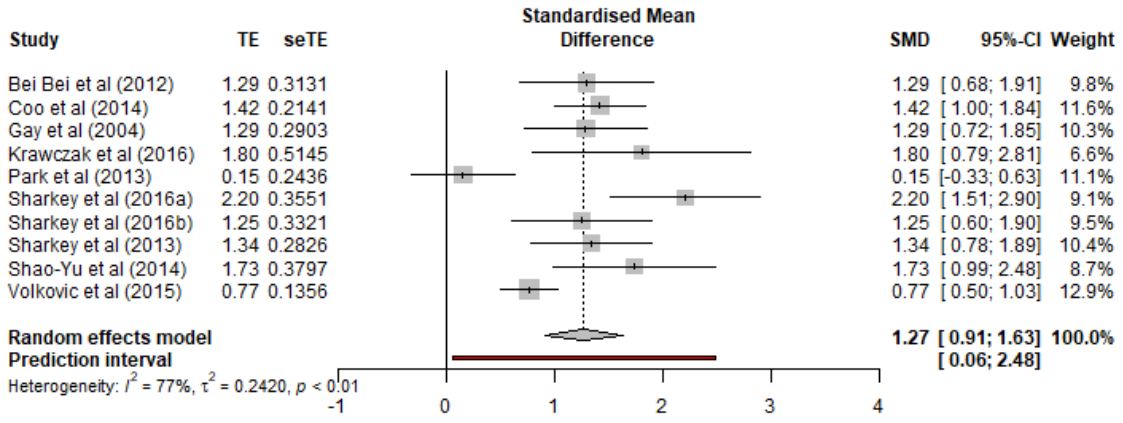
The omnibus test

Across all studies, parents' sleep efficiency reduced by 9.7% when comparing ante- to post- natal data. The random effects model suggested a weighted average standardised mean difference of *SMD*=1.27 (z = 6.93, p < 0.0001) and a 95% confidence interval of between 0.91 to 1.63. An effect of this magnitude would be considered a large effect. The effect demonstrates that parents' sleep efficiency appears to decline following the birth of a child and is represented by a positive effect. A high level of heterogeneity was observed (Higgins' I^2 = 77%, tau^2 = 0.2420, p <0.01). This suggests that there is a high level of variation

in the data reported by these studies with a range of effect sizes reported. All effect sizes for efficiency data reported a positive effect, however a range of effects was observed. A forest plot for this analysis can be seen in Figure 9.

Figure 9

Forest plot of standardised mean difference for sleep efficiency



The impact of influential primary studies

As with TST, A “leave one out” analysis was conducted on the data for sleep efficiency. Two studies, Sharkey et al. (2016a) and Park et al. (2013) were identified as potentially influential, discrepant from the rest of the literature. The analysis concluded that if either of these studies were removed, it would have little observable difference on the effect still producing a significant outcome. However, if either of the studies were removed from the analysis heterogeneity would fall into an acceptable threshold <75%. A summary of this can be seen in Table 10 below. The confidence interval of the effect observed in both these studies falls outside the SMD of the analysis. This may offer some explanation as to why the heterogeneity is above the acceptable level when these studies are included in the final analysis. In addition, the confidence interval of the effect for Park et al. (2013) falls into

a negative effect, which is not observed in any other study. This may offer some explanation as to why it is particularly influential of the level of heterogeneity. A review of both studies identified that their methodologies did not differ greatly from those used in other papers included for analysis.

Table 10

Summary of influential studies for sleep efficiency

	SMD	95%-CI	p-value	tau^2	I^2
Omitting Park et al. (2013)	1.37	[1.08; 1.66]	<0.0001	0.11	65.1%
Omitting Sharkey et al. (2016a)	1.16	[0.82; 1.49]	<0.0001	0.17	72.3%

The effect of risk of bias in the primary studies

As with TST, the quality effects model was calculated using the total score from the risk of bias ratings reported in the method of this paper in Table 4.

The quality effect model reported an effect of *SMD* = 1.27 (95% CI 0.91 to 1.63). A summary of the quality effects model for each area of bias can be seen in Table 11. When the methodological quality of the literature was taken into consideration, no 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 (i.e., either medium or high risk), as seen in Table 11. This suggests that the methodologies used by the studies reviewed have little influence on the effect observed in the risk of bias assessment.

Table 11

Summary of risk of bias assessment

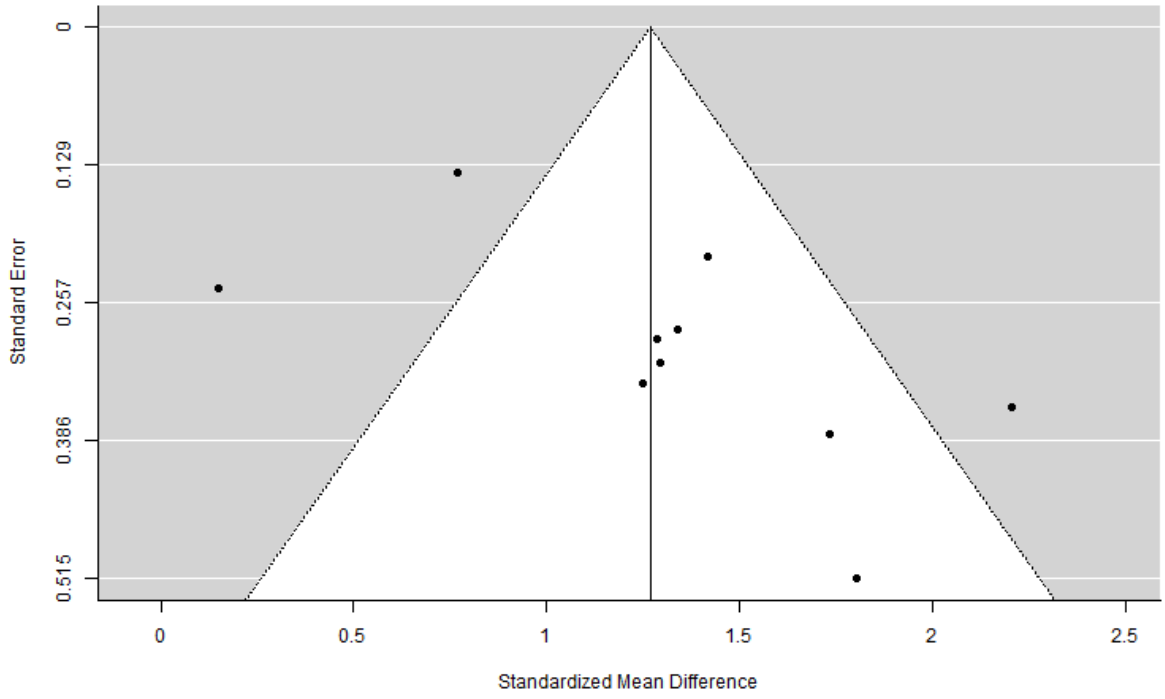
	Low risk			Any risk				
	SMD	**95% CI**	**K**	**SMD**	**95% CI**	**K**	χ^2	***p***
Selection bias	1.27	[0.91; 1.63]	10	-	-	0	0	-
Detection bias	1.21	[0.72; 1.70]	7	1.42	[1.09; 1.74]	3	0.49	0.48
Statistical bias	1.27	[0.87; 1.67]	9	1.29	[0.68; 1.91]	1	0	0.95
Reporting bias	1.27	[0.91; 1.63]	10	-	-	0	0	-
Generalisability	1.27	[0.87; 1.67]	9	1.34	[0.78; 1.89]	1	0.04	0.84

The impact of publication and small study biases

As with previous data, analysis of publication and small study bias was conducted on data for sleep efficiency. If there is an absence of studies in the area of the plot associated with small sample sizes and non-significant results (for this meta-analysis it will be the bottom left-hand corner) then it is likely there is some publication bias leading to an overestimation of the true effect. The funnel plot of standardised mean difference is presented in Figure 10.

Figure 10

Funnel plot of the standardised mean difference. The 95% confidence interval of the expected distribution of standardised mean difference is shown as an inverted "funnel"



Visual analysis of the funnel plot indicates that there is evidence consistent with publication bias, with studies poorly distributed through the funnel plot. The effect of publication bias was simulated using a trim and fill procedure (Duval & Tweedie, 2000). The trim and fill procedure builds on the assumption that publication bias would lead to an asymmetrical funnel plot. Trim and fill procedure iteratively removes the most extreme small studies from the side of the funnel plot associated with positive effects, re-computing the effect size at each iteration until the funnel plot is symmetric about the (corrected) effect size. While this trimming yields the adjusted effect size, it also reduces the variance of the effects, resulting in biased and narrow confidence interval. Therefore, the original

studies are returned into the analysis, and the procedure imputes a mirror image for each on the side of the funnel plot associated with negative effects. The trim and fill procedure yielded a corrected random effects model of SMD = 1.16 (95% CI 0.69 to 1.43). The corrected random effects model evidences an approximately -16% decrease relative to the uncorrected estimate.

A failsafe calculation using the Rosenthal (1979) method was calculated for sleep efficiency data. This procedure suggests that 714 studies would be required to reduce the observed standardised mean difference = 1.27 to non-significance.

Subgroup analysis

Time point sleep is recorded

As with total sleep time there was a difference in the time point that sleep was recorded. Studies were placed into three categories based on their time of recording following birth: 0-4 weeks, 4-8 weeks, and 8-16 weeks. As seen in Table 12, there is a statistically significant difference observed between groups. Like total sleep time, as studies recording of sleep became further from birth, the observed effect decreased. The decrease in the effect from 0-4 weeks to 4-8 weeks represents a larger change that the change in effect from 4-8 weeks to 8-16 weeks. It is also noted that between 8-16 weeks, sleep efficiency has not returned to a pre-birth state as represented by a small effect of 0.38. However, it should be noted that the 95% confidence interval for the 8–16-week group does cross zero. This indicates that there is a possibility that sleep may return to pre-birth levels in this group.

Table 12

Results of the time point sub -group analysis

	Level	SMD	95% CI	K	X^2	p
Time point sleep is recorded	0-4 weeks	1.47	[1.25; 1.69]	8		
	4-8 weeks	0.65	[0.19; 1.11]	7		
	8-16 weeks	0.38	[-0.06; 0.82]	5	24.33	<0.01

Study location

As can be seen in Table 13 there was not an even distribution of studies across areas. It is observed that all areas demonstrated a relatively large effect with Japan and Taiwan demonstrating the largest effect. Due to the limited number of studies representing each area, strong conclusions cannot be drawn from these data. Further analysis was completed to identify if there were any differences between the studies in the western hemisphere compared to the eastern hemisphere. As seen in Table 13, there was no significant difference between the two groups.

Table 13

Subgroup analysis of study location

Level	SMD	95% CI	K	X^2	p

Study location	Australia and New Zealand	1.38	[1.03; 1.72]	2		
	USA and Canada	1.29	[0.72; 1.87]	6		
	Japan and Taiwan	1.73	[0.99; 2.48]	1		
	Israel	0.77	[0.50; 1.03]	1	11.61	p <0.01
Hemisphere	Eastern hemisphere	1.23	[0.81; 1.65]	4		
	Western hemisphere	1.29	[0.72; 1.87]	6	0.03	*P = 0.86*

Wake after sleep onset

Selection of the meta-analytic model

Seven studies were included for the analysis of wake after sleep onset. The variance of the true effect (tau^2) was calculated using REML as above. All studies fall within the 95% confidence interval when using the random effects model as seen in Figure *12* . Therefore, this indicates that the use of REM is an appropriate method for the calculation of the variation of the true effect.

