Factors Affecting the Sleep of One-Year-Olds: A Pilot Study using Objective Monitoring of New Zealand Infants

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Abstract

Sleep takes time to mature and in infancy the structure and cycle of sleep differs greatly to that of adults. Data concerning normative sleep of infants is lacking due to few studies using objective measures. Factors affecting infants' sleep are both intrinsic and extrinsic in nature. The causes of problematic sleep are not well understood. This study aimed to pilot a methodology involving 1 week of actigraphy monitoring of 1-year-olds, as well as collecting normative data concerning sleep and sleep ecology through questionnaires and diaries. Potential factors contributing to sleep quantity, quality and maturation were investigated. Sleeping problems were reported in 35% of the sample of 52 Wellington infants. Current breastfeeding, time awake at night, and poor evening mood were all associated with problem sleep. Short sleep duration and more instances of being put to bed were also significant predictors of reporting problem sleep. Infants were typically rated in a poorer mood and exhibited more bedtime problems at the weekend. Longer sleep onset latencies and poorer sleep efficiency were identified by actigraphy on weekend evenings. The timing of sleep did not differ between genders or between week days and weekends, or childcare and non-childcare days. Mixed model analysis of variance indicated that the maturation and quality of sleep were significantly correlated with age and stages of cognitive and motor development. Sleep duration did not correlate with ponderal index, possibly due to the young age group as well as underrepresentation of short sleeping or overweight infants. Results support previous studies in western societies and autonomous sleeping is common. Potential mechanisms behind reltionships between sleep and feeding, temperament and development are discussed. Strengths and limitations of methods and procedures are assessed. Actigraphic recording of 1-year-olds is demonstrated to be a useful and reliable tool for studying sleep of infants and the results contribute to normative data. Future studies in NZ should consider recruiting a more representative sample and incorporate a longitudinal design to further assess the relationships highlighted here and in previous research.

(331 words)

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List of Terms and Abbreviations

Active interval	Used in actigraphy. The times spent out of bed in active wake, as defined by sleep diary data
ANOVA	Analysis of covariance
ASQ	Ages and Stages Questionnaire
AW64	Actiwatch™ MiniMitter 64, brand of actigraph
BISQ	Brief Infant Sleep Questionnaire
BMI	Body mass index (kg/m^2)
Brain Plasticity	The capacity to adapt and learn in response to internal and external needs
Circadian	Latin for '*about a day*'. Refers to the self sustaining rhythms that have a periodicity of approximately 24-hours
CPHR	Centre for Public Health Research
EEG	Electroencephalography
EMG	Electromyography
EOG	Electrooculography
Excluded interval	Used in actigraphy. The times when data is deemed invalid for analysis
ICSD	International Classification of Sleep Disorders
K-complex	EEG phenomena characteristic of stage two sleep
Log10	Log to the base 10
NREM	Non-rapid eye movement sleep
OSA	Obstructive sleep apnoea
Pākehā	Person of predominantly European descent; not Māori
Plunket	A NZ society set up to support parents of children from 0-5 years of age
Process C	The signal of alertness from the internal circadian clock
Process S	The homeostatic drive for sleep

PSG	Polysomnography, the gold standard measure of sleep using EEG, EMG and EOG channels
Ponderal index	Measurement of body status ($^3\sqrt{}$weight/length)100
REM	Rapid eye movement sleep
Rest interval	Used in actigraphy. The time spent in bed, as defined by sleep diary data
CSN	Suprachaismatic nuclei
SES	Socioeconomic status
SIDS	Sudden infant death syndrome
Sleep cycle	The cycle of NREM/REM sleep stages throughout the sleep period
Sleep interval	Used in actigraphy. The time spent asleep whilst in bed, defined by the Actiware ® software
Sleep spindle	EEG phenomena characteristic of stage two sleep
SQRT	Square root transformation
Sleep/wake cycle	The cycle of sleep and wake throughout the 24 hour day
SWRC	Sleep/Wake Research Centre, Massey University, Wellington
SWS	Slow wave sleep (stages three and four)
Threshold for wake	The number of activity counts per minute of actigraphy required to define wakefulness

1. Introduction

1.1 *Overview: Why is the Sleep of Infants Important?*

A newborn infant sleeps for about 70% of the day, whereas adults spend 25 to 30% of their time asleep. Sleep in infancy is considered developmentally necessary and therefore it is of key importance. Although there is a large body of research into adult human sleep, normative data concerning the sleep of infants is limited. Research in this field is important for the following reasons:

1. The sleep/wake cycle and architecture of sleep cycles are different in infancy compared to adults. The maturation of the sleep/wake cycle to the point of consolidated sleep at night is considered a significant developmental milestone. Therefore it is necessary to understand the stages of, and mechanisms behind, the maturation of sleep.
2. Methods for recording sleep vary in reliability and appropriateness depending on the sample being investigated. A large amount of past research into infant sleep has used subjective reports from parents. Definitions of normal or problem sleep vary between studies, due to different questionnaires being utilised or thresholds being applied. There is also variation within studies due to individual reporting biases. In New Zealand (NZ) to date, no research using objective monitoring of the sleep of infants' has been published.
3. Accurate data are needed to define normal and problem sleep during infancy. The availability of such data provides parents and health professionals with an understanding of whether sleep/wake behaviour is age-appropriate or requires further assessment.

4. Risk factors associated with restricted or problematic sleep have been identified across the lifespan. In the case of infants and older children, internal and external factors have been found to contribute to problem sleep. However there are inconsistencies with findings, especially during early infancy, due to variability between methodologies used, as well as the age and ethnicity of the sample.

These considerations are reviewed in detail below and were used to formulate the methodology and hypotheses for the research presented in this thesis. The research was designed as a pilot to trial objective monitoring in infants around the age of 1 year. Analyses assessed sleep maturation, as well as the factors affecting sleep and contributing to problem sleep.

1.2 *The Maturation of Sleep*

1.2.1 The Development of the Sleep/Wake Cycle: A Two Process Model

It is important to understand the maturation of the sleep/wake cycle as well as the cycle of sleep stages, when interpreting results concerning normal sleep during infancy. The sleep of newborns undergoes considerable maturation to eventually synchronise their fragmented sleep/wake cycle to that of the 24 hour social environment and that of day and night. The sleep/wake cycle is regulated by two processes; a wake drive from the circadian pacemaker in the hypothalamus, and a homeostatic process. These processes interact to create a consistent rhythm of sleep in the night and wake in the day for adults. However, during infancy these processes are still maturing, making the sleep/wake cycle sleep less consistent (Fagioli, Ficca, & Salzarulo, 2002).

Circadian rhythms can be found in many behaviours and physiological measures, for example temperature, hormone secretion, respiration as well as sleep and wake. They are influenced by both internal and external factors. Internally the circadian clock is located in the suprachaismatic nuclei (SCN) of the hypothamalmus (Gander, 2003; Van Gelder, 2004). The circadian clock is sensitive to time cues, such as light exposure, food and activity and is independent of prior amounts of sleep (Dijik & Czeisler, 1995, as cited in Jenni & LeBourgeois, 2006). The circadian clock cycle is often monitored by recording levels of the hormone melatonin or the rhythm of core body temperature (Gander, 2003). Throughout the 24 hour day the signal of alertness from the circadian clock or *wake drive* varies. This is known as *process C*. Changes in the wake drive make it easier to fall asleep late at night when the alerting signal is low, but not so easy to fall asleep during the morning or early evening when the alerting signal is high.

The homeostatic component of the sleep/wake cycle is such that sleep 'need' accumulates during wakefulness, and reduces during sleep (Borbely, 2009). This process is known as *process S*. Unlike process C, process S is influenced by prior sleep duration and quality. No definitive physiological or chemical markers of this process have been identified, however the amount and depth of slow wave sleep (SWS) is considered to be an indicator of the homeostatic drive for sleep (Borbély, 1982, as cited in Gander, 2003; Jenni & LeBourgeois, 2006). A marker of homeostatic pressure is the reduced time it takes to fall asleep if previous sleep is restricted (Taylor, Jenni, Acebo, & Carskadon, 2005). The homeostatic process S interacts with the circadian process C described above. Sleep is initiated when the need for sleep (process S) reaches the upper threshold for process C's alerting system. Likewise when the need for sleep declines to meet the lower threshold for process C, wakeup occurs (Borbely, 2009).