Figure 11

QQ plot of the distribution of the effect using the restricted maximum-likelihood estimator method within the primary studies using the fixed effects model

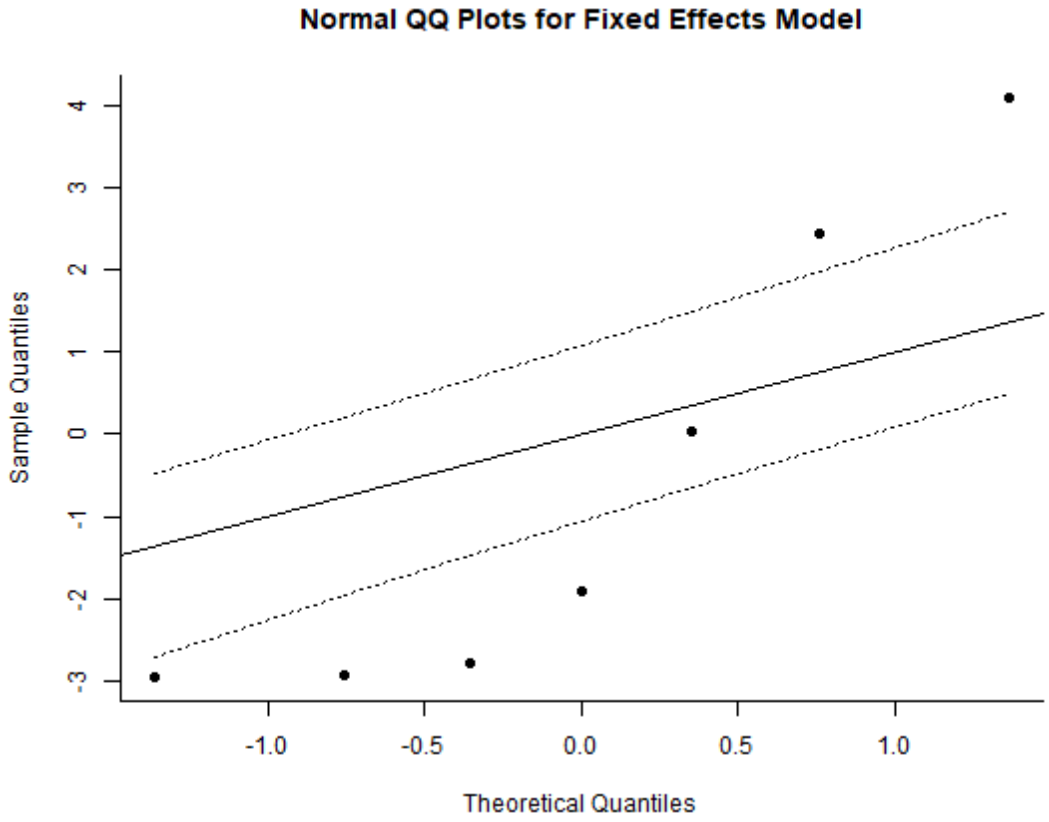
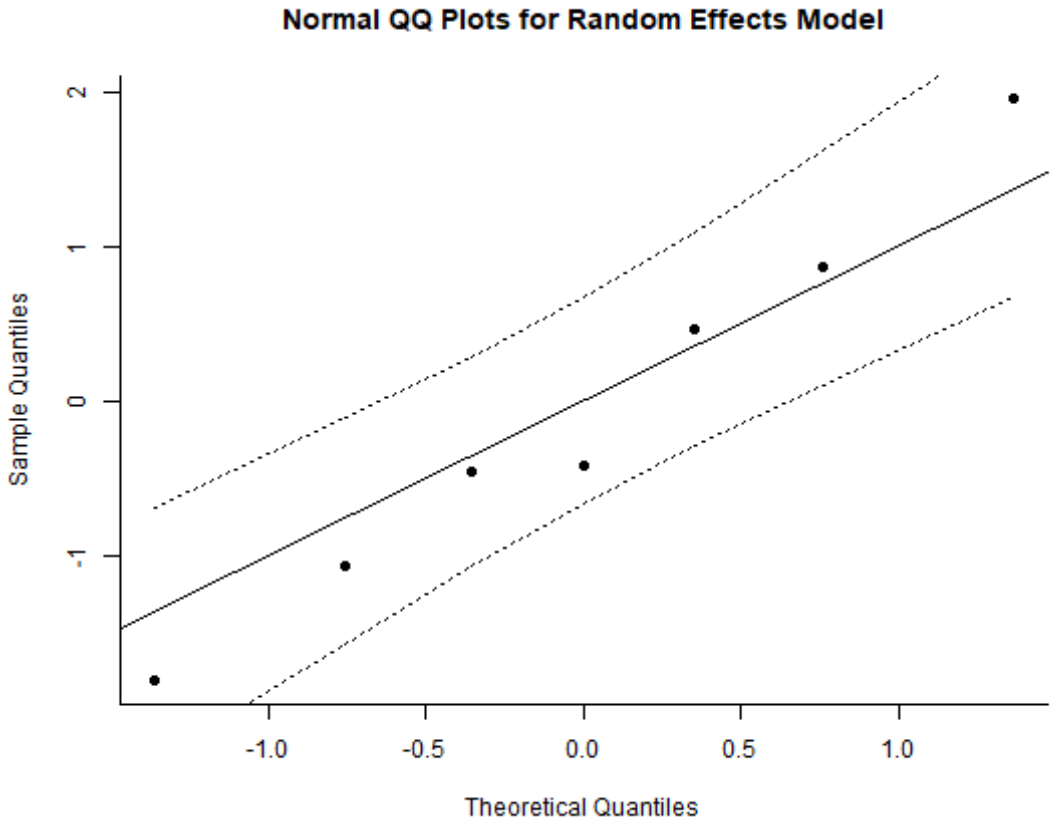


Figure 12

QQ plot of the distribution of the effect using the restricted maximum-likelihood estimator method within the primary studies using the random effects model

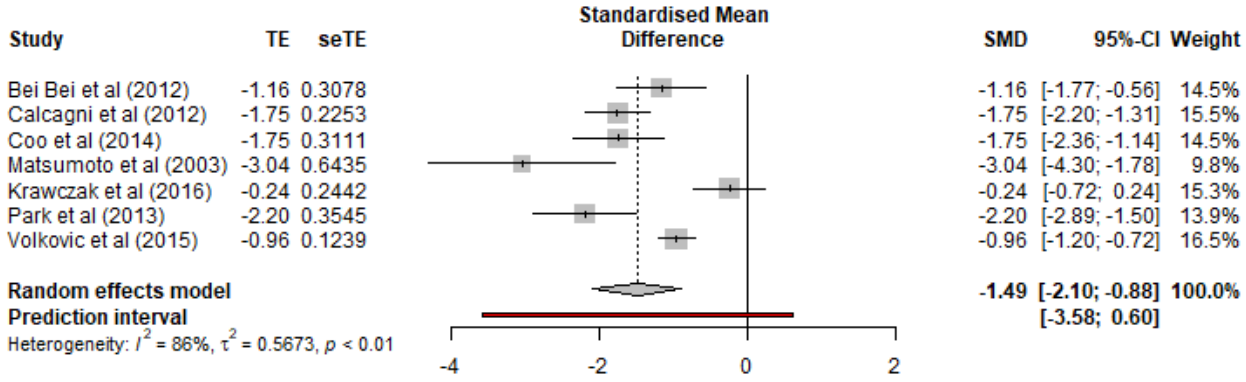


The omnibus test

The random effects model suggested a weighted average standardised mean difference of *SMD* = -1.49 (*z* = -4.81, *p* <0.0001) and a 95% confidence interval of between -2.09 to -0.88. A negative effect indicates an increase in time spent awake following initial sleep onset following childbirth. This represents a significant and large effect. This suggests that the length of time that parents spend waking following the initial sleep onset increases following the birth of the child. On average across studies, weighted by sample size, this meant after the birth of their child, parents were awake 70.7 more minutes each night following childbirth. A high level of heterogeneity was observed (Higgins' I^2 = 86%, tau^2 = 1.5673, *p* <0.01). This suggests that there is a high level of variation in the data reported by these studies with a range of effect sizes reported. A forest plot for this analysis can be seen in Figure *13*.

Figure 13

Forest plot of standardised mean difference for WASO

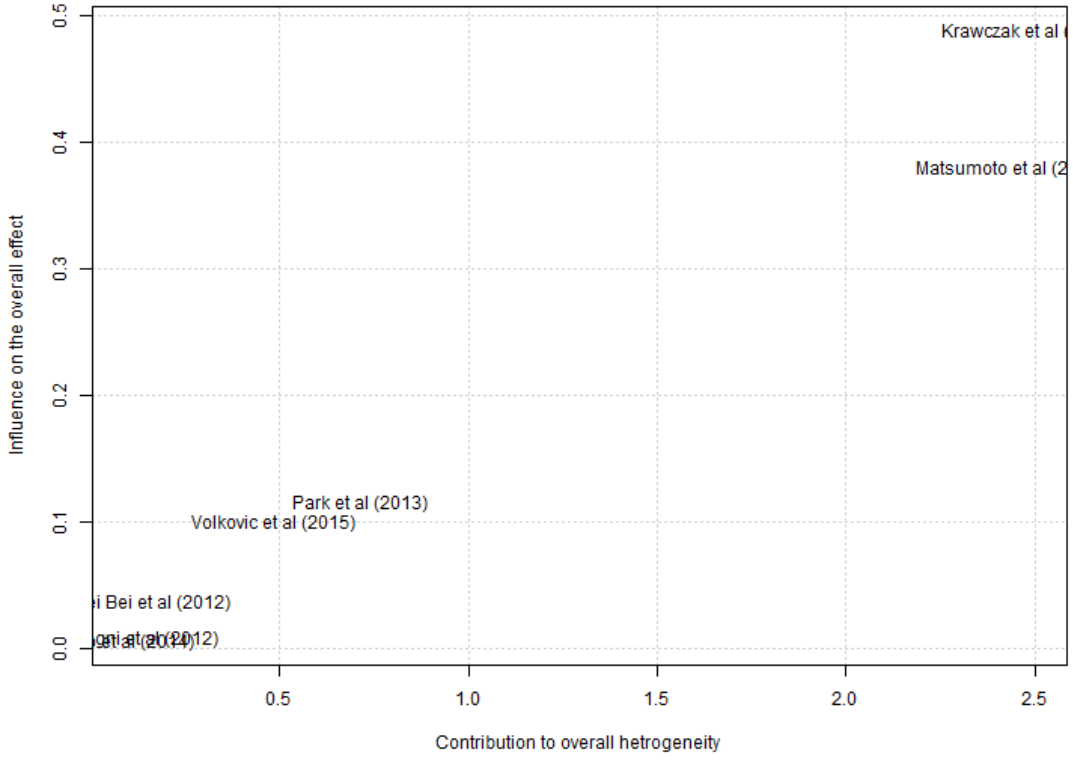


The impact of influential primary studies

A “leave one out” analysis was conducted on the data for WASO. Two studies, Krawczak et al. (2016) and Matsumoto et al. (2003) were identified as potentially influential studies, discrepant from the rest of the literature. This can be seen in Figure *14*. The analysis concluded that if either of these papers were left out of the analysis, heterogeneity would continue to be above an acceptable level with the analysis still producing a significant effect. 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.

Figure 14

Baujat diagnostic plot of sources of heterogeneity. The vertical axis reports the influence of the study on the overall effect and the horizontal axis reports the discrepancy of the study with the rest of the literature



As seen in Figure *14* two studies appear discrepant from the literature (Krawczak et al., 2016; Matsumoto et al., 2003). The influence of leaving each of these studies out of the analysis can be seen in Table 14. It is observed that by leaving each of these studies out of the analysis, there is a small change to the effect with a significant outcome still being observed. A review of each paper found no reason to exclude it from the final analysis.

Table 14

Summary of influential studies for WASO

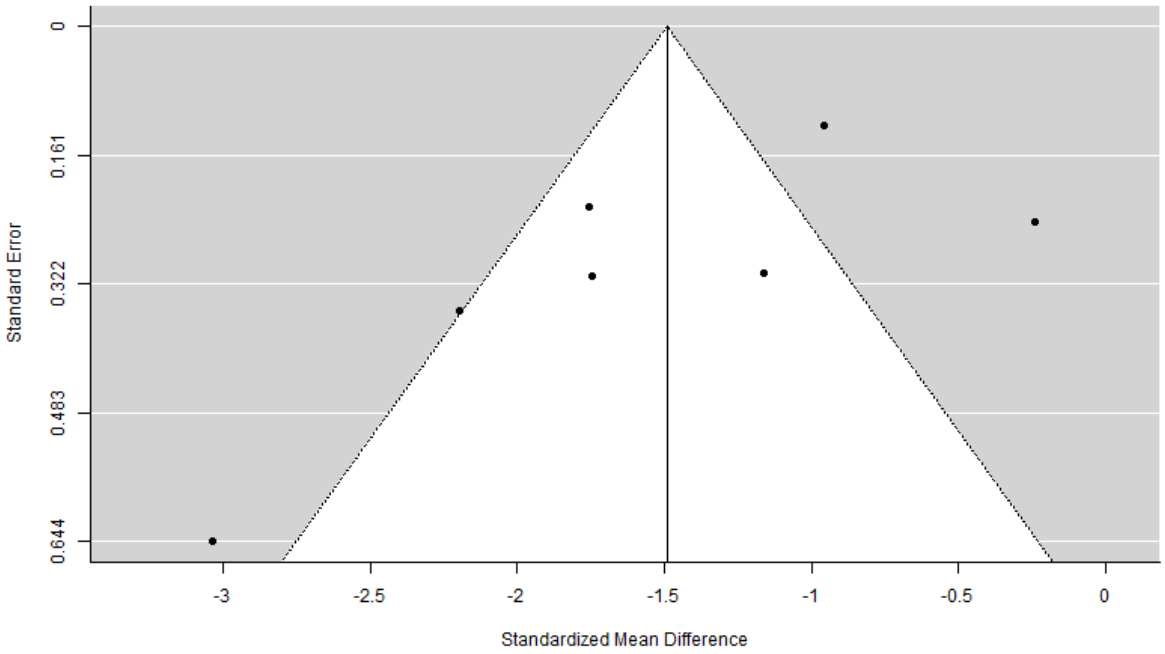
	SMD	95%-CI	p-value	tau^2	I^2
Omitting Krawczak et al. (2016)	-1.67	[-2.17; -1.17]	<0.0001	0.29	81.8%
Omitting Park et al. (2013)	-1.32	[-1.87; -0.76]	<0.0001	0.41	86.0%

The impact of publication and small study biases

Analysis of publication and small study bias was conducted on data for WASO data. If there is an absence of studies in the area of the plot associated with small sample sizes and non-significant results (for this meta-analysis it will be the bottom left-hand corner) then it is likely there is some publication bias leading to an overestimation of the true effect. The funnel plot of standardised mean difference is presented in Figure 15.

Figure 15

Funnel plot of the standardised mean difference. The 95% confidence interval of the expected distribution of standardised mean difference is shown as an inverted "funnel"



Visual analysis of the funnel plot indicates that studies are distributed across the funnel plot with no clear evidence of publication bias.

A failsafe calculation using the Rosenthal (1979) method was calculated for WASO data. This procedure suggests that 495 studies would be required to reduce the observed standardised mean difference = -1.49 to non-significance.

Discussion

Summary of findings

This meta-analysis was the first of its kind to review the effect having a child has on parents' sleep. The findings suggest 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. On average, studies assessed reported that total sleep time reduced by 9.3% in the first weeks after birth, time spent awake after initial sleep onset increased by 47% and, percentage sleep efficiency decreased by 12%. TST data reviewed also suggest that this decrease in total sleep time is much larger in the first 0-4 weeks following the birth of a child. After this, sleep in parents appears to start returning to pre-birth levels, with a much smaller effect being observed at 4-8 weeks and 8-16 weeks. The same was also observed for sleep efficiency. However, it does not appear that TST or sleep efficiency returns to pre-birth levels in this time frame. Further analysis indicates that age of the parent is likely to impact on the total sleep time of new parents. In addition to this, the analysis suggests that location also has a role in the sleep of new parents with studies across the world demonstrating a range of effect sizes. Studies conducted in the eastern hemisphere demonstrate a larger effect size than those in the western hemisphere suggesting parents in the western hemisphere lose more sleep following the birth of a child. Consistent with previous research findings, there was a limited number of male carers involved in parental research (Macfadyen et al., 2011; Tikotzky et al., 2015) so further analysis on these data could not be completed.

Limitations of the evidence

Most studies reviewed agreed that the birth of a child decreases parents' TST and SE and increases WASO. However, this outcome was not consistent across all the literature reviewed. There are many possible explanations for this observed variance. Throughout the literature reviewed there was variability in the way that sleep was recorded and reported. This included the length of actigraphy recording, variables recorded and reported and, the use or absence of sleep diaries. This is consistent with previous reviews of the actigraphy

literature (Berger et al., 2008; Morgenthaler et al., 2007). In a review of 21 studies using actigraphy, Berger et al. (2008) identified variability in the methods of reporting, sampling, processing of data and, analysis and a distinct lack of standardised protocols for the use of actigraphy.

Comparison of sleep data may also be made more difficult by the range of equipment available to researchers. In a comparison of consumer wearables, Saganowski et al. (2020) identified differences in the effectiveness of devices to measure data related to emotions, stress, meditation, sleep and, physical activity. They identified that no device performed well across all parameters, with devices showing greater accuracy in specific areas. This is impacted as well by the software and its configurations between devices (Berger et al., 2008). With such variability in devices, it is important that research considers the inter-device reliability of sleep measurement and how this is reported. Sleep diaries can be used alongside actigraphy to increase reliability of the device in the event of device malfunction or, periods of motionless activity are mistakenly recorded as sleep (Martin & Hakim, 2011). 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. Berger et al. (2008) suggest guidelines which may be considered in the standardisation of sleep measurement using actigraphy.

Across the studies reviewed, not all reported data around diversity of study populations. This made analysis of specific characteristics across multiple studies difficult. Of note was the limited number of studies reporting data from male carers. Evidence suggests

that males also experience an increase in night time activity and a shortening of total sleep time (Gay et al., 2004; Wulff, 2000). However, analysis of so few participants would not be generalisable. The limited number of male participants in this review reflects what is already well defined in the literature (Macfadyen et al., 2011). In a review of parental research between 2005 and 2015, Parent et al. (2017) identified that 38.36% of studies included only mothers, 23.76% of the research included mothers and fathers with separate analysis of each group. Further data showed, 0.76% of studies included fathers and not mothers. The review by Parent et al. (2017) was an update from a previous review of the literature and indicated there had been little change in this trend. Fathers have an important role in the care and development of their children. Researchers need to take further steps to understand why they are not involved in research and, how fathers can be encouraged to share their experiences of parenting. It has been hypothesised that there may be financial, social and, psychological barriers to recruiting fathers that may be considered at the study design stage (Macfadyen et al., 2011). In a survey of 303 fathers, Davison et al. (2017) identified that 80% of respondents felt that they had not been directly asked to participate in research and, 25% stating they were too busy to participate. It may be that researchers need to be flexible around work and childcare routines of both parents, but in particular fathers (Macfadyen et al., 2011). This may reflect more traditional gender roles where the mother is seen as the 'parent' and is more available for childrearing appointments (Bianchi, 2000) but, it does not necessarily reflect current caregiving practices. Furthermore, as family systems evolve, it is important not only to understand the role of fathers in research, but any secondary care giver within the home.

All studies analysed in this review used 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. Total sleep time decreases throughout pregnancy (Hedman et al., 2002) with reported total sleep time being higher before pregnancy when being measured subjectively (Coo et al., 2014) and objectively (Matsumoto et al., 2003). 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.

Limitations of this review

The evidence presented in this review demonstrates that having a baby is likely to negatively impact parents in several parameters of objectively measured sleep. However, there are limitations of this review that must be considered when interpreting these outcomes. Several studies in the review were deemed to be at low risk of bias. However, the outcomes of the risk of bias assessment varied significantly across all domains. All studies used actigraphy with varying approaches, which will affect the conclusions that can be drawn from the data. Given the variability of reporting in the literature and the limited data for WASO, the quality effects analysis and subgroup analysis were only conduced for TST and sleep efficiency.

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 in this review. Inconsistency of demographic reporting in the literature made further analysis difficult.

However, It is well documented that maternal mental health (Covington et al., 2018; Goldberg et al., 2013) and, socioeconomic status (Matthews et al., 2018; Moore et al., 2002) have an influence over sleep and further analysis may explore these factors in relation to childbirth.

Reporting methods varied across the studies reviewed, with not all studies including data for TST, WASO and sleep efficiency. 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 sleep efficiency data analysis was conducted on smaller sample sizes which may have influenced the higher levels of heterogeneity in the data.

Implications of the review

This review is the first of its kind to meta-analyse actigraphy data related to new parents sleep. The findings for this review indicate that parents' biggest loss of sleep is within the first four weeks of the child's life. Although there are many factors that influence maternal mental health, sleep has been identified as an important factor to consider and this review highlights that sleep loss is not just limited to total sleep but also time spent awake during the night and sleep efficiency of sleep.

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 time spent awake following the initial onset of sleep. Sleep deprivation literature in new parents has focused on the effects of partial or total sleep loss, with little research on the

implications of prolonged night-time waking on new parents. There is evidence to suggest from the general population that night time waking is associated with an increased immune response and an increased risk of cardiovascular disease (Tall & Jelic, 2019; Vallat et al., 2020), increased reports of daytime sleepiness (Bonnet & Arand, 2003) and, produces a hormonal response (Späth-Schwalbe et al., 1991). There is evidence to suggest that sleep fragmentation can have clinically significant implications on physical health when compared to sleep deprivation (Sériès et al., 1994). However, research in this area is limited and definitive conclusions cannot be drawn from this.

The results of this meta-analysis support the evidence that suggests that sleep following the birth of a child is sensitive to cultural differences (Kendall–tackett et al., 2010). Although variations of cultural practices have not been analysed, there is evidence to suggest that the differences observed in this analysis may be related to geographical location and parental practices. It should be recognised that this analysis is 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 highlights that fathers continue to be mostly absent from the literature when it comes to parenting. Further research needs to be conducted to understand why the experiences of fathers are not well documented in research. This review has also highlighted the methodological variation when it comes to research using actigraphy. Further considerations around actigraphy guidelines would be of benefit.

Conclusion

Sleep deprivation following the birth of a child is experienced by new parents worldwide and has a potential impact on physical and mental health. This meta-analysis provides clear quantifiable evidence of how much sleep new parents lose. Disturbances in sleep are influenced by age, 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.