The development of the sleep/wake cycle is a process that is not complete until adulthood. Rhythmic cycling of motor activity has been recorded in foetuses as young as 20 to 28 weeks (Parmelee, Wenner, Akiyama, Schultz, & Stern, 1967). Within the first month after birth, a preference to sleep at night has been found (Gnidovec, Neubauer, & Zidar, 2002; Jenni, Deboer, & Achermann, 2006). However, sleep is typically split equally between night and day, and the length of the sleep periods is short, indicating a fragmented pattern (Sheldon, 2006). During the first month, infants sleep typically 16 to 18 hours of the 24 hour day, having three to four daytime naps and fragmented sleep at night (So, Adamson, & Horne, 2007). The duration of sleep and frequency of awakenings typically reduce over the first year. At around 6 months of age, infants are typically sleeping 13 to 14 hours and can stay asleep for up to 6 hours at a time (Sheldon, 2006).

During the first years of life the pressure of process S is speculated to build up faster, resulting in the need for daytime naps. It is also proposed that the pressure for sleep is dissipated more rapidly during sleep, resulting in shorter sleep periods which may be misaligned to the circadian rhythm (Fagioli, et al., 2002; Jenni & LeBourgeois, 2006). The adult and infant interactions between processes S and C are illustrated in Figures 1.1 and 1.2.

By 4 months of age, infants typically sleep much more during the night time, with just 30% of the daytime spent in sleep. Nocturnal sleep is also less fragmented by this time, with approximately 70% of 4-month-olds 'sleeping through the night' (Fagioli, et al., 2002; Jenni, et al., 2006; Jenni, Fuhrer, Iglowstein, Molinari, & Largo, 2005). Video observations reveal that only around one-third of infants are actually sleeping right through (Anders, 1979), therefore this development is more likely related to the maturation of self-regulating behaviours. It is not until the second half of the first year that definitive wake times in the morning and late afternoon are evident, as illustrated in Figure 1.3 (Iglowstein, Jenni, Molinari, & Largo, 2003; Jenni, et al., 2006; Ma, et al., 1993; Matsuoka, Segawa, & Higurashi, 1991; Pollak, 1994).

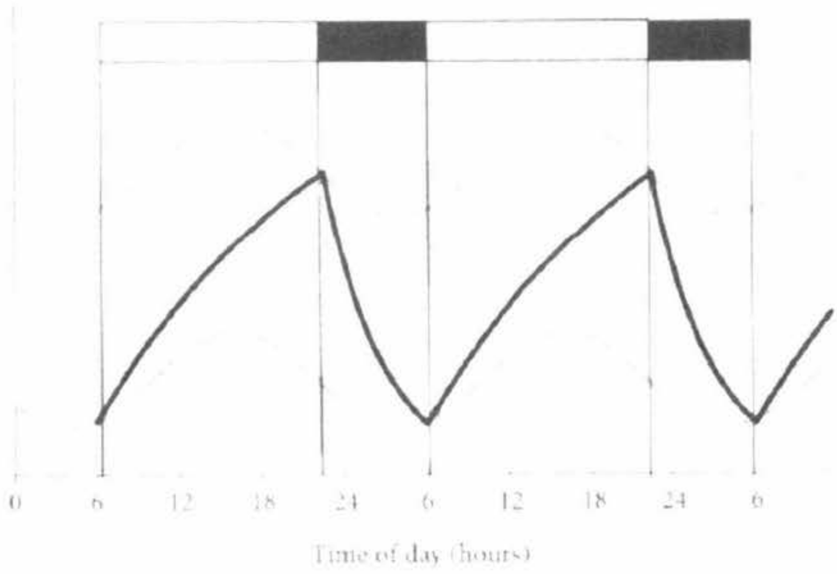


Figure 1.1. The circadian wake drive (process C) and the homeostatic sleep drive (process S) working together to produce the sleep/wake cycle of an adult(sleep indicated by the black bars, Fagioli, et al., 2002, p. 109).