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Empirical paper: The impact of sleep deprivation on emotion recognition in new parents

Abstract

Purpose

It is widely established in the literature that sleep deprivation has a negative impact on basic cognitive processes such as processing speed and memory. Research also continues to establish the link between sleep deprivation and social and emotional abilities in the general population. One population that this is less well understood in is new parents. This study investigates sleep differences between a group of expectant and a group of new parents, alongside their abilities at emotional recognition.

Method

In total, 25 participants were recruited to the study with an average age of 31.65. Of these participants, 14 identified as female with 11 identifying as male. This study used a between participants methodology recruiting expectant parents in the third trimester (mean gestational age (M= 36.3 weeks, SD = 3.1 weeks) and new parents up to 100 days after the birth of their child (M = 87 days, SD = 33.9 days). Participants completed sleep diaries and actigraphy was recorded for seven nights, before parents completed an emotion recognition task. Participants completed a task in which they identified the emotion expressed in the faces of 48 pictures of babies under three months of age.

Results

Bayesian analysis was used to look for preliminary evidence of differences between groups. Using actigraphy measures, there was evidence of group-level differences in waking: the postpartum group spent 41% more time awake following the onset of sleep than the

antenatal group. There was also an 8.7% decrease in Sleep Efficiency for the postpartum group compared to the antenatal group. There was no meaningful differences in each group ability to recognise emotions in infants accurately and confidently.

Discussion

As found in previous studies, new parents experience changes in sleep habits following the birth of a child. There was no evidence that these changes were associated with difficulties for new parents in recognising emotions. This study demonstrates that further work is needed to understand the impact of sleep deprivation on new parents and that it is feasible to do so using actigraphy to measure sleep objectively.

Introduction

There is a growing body of evidence that demonstrates the impact that sleep deprivation, or prolonged wakefulness, has on cognitive functioning (Alhola & Polo-Kantola, 2007; Killgore, 2010). Our knowledge of sleep and cognition comes from a wealth of research conducted on the general adult population in both natural and laboratory studies (Chee & Chuah, 2008; Kaliyaperumal, 2017; Ratcliff & Van Dongen, 2009). A population that we know report changes in sleep habits but is underrepresented in the literature is new parents. Much of the literature in the meta-analysis in chapter one concurs that following the arrival of a new child, new parents experience a loss of total sleep (Bei et al., 2012; Matsumoto et al., 2003; Signal et al., 2007). It is also evident that new parents experience fragmented sleep, with a greater time spent awake following the onset of sleep (Calcagni et al., 2012; Matsumoto et al., 2003; Park et al., 2013). One ability that may be particularly impacted by poor sleep is the ability to respond to emotions accurately (Killgore et al., 2017), which may have a significant impact on new parents.

Effects of sleep deprivation on cognition

Much of the early research evidence on the impact of sleep deprivation on cognition focused on its impact on basic cognitive processes, such as processing speed and vigilance (Goel et al., 2009). More recent evidence, however, has highlighted the broader impact poor sleep has on higher cognitive abilities, such as cognitive flexibility (Honn et al., 2019; Slama et al., 2018) impulse control (Demos et al., 2016) and, working memory (Santisteban et al., 2019). In fact, it has been suggested that such processes may be disproportionately impacted by sleep deprivation, due to its impact on processes predominately engaging the

frontal lobe (Killgore, 2010). Long term sleep disturbance can affect these cognitive processes often unbeknownst to the sleep deprived person (Goel et al., 2009).

Social and emotional cognition rely on higher order cognitive functions and are managed by multiple networks in the brain (Immordino-Yang & Sylvan, 2010). Frith and Frith (2001) suggest that the Medial Prefrontal Cortex plays a role in mentalisation, which includes judging emotions of others and acknowledging one's own emotions. Similarly, these processes often rely on the recruitment of other higher cognitive functions, such as working memory (Phillips et al., 2008), decision making, inhibition and, attention (Tanji & Hoshi, 2001). Given the impact of sleep deprivation on cognitive processes (Jones & Harrison, 2001) and the broader impact on frontal lobe functioning (Killgore, 2010), we should predict that poor sleep has an impact on social and emotional functioning. There is a growing body of evidence that suggests that this is the case (Deliens et al., 2015; Dorrian et al., 2019; Simon et al., 2020).

Killgore et al. (2008) identified that following a period 58 hours of continuous wakefulness, there was a significant reduction in participants' emotional intelligence, which impacts the ability to recognise and manage one's own emotions and may play a role in recognising emotions in others. This study also demonstrated that sleep deprivation affected people's ability to show empathy towards others and the quality of interpersonal relationships. This can be observed across a range of emotions including happiness (Killgore et al., 2017; Tao & Lu, 2020), sadness (Killgore et al., 2017), anger (van der Helm et al., 2010), fear (Almondes et al., 2020) and, neutral expressions (Maccari et al., 2014). It is maybe not surprising that when more ambiguous or complex expressions are used, accuracy and speed

decreases (Cote et al., 2014; Huck et al., 2008). A review of the literature by Beattie et al. (2015) identified that following a period of sleep deprivation, activity in the amygdala increased and may be related to a lack of cognitive control and increased emotional reactivity. The review also identified that emotional expressivity and emotion recognition is impaired.

Much of the literature assessing the impact of sleep deprivation and emotion recognition has been conducted in the laboratory setting, requiring participants to experience total sleep deprivation. The period of total sleep deprivation may vary but is not always reflective of common sleep disturbances experienced in naturalistic environments. It is expected that healthy adults would be more likely to experience sleep disturbances which are partial or chronic as opposed to total and acute. New parents are one population who experience predictable changes to habitual sleep in line with the change in roles and routines that parenthood brings.

Changes occurring with parental roles

Despite the expectation of having a baby for nine months, parenthood is a very sudden transition, with new parents developing parental roles even before leaving the hospital (Miller & Sollie, 1980). Becoming a parent presents a multitude of challenges including navigating the changing dynamic of relationships, balancing work and home and developing a sense of self as a parent (John et al., 2005). At the forefront of these changes is being able to interact with a new child. A new parent will need to understand, interpret, and act upon non-verbal signals or cries from a new baby, often for the first time. In the first few months, crying is the child's main form of communication, which has implications on the

stress and fatigue experienced by new parents (Kurth et al., 2011). New parents are expected to understand when their child is happy, sad, hungry, or tired and act appropriately upon this.

Sleep duration and quality change for both mothers and fathers, particularly in the first month following the birth of the child (Chapter 1; Gay et al., 2004). There is a wealth of research which looks to describe experiences of transition into parenthood relating to fatigue and general health (Elek et al., 2002; Gjerdingen & Center, 2003). New parents initially experience a significant change in their total sleep and time spent awake during the night. This begins to reduce from around four weeks postpartum, as seen in chapter 1. Evidence from the meta-analysis also demonstrates that even after 16 weeks, sleep does not return to its pre-birth state. Although the meta-analysis does not analyse data separately for fathers, objective measures of sleep indicate that fathers total recorded sleep time was higher than mothers following the birth of a child. Mothers sleep may be more fragmented than fathers (Insana, 2011). Despite this difference, mothers and fathers experienced more sleep disturbance when compared to controls (Insana, 2011). This change in sleep quality and duration has also been demonstrated for up to six years after birth when subjective measures are used (Richter et al., 2019). However, the exact course of sleep recovery after birth is subject to the individual's biological, social and, environmental factors. Cultural factors are also likely to play a key role in this recovery after birth.

Few studies have assessed the impact of new parents sleep and cognitive performance in field based studies (Insana, 2011; Insana et al., 2013). As noted above, most studies of sleep and emotion recognition have been conducted in laboratory settings under

conditions of total sleep deprivation. A closer estimation of the effect faced by parents may be the experience of shift workers, who experience disrupted sleep over a longer period. Many studies suggest that shift work is associated with poorer performance on cognitive tasks (Kaliyaperumal, 2017; Marquié et al., 2015; Özdemir et al., 2013). Although not an exact replication of the altered sleep patterns of new parents, it does suggest that irregular patterns of sleep over a longer period are likely to have an impact on various aspects of cognitive performance. We may expect that new parents have an experience that shows some similarities.

Potential implications of social cognition difficulties in new parents

Accurate emotion recognition may be particularly important for new parents. Brazelton et al. (1975) were the first to use the 'still face experiment', in which they studied the reaction of a child when their mother was unresponsive to their attempts to gain their attention. Their research described the toddler as repeatedly seeking the mother's response over a 3-minute trial and "withdraws into an attitude of helplessness, face averted, body curled up and motionless face" when they were unsuccessful. Mothers who demonstrate 'emotional availability' show higher levels of infant-attachment security (Hoffman et al., 2017; Ziv et al., 2000). In early attachment research, it was demonstrated that the mother's response to the child's emotional state acted as a predictor of attachment style (Smith & Pederson, 1988). Positive interactions and parental attunement with their child's emotions are likely to support the child to develop positive beliefs about emotions and skills in emotion recognition (Castro et al., 2015). Children who have developed secure attachments are likely to develop skills in emotion recognition later in life (Colle & Del Giudice, 2011) and

are likely to be able to develop strategies to regulate their own emotions (Brumariu, 2015). It may be hypothesised that the duration of irregular sleep experienced by the parent will play a role in the development of attachment. Parents whose sleep recovers to ante-natal levels quickly may see little impact - there is some evidence of recovery in cognitive tasks following a period of sleep deprivation (Drummond et al., 2006; Rupp et al., 2009). As seen in chapter one, most parents appear to begin to return to normal patterns of sleep as their child grows older. A parent who can recover from a period of disturbed sleep will likely be able to return to their regular social and emotional state, but we know less about the impact of sleep during the early months post-partum.

Rationale

Literature for the general adult population demonstrates that sleep deprivation can influence people's ability to recognise emotions. There is good reason to believe that following the birth of a child, changes in sleep may cause new parents to experience similar effects. However, this effect has not been systematically tested in this population. This pilot study aimed to address the feasibility of addressing this gap in the literature using a UK based population and utilising actigraphy to measure sleep. The meta-analysis in chapter one demonstrates that this has not been done using a within subject's design in the UK and further exploration of the literature indicates this is the first study of this effect using a between subjects' design. This pilot also addresses the feasibility of conducting this type of research with expectant parents in the third trimester of pregnancy and, parents of young children under three months of age. Based on data from the meta-analysis, it is hypothesised that new parents will have shorter and more disrupted sleep than a matched

sample of parents expecting a baby. This change in sleep may reduce parents' ability to recognise emotions in infants, such that new parents may perform worse than expectant parents, and this may correlate with sleep quantity and quality. This study provides preliminary data using a method to address these hypotheses.

Method

This study used a between subjects' design recruiting parents in the third trimester of pregnancy and in the first 100[1] days following birth. Sleep was measured subjectively using a sleep diary and objectively using Ōura rings. Recognition of infant emotions was measured during the period of sleep recording using a series of 48 pictures of children under the age of 3 months. An a-priori power analysis was completed using g*power (Faul et al., 2007) and medium-large effect size, (ηp^2 = 0.10), suggested the need of N>36, to give power (1- β) = 95%. Given the impact that the covid pandemic had on this study, and the constraints of a ClinPsyD thesis, it was not possible to achieve these participants numbers.