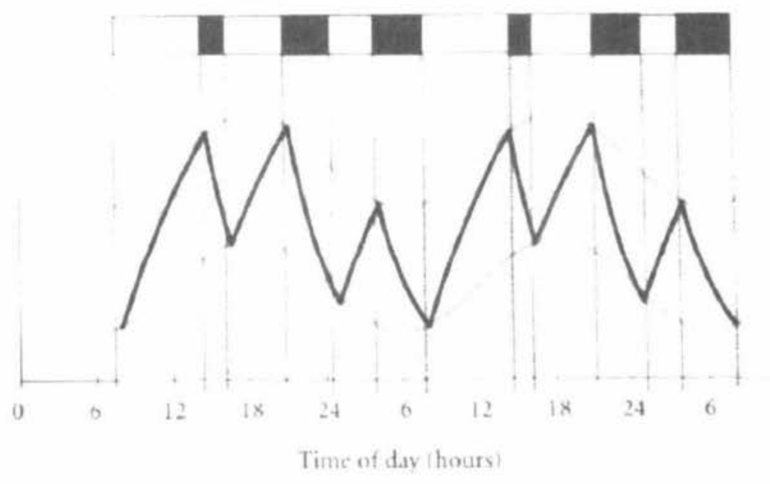


Figure 1.2. The two process model of the sleep/wake cycle in infancy (sleep is indicated by the black bars. The faster decrease of process S (sleep pressure) during sleep allows wake-ups to occur even when the alerting signal (process C) is low at night. Conversely, the more rapid build-up of sleep pressure allows sleep onset to occur even when the alerting signal is high during the day (Fagioli, et al., 2002, p. 109).

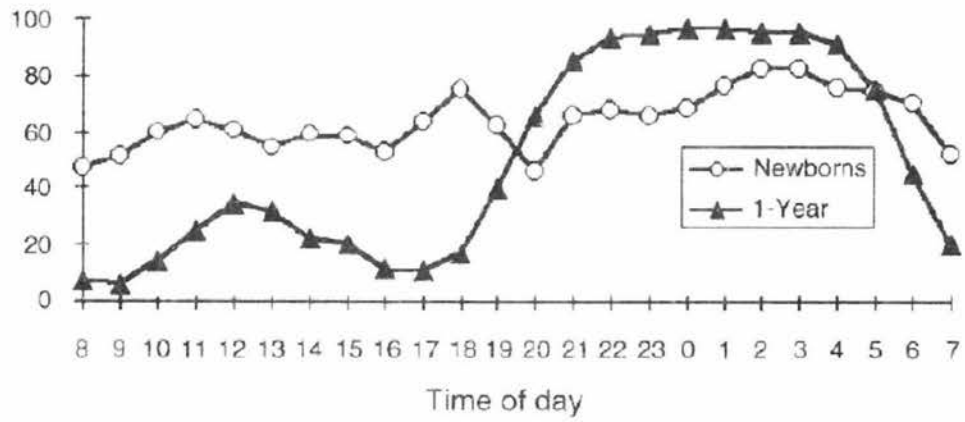


Figure 1.3. The percentage of infants sleeping throughout the 24-hour day: the development of the sleep/wake cycle from newborn to 1 year of age (Sadeh, 2001, p. 21).

Figure 1.3 shows the clear development of the sleep/wake cycle during the first year. By the age of 1 year, sleep is more consolidated to the night time with daytime napping occurring mostly around midday (Sadeh, 2001). The homeostatic need for sleep reduces, which is evident through a reduction in total sleep duration (to 12-14 hours per 24-hours). By the age of 2 years, process S matures as exhibited by a reduced number of daytime naps and increased time to fall asleep in the day (Jenni & LeBourgeois, 2006; Wooding, Boyd, & Geddis, 1990). Studies using objective monitoring of sleep reveal great variability in the time it takes to reach a mature sleep/wake cycle (Jenni, et al., 2006), with the milestone of consolidating all sleep into the night time and reduction of night awakenings occurring between 2 and 6 years of age (Fagioli, et al., 2002; Jenni & LeBourgeois, 2006).

1.2.2 Development of Sleep Stages and Architecture

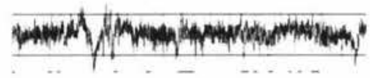
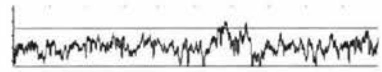
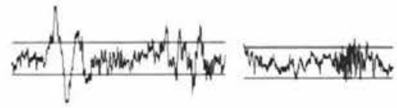
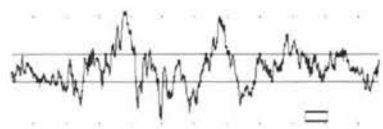
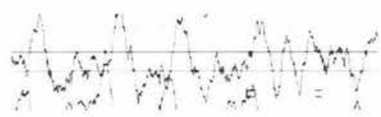
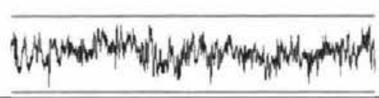
The stage and depth of sleep can be defined by measuring the electrical activities from the cortex, measured through the electrical potentials from the scalp (electroencephalogram, EEG). Eye movements (electrooculogram, EOG) and muscle tone (electromyogram, EMG) are also recorded through electrodes attached to the face (see section 1.3.1). Wave forms differ in infants and children compared to adults, and it takes time for the frequency and amplitude of waves recorded to resemble the five adult stages.