Participants

Participants were recruited through adverts posted on social media with the support of the National Childbirth Trust (NCT) and through snowballing on social media. Recruitment took place between December 2020 and August 2021. The study was open to any participants residing in England, Wales and, Scotland at the time of the study. Participants could participate in the study if they were over 16 years of age, were expected to be in the third trimester of pregnancy at the time of testing or, their child was under 100 days old

[1] *Note, one participant was assessed beyond the 100 days cut-off, due to an administration error. Due to the small sample size, their data were maintained in the final sample.

during the study period. A total of 25 participants took part in the study. Of these, 14 participants identified as female and 11 identified as male. Participants ranged in age from 25-41 years old (M= 31.65) with the gestational age in the antenatal group ranging from 31.6-40.3 weeks (M= 36.3 weeks, SD = 3.1 weeks). Children in the postpartum group ranged from 31-158 days (M = 87 days, SD = 33.9 days). Participants identified their ethnicity as white European, American or, other (91.3%), Asian: Indian sub-continent, Chinese or other (4.35%) or Mixed/multiple ethnic groups (4.35%). English was identified as the first language for 95.65% of participants with 4.35% identifying their first language as other. Adoptive and prospective adoptive parents were also eligible for the study, but none took part.

Measurements

Objective sleep

Ōura rings were used as an objective measure of sleep. Ōura rings are small, non-invasive and do not require user actions to initiate bedtime or sleep detection. This makes them particularly suitable for this study compared to wrist-based actigraphy. Ōura rings use infrared light photoplethysmography (PPG) to record heart rate, respiration rate and, body temperature and an accelerometer to measure movement to estimate sleep duration, quality, and efficiency. They demonstrate a significant level of correlation in the estimation of total sleep time (TST), wake after sleep onset (WASO) and, sleep onset latency (SOL) when compared to lab based polysomnography (PSG) (de Zambotti et al., 2019) and medically approved actigraphy (Asgari Mehrabadi et al., 2020). They have demonstrated particular strength in sleep recording when compared to other commercially available actigraphy devices (Saganowski et al., 2020). Participants wore the ring on a finger on their non-

dominant hand between 16:00 and 10:00 and were instructed to remove the device during these times for activities that may involve the ring being fully submerged.

Actigraphy has been used increasingly in sleep research (Sadeh, 2011). There are no published guidelines outlining methodological best practice for use of Ōura rings, but such guidance does exist for wrist actigraphy (Sadeh, 2011), and attempts were made to follow these where possible. This study aimed to record a minimum of seven nights sleep per person. It is recommended that a minimum of five consecutive nights of actigraphy recording is required to increase reliability of data (Sadeh, 2011). The number of nights of recordings for the antenatal group ranged from six to seven (M = 6.6 nights). The range for the postpartum group was from two to eight (M = 6.5 nights). Where the targeted seven nights were not achieved, data were included, given the small overall sample size. For traditional actigraphy, it is recommended that data are cleaned using sleep diaries to ensure reliability of recordings (Sadeh, 2011). Due to the lack of clear protocols for best practice on using diary data for improving Ōura ring data accuracy and evidence of impact, data were not "cleaned" in this way. It is possible that not following a data cleaning procedure will affect the reliability of the data. However, it is unlikely that this will introduce systematic confounds.

Subjective sleep

As well as using the Ōura ring, participants recorded their sleep using a paper sleep diary (Appendix 2). Subjective measures of sleep are useful in developing an understanding of the participants' perspective of their own sleep. Participants recorded the time they got into bed, estimated time they fell asleep and record any periods of night-time waking as

well, as final waking time and time out of bed. Total sleep time (TST) was defined by the total recorded night-time sleep following the onset of night-time sleep. TST did not include any periods of time during the night where the participant states that they are awake. TST also did not include any daytime naps. Wake after sleep onset (WASO) was defined as the total amount of time awake following the initial onset of sleep. SOL was defined as the period spent awake in bed before the initial sleep onset. Sleep Efficiency was defined as the ratio of TST to time in bed (TiB)(Reed & Sacco 2016). This was calculated from the paper sleep diaries using the formula TST/TiB (x100) presented by Reed & Sacco (2016). The total and average for TST, WASO, SOL and, Sleep Efficiency were calculated for all participants sleep diary data. These data were compared to the total for the same parameters taken directly from the Ōura ring output. It is suggested that a minimum of six nights of recordings are made when using a sleep diary (Aili et al., 2017). An average of 6.9 nights of sleep data were collected by diary for the antenatal group (range 6-7), with all participants providing seven nights of data in the postpartum group (M = 7). A summary of objective and subjective nights of sleep data collected can be seen in Table 1 below. These data are somewhat limited as data were not collected regarding the proximity of the emotion recognition task to the period of sleep recording.

***Table* 1**

Summary of objective and subjective sleep data collected

	Antenatal sleep			
Nights recorded	Sleep diary	Mean	Actigraphy	Mean
TST	76	6.9	40	6.7
WASO	76	6.9	40	6.7
SOL	76	6.3	40	6.7
Sleep efficiancy	69	6.9	40	6.7
	Postpartum sleep			
Nights recorded	Sleep diary	Mean	Actigraphy	Mean
TST	70	7	59	6.5
WASO	70	7	59	6.5
SOL	70	7	58	6.4
Sleep efficiancy	70	7	59	6.5

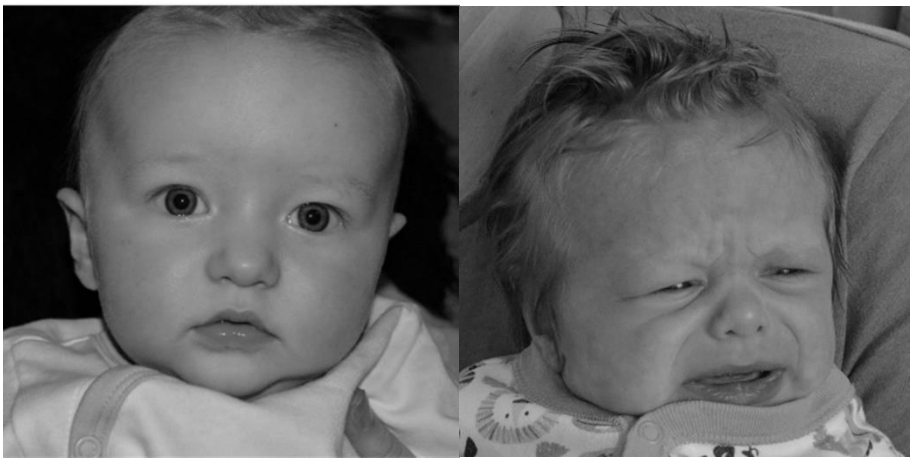
Emotion recognition task

Participants completed an emotion recognition task adapted from Elliot et al. (2014). Participants were presented with a series of 48 colour images of infants under the age of 3 months, which comprised of 16 happy, 16 sad and, 16 neutral pictures. Each image was cropped to ensure only the child was in the frame and sized to 15cm/15cm. An example of this can be seen in Figure 1 below. The pictures were then loaded into a Microsoft PowerPoint presentation with one image placed in the centre of each page. No other information was placed on the page other than a page number in the bottom right corner.

Pictures were provided by parents who did not participate in the study, following direct requests from the research team. A proposed emotion in each image was given by the parent prior to an independent rating. Each image was then rated by four parents independent of the research to reach an agreement on the emotion expressed by the infant. Only images where at least three of the independent reviewers reached an agreement were included in the study. The final 96 images were then randomised into two sets of 48 using a random number sequencer. Each set of 48 was included once in its original order then again in a separate reverse order sequence eventually producing four sets of images labelled 1a, 1b, 2a and, 2b. Sets of pictures were administered to participants in the sequence listed above with the first participant rating set 1a, second participant 1b, and so on. When participant 4 rated the emotions of set 2b, the cycle would begin again with the next participant being administered 1a.

Figure 1

Example pictures used in the emotion recognition task



Procedure

This study was approved by the University of Birmingham Science, Technology, Engineering and Mathematics ethics committee (ERN_18-1935). The protocol for the antenatal and postpartum groups was the same. Each participant was given a copy of the participant information sheet and given the opportunity to ask any questions about the study either by email, phone, or video call. Participants signed an electronic consent form to confirm that they had read and understood the information and agreed to participate in the study. Participants who met the inclusion criteria completed the study in two phases. Phase 1, recording of sleep using the Ōura ring and a sleep diary. Phase 2, emotion recognition task. Couples from the same household participating in the study monitored their sleep at different time points. All testing took place remotely with actigraphy devices and sleep diaries posted to participants. The emotion recognition task took place remotely over video call.

In phase 1 participants were sent the Ōura ring in the post. They were given instructions to charge the ring when it arrived and after every 2 nights of recording. Participants were asked to confirm when they started their first night of sleep recording using the ring and paper diary. Once it was confirmed they had started recording, a day and time was set to complete the emotion recognition task. This was set within the recording period or as close to the recording period as possible. The ring was placed on either their index, middle or ring finger on their non-dominant hand. After seven nights of recording, the ring was placed in the pre-paid envelope and posted back to the research team. During this time, participants also monitored their sleep using a paper diary.

In phase 2 participants completed the emotion recognition task over Zoom video conferencing software. After discussing the procedure and purpose of the research, participants were asked for their verbal consent to proceed. Once they had given consent, participants provided demographic information which was stored securely on the University of Birmingham's research data store. Each participant was then shown a series of 48 pictures of infants and asked to rate if they thought the chid looked happy, sad, or neutral. They were also asked to rate their confidence in this from a scale of 0-10, 0 being not confident at all and 10 being certain of their emotion rating. At the end of the procedure participants were thanked for their time and offered the opportunity to ask any questions about the research.

Attrition

Initial power analysis prescribed sample sizes were not met due to shorter than planned recruitment time (due to Covid-19 restrictions).

Through the initial advert, participants were asked to contact the research team for further information on the study. This information, along with a link to the online consent form was sent to all who demonstrated an interest in the study. For the postpartum group, 21 participants completed the consent form. Of these 21 participants, 12 participants provided either full or partial data for the study. Nine participants became ineligible for the study in the process of recruitment as their child became older than 100 days. Of the 12 participants who completed the study, actigraphy data were not obtained for three participants due to the ring being lost in the post for one participant (with no personally identifiable information included) and the data not being on the ring upon its return for the other two. For the antenatal group, 21 participants completed the online consent form. Of these 21 participants, full actigraphy (and sleep diary) data were collected for six participants and four participants were able to provide sleep diary data only. Ten participants completed the emotion recognition task however, two participants were unable to complete the task, as they had to attend the hospital following the sleep recording and gave birth in this time. Of the 21 participants who initially consented five participants were asked to participate using the paper diary only but were unable to participate for unknown reasons. Three participants were unable to participate due to either needing to remain in hospital or giving birth in the data collection period. One participant was sent the actigraphy ring, but it did not fit and ultimately gave birth before they could be recruited to the study.