The five stages of adult sleep are consolidated into two subcategories: non-rapid eye movement sleep (NREM) and rapid eye movement sleep (REM) (Table 1.1). The stages of NREM sleep are on a continuum of depth and threshold for arousal (from the lightest, stage one, to the deepest, stage four). In adults, sleep is entered through NREM stage one, often accompanied by slow rolling eye movements. Stage two is a light stage of sleep characterised by phenomena known as sleep spindles and K-complexes identified by EEG. Slow wave sleep is made up of stages three and four. Characterised by slow frequency and high amplitude delta waves (of 2 or less hertz), these stages are the deepest stages of sleep, therefore being roused at this time is particularly difficult. During REM sleep the frequency and amplitude of the EEG is similar to that of wake, however this state of consciousness is differentiated by the loss of muscle tone in the body, an increase of eye movements, and the experience of dreaming.

The stages of sleep cycle across the sleeping period in a particular fashion, known as sleep architecture. In adults, the NREM and REM sleep stages cycle approximately every 90 to 120 minutes. As the night progresses there are increased proportions of REM and a decrease of SWS (Gander, 2003, Figure 1.4)

Table 1.1

Sample Electroencephalographic Tracings Obtained from Adults during Wakefulness, NREM Stages (1-4) and REM sleep.

Sleep stage		Description	EEG trace example
Wake		low voltage, fast activity	
NREM	1	Alpha waves (8-13 hertz) mixed with theta waves (3-7 hertz)	
	2	K complex wave forms and sleep spindles (12-14 hertz) appear	
	3	High amplitude delta waves (0.5-2 hertz) range make up 50% or less of the 30 second epoch	
	4	Delta waves make up over 50% of the 30 second epoch	
REM		Low voltage, fast activity, eye movements and low muscle activity differentiates from waking EEG	

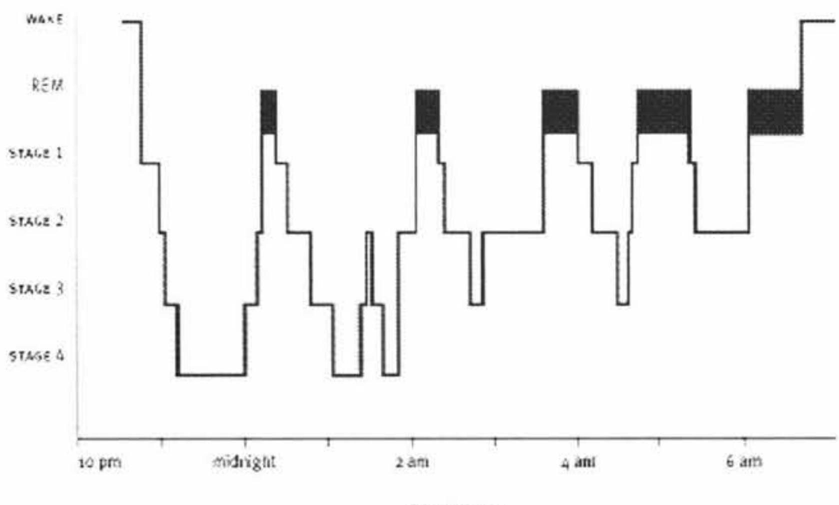


Figure 1.4. Diagram of the adult NREM/REM cycle across the night (Gander, 2003, p. 44).

In the case of newborns', sleep stages are defined as *quiet sleep* (early form of NREM) or *active sleep* (early form of REM) with *intermediate sleep* being the transitional stage between the two. These stages can be identified from preterm age (from 36 weeks) until 1 to 2 months postnatal age, at which point the stages of sleep become more organised (M. S. Scher, 2006). By 6 months of age the EEG can be scored using adult scoring criteria (G. Rosen, 2006).