Table 2

Summary of attrition data following consent to participate

	N (overall)	Percentage of original consenting sample	N (antenatal)	Percentage of consenting antenatal sample	N (postnatal)	Percentage of postnatal consenting sample
Actigraphy data	16	38%	6	29%	9	43%
Diary data	21	48%	11	52%	10	48%
Emotion recognition data	23	55%	11	52%	12	57%

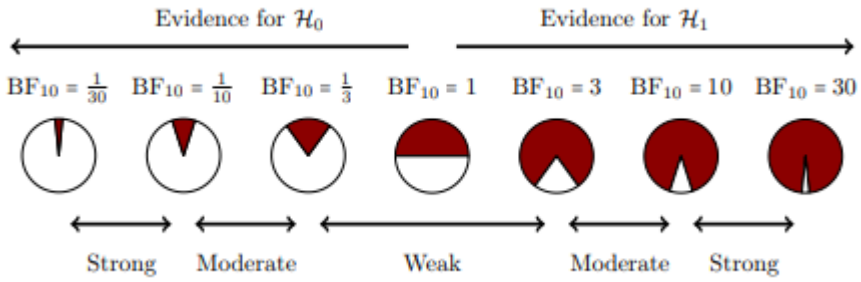
Analysis

Bayesian analysis was employed on data collected. Unlike frequentist approaches, Bayesian analysis is not dependant on a sampling plan and achieving a specified N. It allows researchers to determine that data collection is complete at the point that the study has run out of resources (Wagenmakers et al., 2018). Bayesian analysis is a measure of probability that the evidence obtained is in support of either a null hypothesis H_0 or an experimental hypothesis H_1 (van Doorn et al., 2021) and therefore can offer an approximation of the usefulness of further exploration of the research area. It does not provide a significance test,

but rather a ratio of the likelihood of results under each hypothesis. How much the Bayes Factor$_{10}$ deviates from 1 is considered an indication of the probability that a given hypothesis is true. Bayes factor of 1-3 is often considered weak support for H_1, 3-10 is considered moderate support and a Bayes Factor is more than 10 is considered strong support for H_1. A Bayes factor of 1-1/3 is considered weak support for the null hypothesis, 1/3-1/10 is considered moderate, and a Bayes factor of 1/10-1/30 is considered strong support for H_0. This is represented by the illustration from Van Doorn et al. (2021) in Figure *2*.

Figure 2

Representation of the strength of Bayes factor as found in (van Doorn et al., 2021)



Prior probability distribution, or priors, can be used in Bayesian analysis to express belief about the research question prior the inclusion of evidence. This allows researchers to use current knowledge about populations to inform the outcome of the analysis. Given the limited evidence in relation to new parents abilities on emotion recognition tasks, strong assumptions about the data may not be possible. In addition to this, given the small sample size, conclusions drawn from the data may be heavily influenced by the inclusion of priors. Given that so little is known in this area, and the potential influence of priors, caution was taken and priors were not used in the Bayesian analysis.

Results

Table *3* shows a summary of the mean and standard deviations for TST, WASO, SOL and Sleep Efficiency for the antenatal and postpartum groups of objective and subjective measures. Data for TST, SOL and WASO are represented in minutes. Sleep Efficiency is represented as a percentage.

Table 3

Summary of subjective and objective sleep data for antenatal and postpartum groups

		N	Mean	Std. deviation	Bayes Factor
TST^{Diary}	Antenatal	11	432.58	30.22	
	Postpartum	10	454.41	52.8	0.48
$WASO^{Diary}$	Antenatal	11	33.11	43.63	
	Postpartum	10	83.61	42.74	3.89
SOL^{Diary}	Antenatal	11	36.24	22.73	
	Postpartum	10	25.56	19.17	0.52
Sleep $Efficiency^{Diary}$	Antenatal	10	83.2	6.76	
	Postpartum	10	76.70	7.87	1.35
TST^{Acti}	Antenatal	6	424.14	44.4	
	Postpartum	9	429.23	47.05	0.36
$WASO^{Acti}$	Antenatal	6	69.1	26.96	
	Postpartum	9	116.3	24.82	11.49
SOL^{Acti}	Antenatal	6	8.48	2.43	

	Postpartum	9	10.14	3.31	0.53
Sleep Efficiency^{Acti}	Antenatal	6	86.17	5.56	
	Postpartum	9	78.67	3.61	7.30

Note. TST^{Diary} = Total Sleep Time recorded using a paper diary, $WASO^{Diary}$ = Wake After Sleep Onset recorded using a paper diary, SOL^{Diary} = Sleep Onset Latency recorded using a paper diary, Sleep $Efficiency^{Diary}$ = Sleep Efficiency recorded using a paper diary, TST^{Acti} = Total Sleep Time recorded using an actigraph, $WASO^{Acti}$ = Wake After Sleep Onset recorded using an actigraph, SOL^{Acti} = Sleep Onset Latency recorded using an actigraph, Sleep $Efficiency^{Acti}$ = Sleep Efficiency recorded using an actigraph.

The summary data in Table *3*demonstrates some differences in data collected objectively and subjectively. Diary data suggest moderate evidence in favour of postpartum participants experiencing higher WASO than the antenatal group. The data suggest weak evidence in favour of null for TST and SOL. The data for Sleep Efficiency suggest weak evidence in favour of the experimental hypothesis. Parents in the postpartum group slept, on average, longer than those in the antenatal group and had shorter sleep latencies, but worse Sleep Efficiency. Further data collection would be needed to understand the likelihood that any of these differences reflected a meaningful change to new parent sleep.

Actigraphy data suggested there was strong evidence in support of the experimental hypothesis for WASO and moderate evidence in support of the experimental hypothesis for Sleep Efficiency: Postpartum parents were awake for longer and had less efficient sleep than antenatal parents. Reed and Sacco (2016) state that in sleep restriction therapy (SRT) a Sleep Efficiency of 85%-89% is considered the goal. The antenatal and postpartum groups fall below this value in the diary group, with the antenatal group recording an average Sleep

Efficiency in this range when recorded using actigraphy. SOL and TST data were similar for the two groups, providing weak evidence in favour of the null hypothesis.

As can be seen in Table *4*, there were some differences in the reported means of data recorded by actigraphy and sleep diary. Correlation analysis was completed between actigraphy and sleep diary using Spearmans rho, due to non-normally distributed data. Due to a Bayesian analysis not being available for Spearmans rho, Bayes Factor is not reported.

Table 4

Correlation data using Spearmans rho observing differences in actigraphy vs sleep diary data

Sleep parameter	Correlation coefficient
TST^{Diary} Vs. TST^{Acti}	.716**
$WASO^{Diary}$ Vs. $WASO^{Acti}$	.381
Sleep $Efficiency^{Diary}$ Vs. Sleep $Efficiency^{Acti}$	.392
SOL^{Diary} Vs. SOL^{Acti}	-.081

Note. TST^{Diary} = Total Sleep Time recorded using a paper diary, $WASO^{Diary}$ = Wake After Sleep Onset recorded using a paper diary, SOL^{Diary} = Sleep Onset Latency recorded using a paper diary, Sleep $Efficiency^{Diary}$ = Sleep Efficiency recorded using a paper diary, TST^{Acti} = Total Sleep Time recorded using an actigraph, $WASO^{Acti}$ = Wake After Sleep Onset recorded using an actigraph, SOL^{Acti} = Sleep Onset Latency recorded using an actigraph, Sleep $Efficiency^{Acti}$ = Sleep Efficiency recorded using an actigraph.
**. Correlation is significant at the 0.01 level (2-tailed)

Schober et al. (2018) define a weak correlation as being between 0.10-0.39. According to this, data for WASO represents a weak correlation between diary and actigraphy data. The coefficient for Sleep Efficiency would also represent a weak positive correlation. A coefficient between 0.70-0.89 would represent a strong correlation (Schober et al., 2018). The data for TST would fall within this range. Data for SOL represents a

negligible correlation suggesting that there is no relationship between these data. Ōura rings have demonstrated good reliability compared to PSG and other, medically approved devices in the general population (Asgari Mehrabadi et al., 2020; de Zambotti et al., 2019; Saganowski et al., 2020). Here, whilst individual differences in TST were well-matched across objective and subjective measurement, there were distinct differences for WASO and Sleep Efficiency and there was almost no relationship between measures of SOL. It may be the case that sleep diary data must be interpreted with caution and differences in the data acknowledged.

Table *5* shows the data recorded during the emotion recognition task. It shows the percentage of correct answers given by participants for each emotion as well as an overall percentage correct. It also shows the confidence rating of their responses. Overall, participants performed with a high level of accuracy and a high level of confidence in their responses.

Table 5

Summary of emotion recognition data including percentage correct responses for each emotion and confidence rating for each emotion

		N	Mean	Std. deviation	Bayes factor
Happy	Antenatal	11	97.16	4.3	
	Postpartum	12	91.67	6.71	2.20
Sad	Antenatal	11	96.02	4.21	
	Postpartum	12	98.44	2.83	0.83

Neutral	Antenatal	11	85.8	9.72	
	Postpartum	12	89.58	8.14	0.45
Total	Antenatal	11	92.0	3.64	
	Postpartum	12	93.23	2.96	0.30
Happy confidence	Antenatal	11	8.83	0.56	
	Postpartum	12	9.06	1.13	0.34
Sad confidence	Antenatal	11	8.9	0.89	
	Postpartum	12	9.26	0.54	0.51
Neutral confidence	Antenatal	11	8.21	0.84	
	Postpartum	12	8.18	1.31	0.29
Overall confidence	Antenatal	11	8.65	0.69	
	Postpartum	12	8.84	0.87	0.34

For infants showing a happy expression, there was weak evidence for a difference between groups, with the antenatal group, on average, scoring higher for these emotions. For neutral expressions there was moderate evidence in favour of the null hypothesis. For sad emotions, there was weak evidence in favour of the null hypothesis. When combined into a total score, there was moderate evidence for the null hypothesis: that antenatal and postpartum groups performed equivalently.

There was no evidence of difference in scores for confidence ratings between groups. For all emotions, the data represent weak evidence in favour of the null hypothesis.

Correlation analyses for the antenatal and postpartum groups were used to examine the relationship between TST^{Acti}, $WASO^{Acti}$, $Efficiency^{Acti}$ and, overall percentage accuracy on the emotion recognition task. Given the non-normal distribution of the data, Spearmans rho was used. Due to a Bayesian analysis not being available for Spearmans rho, Bayes Factor is not reported. The results of this can be seen in Table *6* below.

Table 6

Correlation coefficients for actigraphy data and percentage of correct answers overall on the emotion recognition task

	TST^{Acti}	$WASO^{Acti}$	Sleep $Efficiency^{Acti}$	Percentage correct on emotion recognition task
TST^{Acti}	1	.089	.217	.184
$WASO^{Acti}$	.089	1	-.905**	.490
Sleep $Efficiency^{Acti}$	.217	-.905**	1	-.339
Percentage correct on emotion recognition task	.184	.490	-.339	1

Note. TST^{Acti} = Total Sleep Time recorded using an actigraph, $WASO^{Acti}$ = Wake After Sleep Onset recorded using an actigraph, Sleep $Efficiency^{Acti}$ = Sleep Efficiency recorded using an actigraph.
**. Correlation is significant at the 0.01 level (2-tailed)

Data were treated cautiously, as potential relationships that may inform hypotheses for a larger study. With this in mind, Schober et al. (2018) recommends that a coefficient of 0.10-0.39 indicates a weak correlation. Results indicate that there was a weak positive correlation between $TST^{Acti,}$ and the percentage of correct answers given on the emotion recognition task. There was also a weak negative correlation between Sleep $Efficiency^{Acti}$ and

percentage of correct answers. There was a moderate correlation between $WASO^{Acti}$ and the percentage of correct answers on the emotion recognition task (Schober et al., 2018). In sum, correlation data provided weak evidence for an unexpected finding: good performance on the emotion recognition task showed some evidence of being associated with longer night waking and worse Sleep Efficiency. This is likely a spurious finding but provides reasonable evidence that the predicted effect was not apparent – that fragmented sleep would precipitate poor performance. There was a strong negative relationship indicated between Sleep $Efficiency^{Acti}$ and $WASO^{Acti}$. It may be expected that as time spent awake during the night increases, Sleep Efficiency decreases.