Quiet sleep is characterised using EEG by its slow, irregular frequency waves with bursts of high amplitude delta waves (Figure 1.5). During this stage, the heart rate and breathing are regular and there are no eye movements and few muscle or body movements. Four to six weeks after birth, characteristics of adult NREM sleep (such as sleep spindles) become apparent within quiet sleep. These characteristics become more evident around the age of 6 months when K-complexes begin to occur. The high incidence of these EEG characteristics in infancy correspond with the maturation of the central nervous system at this time (Louis, Morita, & Sei, 1992, as cited in Sheldon, 2005b). Quiet sleep makes up 25 to 35% of an infant's total sleep time, a proportion that gradually increases to over 50% by 1 year of age (Goodlin-Jones, Burnham, Gaylor, & Anders, 2001; Mao, Burnham, Goodlin-Jones, Gaylor, & Anders, 2004). The proportion of NREM stays the same until adolescence when it starts it's slow decline throughout adulthood (Jenni & Carskadon, 2005).

Active sleep is identified by a more continuous, low voltage mixed frequency EEG pattern (Figure 1.6). There is also a density of eye movements during this stage representing REM sleep, however the state is termed active sleep because infants typically exhibit muscle twitches concurrently with eye movements (M. S. Scher, 2006). Rapid eye movements have been recorded in the foetus and premature infant (Kohyama, 1998; Parmelee, et al., 1967). At 30 weeks preterm, active sleep comprises 80% of total sleep, decreasing to 50 to 60% at term time and further decreasing to 30 to 40% by the end of the first year (Goodlin-Jones, Burnham, Gaylor, & Anders, 2001). The high proportion of active sleep has been related to development and learning (see section 1.6.3), and until 6 months of age infants enter sleep through REM rather than NREM sleep. A key time for sleep maturation is 9 months of age when REM begins to reduce and stage two becomes more pronounced, the characteristics of which have also been related to brain plasticity (see section 1.6.3). It is not until the age of 2 or 3 years that REM sleep matures to its adult proportion of 20 to 25% of the night (Louis, Cannard, Bastuki, Challamel, 1997, as cited in Kohyama, 1998).

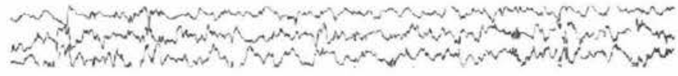


Figure 1.5. The slow, irregular frequency of quiet sleep in a newborn infant (M. S. Scher, 2006, p. 495).

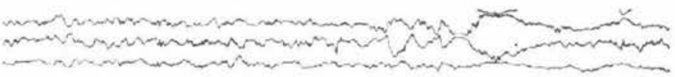


Figure 1.6. The mixed frequency of active sleep in a newborn infant (M. S. Scher, 2006, p. 495).

Premature infants tend to exhibit more quite sleep compared to term infants. They also have fewer arousals and movements within sleep (M. S. Scher, 2006). This has been related to the vast amount of neural maturation occurring at this time and the importance of sleep for such development (see section 1.6.3). Unlike the adult NREM/REM cycle of sleep, infants' and young children's sleep stages cycle more quickly (approximately 60 minutes, Gander, 2003; M. S. Scher, 2006; Sheldon, 2006). Figure 1.4 shows that while adults have four or five NREM/REM cycles per night, children up to the age of 5 years will have about seven cycles (Sheldon, 2006).

Between 3 and 6 years of age, adult patterns of sleep can be detected, however the EEG frequencies are slower and amplitudes are higher. Full maturation of electrophysiological sleep stages occurs between 6 and 12 years of age. At this pre-pubertal stage, there are a high proportion of stages three and four sleep. These stages of sleep have been associated with higher metabolic rate (Shapiro, Bortz, Mitchell, Bartel, & Jooste, 1981), the secretion of growth hormone (Sassin, et al., 1969), as well as alterations in synaptic connectivity among neurons (Jenni & Carskadon, 2005). At this age, total sleep at night reduces from 10 down to 8 hours. In adolescents this time reduces further to adapt to academic and social 'needs' of the age group.

1.3 *Measuring Infants Sleep*

Many tools have been designed in order to assess the quantity and quality of sleep. Objective measures have the advantage of measuring the physiological nature of sleep, however such measures typically have the disadvantage of being more costly or invasive. On the other hand, subjective measures give a non-invasive insight to quantity and quality of sleep but will often be biased by participants' perceptions. In the majority of situations, it is preferable to use both objective and subjective forms of measurement to gain a descriptive picture of sleep.

1.3.1 Objective Measures

Polysomnography.