Table 7

Gender difference in sleep recorded by actigraphy and percentage of correct answers in the emotion recognition task

		N	Mean	Std. deviation	Bayes factor
TST^{Acti}	Male	5	422.57	35.17	
	Female	10	429.51	50.05	0.37
$WASO^{Acti}$	Male	5	109.08	39.86	
	Female	10	91.59	31.98	0.5
SOL^{Acti}	Male	5	10.21	3.08	
	Female	10	9.11	3.08	0.42
Sleep $Efficiency^{Acti}$	Male	5	79.6	5.13	
	Female	10	82.7	6.01	0.52

Happy	Male	10	93.13	6.88	
	Female	13	95.19	5.79	0.38
Sad	Male	10	98.75	2.64	
	Female	13	96.15	4.07	0.98
Neutral	Male	10	85	10.7	
	Female	13	89.9	7.01	0.59
Total	Male	10	92.29	3.41	
	Female	13	93.74	3.07	0.47

Note. TST^{Acti} = Total Sleep Time recorded using an actigraph, $WASO^{Acti}$ = Wake After Sleep Onset recorded using an actigraph, SOL^{Acti} = Sleep Onset Latency recorded using an actigraph, Sleep $Efficiency^{Acti}$ = Sleep Efficiency recorded using an actigraph.

Table *7* represents gender differences in sleep recorded using actigraphy and percentage of correct answers on the emotion recognition task. The data show that there was no evidence in favour of the experimental hypothesis with data across all parameters demonstrating weak evidence in favour of the null hypothesis.

Discussion

This study provides the first insights into the feasibility of conducting emotion recognition research within a new parent population and how these abilities relate to sleep. Although the sample in this study did not reach that to achieve planned power, it offers preliminary evidence into how hypotheses in this area may be tested using objective measurement of habitual sleep.

Summary of findings

Sleep data

Sleep data were recorded from antenatal and postpartum parents, using diaries and Ōura rings. Data suggest that such recording was feasible and tolerable to parents, though note the high rate of attrition of originally consented participants (Table *2*). Actigraphy data provided moderate-strong evidence in favour of differences between antenatal and postpartum groups. There was evidence to support the hypothesis that postpartum parents experience a greater duration of time spent awake following the initial onset of sleep than their antenatal counterparts. The results also provide support for the hypothesis that the efficiency of new parent's sleep reduces compared to the antenatal group. Given the increased time spent awake during the night, this would be expected. Correlation analyses suggest that there was a strong negative correlation between these two variables. These findings are consistent with numerous previous findings, as summarised in the meta-analysis in chapter one. Conversely, data did not support evidence of difference in total sleep time between groups. Given the evidence presented in chapter one, this is somewhat surprising. However, studies have demonstrated a similar effect in relation to TST (Krawczak et al., 2016; Park et al., 2013). Park et al. (2013) demonstrated a similar effect overall with a slight increase in TST and WASO and a reduction in Sleep Efficiency in the postpartum group. It is beyond the scope of this pilot study to explore the reasons for this change in sleep. However, other studies have identified similar patterns of sleep change in breast feeding parents (Doan et al., 2007) and when analysing data from a similarly small sample size (Sharkey et al., 2013). It should also be recognised that the average age of children for

parents in the postpartum group was 87 days. According to data in chapter 1, many parent's sleep will have started returning, although not completely, back to pre-birth levels.

Diary recorded data provided weak support in favour of the null hypothesis for TST and SOL, weak support for the experimental hypothesis in relation to Sleep Efficiency and moderate support for the experimental hypothesis for WASO. In sum, data were broadly consistent with Ōura ring data, but differences were less pronounced. As seen in Table *4*, there was limited agreement between diary and actigraphy data, except for TST. Measuring sleep objectively may be important in accurately identifying changes to parent sleep. Part of the challenge in this area is supporting participants to complete the paper sleep diaries effectively and provide all key information. It is recommended that subjective sleep recording is collected over a period of six nights (Aili et al., 2017), which was achieved in this study suggesting other factors may have affected the reliability of data collected. Inaccurate reporting of sleep can lead to data loss. Paper sleep diaries are subject to ineligible content, the form not being completed in its entirety and "parking lot syndrome" whereby participants complete the diary retrospectively, reducing their accuracy of judgement (Tonetti et al., 2016). It was identified that Ōura rings demonstrated particular reliability in measuring sleep and were chosen for this study (Saganowski et al., 2020). It may be hypothesised that Ōura rings and sleep diaries may have been measuring different constructs. For example, the sleep diaries may have been more suited to measuring a perception of sleep (Kawada, 2008), with Ōura rings measuring actual sleep.

Implications of findings

Given the limited data analysed in this study, further research is required to draw conclusions about the impact of sleep on emotion recognition in new parents. Parenthood is a complex biopsychosocial process with sleep and emotion recognition playing an important role in this. Further research is needed to understand other factors that are likely to impact on parent sleep and impact on emotion recognition in new parents. This includes cultural influences, parenting styles, napping and, parity to name a few.

The findings of this study and chapter one indicates that total sleep and wake after sleep onset are both impacted when parents have a new child. Further work is needed to build on this to develop a clearer understanding of the cognitive impact of sleep deprivation in new parents. This study does however demonstrate a similar pattern of sleep loss to research reviewed in chapter 1. It may be beneficial for healthcare workers to support parents who experience chronic sleep loss that does not return to a regular pattern. In particular, attention needs to be given to groups of parents who may be considered at risk of experiencing chronic sleep deprivation and the potential compounding impact a new child may have on this.

Emotion recognition data

Both groups performed with a high degree of accuracy on the emotion recognition task, averaging over 90% at recognising each emotion (SD = 2.23). The confidence data suggest that parents felt similarly confident in their appraisal of emotions with there being little difference in the overall confidence or individual confidence of each emotion. These data reflect a high overall confidence in recognising emotions for both groups. Weak evidence for the null hypothesis was found for overall accuracy on the emotion recognition

task. Data for individual emotions, sad and neutral, provide weak evidence for the null hypothesis, that there is no effect observed between groups. Weak evidence in favour of the experimental hypothesis was found for accuracy of judgements of happy face, with the antenatal group performing marginally better. For confidence ratings, all analysis was in favour of the null hypothesis, with moderate support for neutral emotions, and weak evidence for happy, sad, and overall accuracy. These findings do not support the hypothesis for this pilot study. Possible reasons for this are discussed below.

As previously recognised, a substantial contribution to the literature on sleep deprivation and emotion recognition is obtained through total sleep deprivation studies in a laboratory based setting (Beattie et al., 2015; de Almondes et al., 2016). The observation from previous literature is that sleep deprivation is likely to impact on a range of cognitive functions (Jones & Harrison, 2001; Phillips et al., 2008; Tanji & Hoshi, 2001), which then may have an impact on higher order cognition, such as social and emotional functioning (Simon et al., 2020). However, in this study, little difference was observed between groups with respect to their accuracy in recognising emotions in infants. This study identified little difference in total sleep time of expectant parents and those shortly after birth. Whilst there were notable differences in WASO and Sleep Efficiency, participants still gained far more sleep than in lab-based studies employing total sleep deprivation. It may be that more substantial, acute sleep deprivation is required to cause difficulties with emotion recognition. Alternatively, lack of differences may result from lack of sensitivity in the emotion recognition task. Recognising emotions in children is a complex task which demands that parents are aware of their child's habits, routines, verbal, and non-verbal cues. The task in this study required participants to look at a still image of an infant face under no time

limit. Including a time limit or another stressful stimulus is likely to inhibit performance on such a task (Hänggi, 2004). Swain (2008) identified that when exposed to a baby crying, the pre frontal cortex and hypothalamus are stimulated in parents. The pre-frontal cortex being an area of the brain associated with mentalising and judging emotions (Frith & Frith, 2001). It may be hypothesised that in a protocol where no additional demands were placed on the participant, the task was relatively easy for participants.

The conclusions drawn from this study indicate that more work will need to be done to understand the role of sleep in new parents' ability to recognise emotions in infants. Recommendations for future research may be to use more subtle measures of emotion, measure sleep closer to the child's birth, or measurement of parents whose sleep is particularly disrupted by a child's arrival.

Limitations, future directions, and considerations for the feasibility of future studies

As well as providing preliminary data for consideration, a pilot study aims to provide insights to improve reliability and validity of future studies to conduct hypothesis testing directly by asking 1) if something can be done and 2) if something should be done (In, 2017). Due to the COVID 19 pandemic, this study was conducted completely remotely, and the final sample represented a smaller data set than originally targeted. Several considerations can be drawn as a direct result of this, with others being general considerations around conducting research of this nature.

Recruitment of expectant and new parents

In spite of their frequency, expectant and new parents, particularly fathers (Leach et al., 2019), can be a difficult population to recruit. For this study, recruitment took place

through social media and by word of mouth. Through this mechanism, this study recruited 42 participants to consent over an eight-month period. This was in line with original targets and reflected interest of parents in participating in research (which intended to recruit over a longer period, prior to covid restrictions). Conversely, there were significant problems with attrition. Only 60% of the initial consenting sample continued to provide full or partial data for the study. There were various reasons for this as recognised above. The initial phase of recruitment was positive with large numbers of participants expressing an interest in the study. This first 'wave' of recruitment yielded 21 consenting participants. However, availability of equipment meant that it was not possible to schedule all these participants for data collection while they remained eligible. In total, 26% of the consenting sample were not included in the study because they became ineligible, either due to giving birth or their child reaching 100 days old. Future studies may consider the resources available and readiness for testing at the time of advertising, or advertising to parents earlier in pregnancy.

In chapter one it was recognised that fathers are an underrepresented in research related to their children. Recruitment for this study was positive in this respect with 11 participants (45.8%) identifying themselves as male. Recruitment of the postpartum group showed a more even split in relation to gender than the antenatal group. When advertising for the study it was made clear that this research was open to both male and female participants. Previous research has demonstrated that when gender neutral language is used, fathers are less likely to express an interest in research (Leach et al., 2019). When contacting participants, they were also encouraged to share the research poster with others, including their partners. It may be suggested that future research considers making the including criteria explicit throughout recruitment. Although positive steps were made to

include fathers in this study, the population recruited lacked diversity in relation to ethnicity, with most participants identifying themselves as coming from a white background. As previously recognised, culture is likely to have an impact upon parenting style and sleep (Airhihenbuwa et al., 2016; Super et al., 2021). Future studies must consider how accessible the research is to a range of people from a range of cultures to present data that is representative of the target population.

Use of smart devices and actigraphy rings

Actigraphy data provide objective measurement of sleep, that can be crucial in groups for whom accuracy of recording may be difficult. As highlighted above, these data provided support for group-level differences, where diary data did not. The choice of Ōura rings, as opposed to traditional wrist-worn actigraphy reflected ease of wearing by parents of small babies and evidence of good concordance with other forms of actigraphy (Asgari Mehrabadi et al., 2020) and PSG (de Zambotti et al., 2019). There were, however, notably limitations to their use.

This study relied on Ōura rings being paired with a single smart device where the data could be downloaded upon the rings return to the research team. The smart devices were not connected to the internet to prevent participant health data from being uploaded to the internet. Unfortunately, due to the age of some of these devices the rings were not able to be connected, even with a software update. This created a delay in data collection and during this time some participants became ineligible for the study. Future research teams may consider investing in newer smart devices which would come at a cost to the research team. Data were lost from five of the rings through either the ring being lost in the

post or, the data not being on the ring when it was returned. Participants were asked to post the rings back once they had completed the study. Due to the COVID 19 pandemic, they were not asked to go into the post office and provide evidence of delivery. Ōura rings can complete a 'hard reset' by being placed on the charger and being hit with force on a hard surface. It is speculated that during transit a similar occurrence may have happened resulting in data being lost from the ring. Future studies may also benefit from being aware of such functions and protecting the devices in transit to reduce the loss of data.

Emotion recognition task

The emotion recognition task was administered by Zoom video conferencing software. This meant that the research team could be flexible in relation to organising times to meet with participants. This was of benefit to organising the research and working around participants' busy schedules. It would be of benefit to future studies to be able to offer a similar opportunity to reduce the burden of the task on participants. However, this did come at a cost to the data collected. Initially, speed of emotion recognition was going to be measured, which was not possible over Zoom.

The procedure for the emotion recognition task was adapted from that of Elliot et al. (2014) with some key differences. In the study by Elliot et al., the stimulus included pictures of participants own child which this study did not. However, there were no systematic differences observed in parents' ability to accurately identify emotions in their own child and others. Elliot et al. used fewer images in their study, 30 compared to 48 in this study. When independent reviewers were asked to make a judgement on the initial pool of pictures, they reached an agreement on 154 out of 155 pictures presented. This means that only one

picture did not reach a majority agreement on the expressed emotion and was not eligible for inclusion. This high level of performance is reflective of that observed in the study. As previously recognised, research methodology that present the participants with more ambiguous or a time sensitive component (Cote et al., 2014; Huck et al., 2008) may increase the sensitivity of the stimuli. It may be that having 48 pictures reduced the sensitivity of the stimuli. Future research may consider reviewing the optimum number of images used in such research to mitigate these effects.

As previously noted, the procedure in this study required participants to make a judgement on the child's emotion without a time limit or ambiguity of the image. This may have contributed to the high accuracy of recognition observed and the reduced sensitivity of the stimuli. Other methodologies have used morphed emotions to vary the intensity of emotion observed by the participant (Cote et al., 2014; Huck et al., 2008) and assessed speed of recognition (Byrne et al., 2019). Both these methods may help to increase the sensitivity of the measure and provide a naturalistic testing condition. Byrne et al. (2019) utilised morphed images and timed the response of participants on an emotion recognition task with pregnant participants. In this study they identified that pregnancy was associated with enhanced attention to infant and distressed faces. This provides some evidence to suggest that prospective parents can retain some ability in recognising emotions in infants and may support the effect observed in this study. This provides support that further research in this area is required to explore factors that may influence the emotion recognition of prospective and new parents.

Conclusion

This pilot study demonstrated that it is feasible to conduct research looking at sleep and emotion recognition in new parents in the UK. Although there were several challenges with this study, it demonstrates that when using social media, expectant and new parents are willing to take part in research in this area with interest from both men and women. Further efforts would be needed to recruit from a diverse population. The data for this study demonstrated some evidence for disturbed sleep in new parents, who spent more time awake at night and consequently had less efficient sleep than expectant parents. Expectant and new parents demonstrated a high degree of accuracy and an associated high level of confidence in their ability to recognise emotions in young children. However, there are methodological considerations which limit the conclusions that can be drawn from the data and further research is needed to fully understand the relationship between sleep and emotion recognition in new parents.

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Public dissemination document

Changes in new parents sleep following the birth of a child – a meta-analysis

New parents spend less time sleeping during the night compared to during pregnancy and spend 47% more time awake during the night. Sleep efficiency of new parents also reduces by 9.3%.

Sleep is an important part of our everyday life. If we were to be deprived of sleep it would affect our memory, attention, and our ability to process information quickly and accurately. When we are asleep, the brain can recover from the activities of the day, ready

to start again when we wake up. Researchers have been interested in sleep for many years and our understanding of sleep and its functions continues to develop.

For this meta-analysis we were specifically interested in how sleep changes in new parents. A meta-analysis is a way of compiling data from previous studies and assess the results to draw conclusions about the area of interest. We compiled data from 14 studies that used actigraphy to measure sleep in new parents. Actigraphy measures sleep and activity by monitoring heart rate and movement using a device that is often worn around the wrist or finger. Many smart watches on the market today use this type of technology to measure sleep and activity.

The findings show that the total sleep time of new parents decreased by 9.3% in the weeks after giving birth. Up to four weeks after birth was the biggest change in parents' total sleep. Up to 16 weeks after birth, the total sleep time of new parents had not increased back to pre-birth levels but had begun to increase again. Analysis across cultures was also completed and demonstrated that greater sleep loss was observed in Australia, New Zealand, Japan, Taiwan, and Germany compared to USA, Canada, and Israel. Analysis was also conducted to observe differences in the eastern and western hemispheres, as defined by the prime meridian, which indicated greater sleep loss in the eastern hemisphere.

Analysis was also completed for sleep efficiency. Sleep efficiency can be thought of as the amount of the time in bed spent asleep. The more time that is spent in bed asleep, as opposed to trying to get to sleep or awake, the higher the efficiency. This data showed a similar effect to total sleep time with the greatest reduction in efficiency being observed in the first four weeks after birth, slowly increasing after that. This effect, like total sleep time

had not returned to pre-birth levels after 16 weeks. Further analysis of cultural differences identified a considerable reduction in sleep efficiency across all cultures.

Analysis of data related to time spent awake after initial sleep onset were also completed. These data suggested, as may be expected, new parents spent significantly more time awake following the initial onset of sleep compared to during pregnancy as wakefulness after the initial onset of sleep rose by 47%.

The literature reviewed in this analysis shows that new parents sleep is disrupted following the birth of their child. This affects not only the total sleep time but, unsurprisingly, the time spent awake during the night and reduces sleep efficiency.

The impact of sleep deprivation on emotion recognition in new parents – Pilot study

New parents experience less efficient sleep and spend more time awake during the night compared to those in the third trimester of pregnancy. This pilot study identified that parents' ability to recognise emotions in infants did not show any meaningful difference between those in the third trimester and following the birth of a child.

Studies have shown that when we experience sleep deprivation it makes it harder to recognise emotions in others and ourselves. One population we know experiences sleep deprivation is new parents. However, limited research has looked at the effects of sleep deprivation on new parents' ability to recognise emotions.

This study recruited a total of 25 parents. Parents were either in the third trimester of pregnancy or in the first 100 days following birth. Sleep was measured using a sleep diary and Ōura rings. An Ōura ring is a small device that is placed on the finger. It uses heart rate and movement to record sleep patterns. Participants took part in a simple task over Zoom.

They were shown 48 pictures of babies and had to respond with what emotion they thought the baby was expressing.

The actigraphy data showed a similar effect to the sleep diary data however, there was some disagreement as to how big the difference between the antenatal and postnatal group was. The data from the Ōura ring and the sleep diary both agreed that the new parents spent more time awake during the night than the antenatal group and that new parents experience less efficient sleep. This means that less time spent in bed was spent sleeping. Data from the Ōura ring suggest that the difference between sleep in these two groups was much bigger than the difference in groups recorded using the sleep diary.

Results of the emotion recognition task showed that although there was evidence for some differences in each groups ability to recognise happy emotions, the evidence was not strong. For sad and neutral emotions, the data showed no meaningful difference between the groups. In addition to this, participants were asked to rate their confidence in their answers. There was no difference in the confidence of their responses between the postpartum and antenatal groups. When sleep and emotion recognition data were analysed together, the results show that there was a small link between how much time was spent awake during the night and overall ability to recognise emotions.

This study identified key difference in sleep between the antenatal group and the postpartum group. However, no significant differences were found in each groups ability to recognise emotions in infants.

Appendix 1

Author	Study location	N	Mean age (SD)	Gender	Ethnicity	Participant educational attainment
Bei Bei et al. (2012)	Australia	24	30.5 (SD=5.3)	Female	-	
Calcagni et al. (2012)	Australia	68	30.4 (SD=5.4)	Female	64% Australian 36% Other	High school education 40% Graduate or postgraduate 60%
Coo et al. (2014)	Australia	29	31.1 (SD=3.82)	Female	-	Undergraduate degree 55% Postgraduate degree 45%
Gay et al. (2004)	USA	144	33.4 (SD=5.9)	Female Male	Caucasian (68%) Asian (13%) Hispanic (12%) African American (3%) Mixed other (4%)	-
Matsumoto et al. (2003)	Japan	10	29.5 (SD=2.2)	Female	-	-
Krawczak et al. (2016)	Canada	33	31.2 (SD=3.9)	Female	-	-
Park et al. (2013)	USA	25	28.4 (SD=4.4)	Female	Caucasian (64%)	College graduate 68%
Sharkey et al. (2016a)	USA	21	29.5 (SD=4.7)	Female	-	-
Sharkey et al. (2016b)	USA	30	28.3 (SD=5.1)	Female	-	-
Sharkey et al. (2013)	USA	12	26.9 (SD=5)	Female	-	-
Signal et al. (2007)	New Zealand	19	34*	Female	-	-
Shao-Yu et al. (2014)	Taiwan	124	31.76 (SD=4.4)	Female	-	High school 6.5% College 68.5% Graduate school 25%
Volkovich et al. (2015)	Israel	153	28.9 (SD=2.9)	Female	-	-
Wulff (2000)	Germany	14	33.2 (SD=5.6)	Female Male	-	-

Note. *SD not reported

Appendix 2: Initial ethical approval email following requested amendments

Dear Dr Surtees

Re: "The impact of sleep deprivation on emotion recognition in new parents"
Application for amendment ERN_18-1935A

Thank you for the above application for amendment, which was reviewed by the Science, Technology, Engineering and Mathematics Ethical Review Committee.

On behalf of the Committee, I can confirm that this amendment now has full ethical approval.

I would like to remind you that any substantive changes to the nature of the study as now amended, and/or any adverse events occurring during the study should be promptly brought to the Committee's attention by the Principal Investigator and may necessitate further ethical review. A revised amendment application form is now available at https://intranet.birmingham.ac.uk/finance/accounting/Research-Support-Group/Research-Ethics/Ethical-Review-Forms.aspx . Please ensure this form is submitted for any further amendments.

Please also ensure that the relevant requirements within the University's Code of Practice for Research and the information and guidance provided on the University's ethics webpages (available at https://intranet.birmingham.ac.uk/finance/accounting/Research-Support-Group/Research-Ethics/Links-and-Resources.aspx) are adhered to and referred to in any future applications for ethical review. It is now a requirement on the revised application form (https://intranet.birmingham.ac.uk/finance/accounting/Research-Support-Group/Research-Ethics/Ethical-Review-Forms.aspx) to confirm that this guidance has been consulted and is understood, and that it has been taken into account when completing your application for ethical review.

Please be aware that whilst Health and Safety (H&S) issues may be considered during the ethical review process, you are still required to follow the University's guidance on H&S and to ensure that H&S risk assessments have been carried out as appropriate. For further information about this, please contact your School H&S representative or the University's H&S Unit at healthandsafety@contacts.bham.ac.uk.

If you require a hard copy of this correspondence, please let me know.

Kind regards

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Appendix 3: Parent sleep diary

Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Sleep 1						
Time to bed	Time to bed	Time to bed	Time to bed	Time to bed	Time to bed	Time to bed
Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake
Sleep 2						
Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake
Sleep 3						
Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake
Sleep 4						
Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake
Sleep 5						
Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake
Sleep 6						
Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake
Sleep 7						
Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake	Time to sleep Time awake
Time out of bed	Time out of bed	Time out of bed	Time out of bed	Time out of bed	Time out of bed	Time out of bed