Polysomnography (PSG) is the term used to describe a procedure using many channels of recording, most importantly the inclusion of EEG, EOG and EMG. Through attaching electrodes to the scalp, chin and surrounding the eyes it is possible to record electrical potentials and create a record of the sleep stages described above. Airflow, oxygen saturation and respiratory movements as well as body position, limb movements and snoring sensors are typically included to reliably score stages of sleep and identify sleep disorders (Griebel & Moyer, 2006; M. S. Scher, 2006). Polysomnography is considered the gold standard in measuring sleep as it records true sleep physiology in a controlled environment (Griebel & Moyer).

Running PSG requires the connection to a computer as well as technical observations. Therefore the participant's sleep is typically recorded in the research lab or hospital environment. The 'first night effect' is a common issue when recording sleep. This is a phenomenon related to the experience of being in a laboratory affecting sleep time and efficiency, therefore subsequent nights of recording may be necessary (Wiater & Niewerth, 2000). The analysis of PSG can be very time consuming and costly. Manual rescoring of data is essential to provide reliable outcomes. Although key definitions for staging sleep have been created (Rechtschaffen & Kales, 1968), there remain issues of discrepancy between individuals' scoring (Collop, 2006).

Using PSG to record the sleep of infants has several limitations. Firstly, it is important to study sleep at usual sleeping times and allow space for an accompanying parent which can disrupt the recording process (Griebel & Moyer, 2006; Wiater & Niewerth, 2000). Secondly, running PSG can be a stressful experience for both parent and child, adding to the costs and limitations of using this method. Thirdly, with the differences in EEG waveforms in infancy and the fast rate of maturation, using PSG to define stages of sleep and diagnose sleep disorders can be more difficult than in adults (Griebel & Moyer).

Polysomnography is an important technique when assessing for clinical sleep disorders and evaluating the development of the central nervous system. However, the costs and stressors that come alongside such recordings make this method undesirable and impractical for the measurement of infants' sleep. It is especially impractical when aiming to gather large samples of normative data and record additional factors and behaviours surrounding sleep.

Actigraphy.

Actigraphy refers to a methodology for recording and analysing movement. An actigraph attached to the wrist, leg or waist contains a piezoelectric sensor that records the acceleration of movements which are captured in short epochs of time and stored in the monitor's memory. Actigraphy is less costly than PSG and can be used in the participants' home for long periods of time, enabling data from large samples to be collected and night to night variability to be assessed. The output from the actigraph is quantified using a series of algorithms to identify periods of sleep and wake based on the premise that during sleep there is an absence of movement compared to when awake (Ancoli-Israel, et al., 2003; Littner, et al., 2003). In the case of infants, a higher threshold for defining wake (and thereby lower threshold for defining sleep) has been recommended due to the nature of infants movements (Hyde, et al., 2007; So, Buckley, Adamson, & Horne, 2005).

A clear disadvantage of actigraphy is that is does not measure actual sleep, it infers sleep from activity. Manual scoring of actigraphy studies is necessary and is augmented by a sleep diary (Littner, et al., 2003). Scoring of actigraphy is not as time consuming as for PSG, however validated sleep scoring rules and algorithms vary between devices and with the software used, making comparisons between studies somewhat unreliable (Ancoli-Israel, et al., 2003; Sadeh & Acebo, 2002). Although actigraphy has been used to identify the different sleep stages of both adults and infants, agreement rates with PSG are just 50 to 60%. Therefore actigraphy alone should not be relied on for documenting sleep architecture (Gnidovec, et al., 2002; Pollak, Tryon, Nagaraja, & Dzwonczyk, 2001; Sadeh, Acebo, Seifer, Aytur, & Carskadon, 1995; Sazonova, Sazonov, Tan, & Schuckers, 2006).

The small size of the actigraph makes this a less invasive and useful tool in populations where using PSG would be difficult. However due to its nature, participants with abnormally high or low activity levels may not be suitable for such recordings. Due to day to day variability in activity levels, 1 week of recording is recommended for reliable output (Sadeh, Hauri, Kripke, & Lavie, 1995; Trost, McIver, & Pate, 2005).

Studies of adolescents and adults generally show high agreement rates between actigraphy and PSG (79-96%) (Pollak, et al., 2001; Sadeh, Sharkey, & Carskadon, 1994; Signal, Gale, & Gander, 2005). However, actigraphy tends to define sleep onset earlier than PSG, therefore overestimating time spent asleep and the sleep efficiency. This discrepancy has been related to the different measures; actigraphy picking up on earlier stages of sleep onset and arousals through movement, while PSG defines sleep onset and arousals through physiological change (Pollak, et al., 2001; Sitnick, Goodlin-Jones, & Anders, 2008; Tryon, 2004). The number of awakenings and time spent awake are also not as reliably represented by actigraphy compared to PSG. Therefore when considering the entire 24 hour day, the agreement rate between actigraphy and PSG reduces (Pollak, et al., 2001). Reliability becomes more of an issue when more time is spent awake during time in bed (Paquet, Kawinska, & Carrier, 2007; Pollak, et al., 2001). In a study comparing actigraphy to PSG with adults, Jean-Louis et al. (2001) found high overall agreement rates between the two methods. Although actigraphy was most highly correlated to the duration of sleep ($r = 0.79 - 0.94$) rather than the efficiency of sleep ($r = 0.55 - 0.87$). Considering that interrater scoring agreements for PSG are less than 100%, agreement rates to actigraphy are reasonable (Tryon, 2004).

In the case of infants and children, agreement between PSG and actigraphy are variable (77-94%, Hyde, et al., 2007; Sadeh, Lavie, Scher, Tirosh, & Epstein, 1991; So, et al., 2005). This could be due to an increased amount of time spent awake during rest time or the effects of artifacts (e.g., parental handling) on the recording. The predictive values for being able to detect sleep are high (90%, sensitivity of 68 – 96%) compared to wake (17 - 88%, Gnidovec, et al., 2002; Hyde, et al., 2007; So, et al., 2005). Some studies have used smoothing algorithms to make actigraphy a more valid tool for identifying the number of awakenings. For example wake is only determined after 3 or 5 minutes rather than 1 minute (e.g., Acebo, et al., 2005; Goodlin-Jones, Tang, Liu, & Anders, 2008; Sadeh, 1994; Sitnick, et al., 2008). However, discrepancies remain between studies and therefore comparisons of the number and duration of awakenings are unreliable. Regardless of actigraphy's disadvantages it has been deemed a reliable and effective tool across age groups in the identification of sleep disturbed individuals as well as assessing treatments of clinical sleep disorders (Kushida, et al., 2001; Morgenthaler, et al., 2007; Sadeh, 1994; Sadeh, Hauri, et al., 1995; Sadeh, et al., 1991; Tryon, 2004).

Observations.

Early research into the sleep of infants used direct observations (Kleitman, 1963). A taxonomy of behavioural states has been developed and refined in order to correctly identify levels of alertness throughout the first year of life (Thoman, 1990). Used longitudinally, the taxonomy provides information concerning the developmental organisation of states of sleep and wakefulness, and has been related to social interactions as well as future health outcomes.

As with PSG and actigraphy, observations need to be coded and scored in order to identify sleep and wake as well as sleep stages. Reliability of state identification between scorers is high, with an agreement rate of over 90% (Thoman, 1990). However, accuracy may decrease with longer periods of recording and less rigid protocols. Compared to actigraphy, using observations to identify sleep or wake in infants is good (72 - 95%, Gnidovec, et al., 2002; Sadeh, Acebo, et al., 1995; Sitnick, et al., 2008). Indeed, studies of infants and pre-schoolers reveal that observations may be more reliable than objective measures for defining the number of awakenings and the stages of sleep (Anders, 1979; Gnidovec, et al., 2002; Sitnick, et al., 2008).

An advantage of using observations is that parental interactions with the infant can be recorded. Such interactions are useful to consider when assessing the variability of infants' sleep and risk factors associated with problem sleep (Goodlin-Jones, et al., 2001). However the costs and invasion of privacy involved with observations are great, making this an undesirable method for long term recording.

1.3.2 Subjective Measures of Sleep

How somebody perceives their sleep can be quite different from objective measures of sleep quality and duration. Subjective measures of sleep include questionnaires, diaries and interviews. These methods can be a time and cost effective way of collecting data and are less invasive than objective measures. Subjective measures provide useful data concerning the behaviours surrounding sleep as well as personal ratings of sleep duration and quality, which can be useful both clinically and scientifically.

Common problems with the use of subjective measures are over or under estimations by the participant, misunderstanding the question, and too much or too little information. In populations who cannot self report, these measures are also subject to the fact that ratings are being made by another person. From a diagnostic perspective, sleep diaries and questionnaires should not be used alone, as they may be biased by perceptions of problem sleep (Sadeh & Anders, 1993). However, they remain a valuable tool for obtaining information on factors affecting sleep. Validated questionnaires have been developed for both adults and children (e.g., Bruni, et al., 1996; Johns, 1991; Matthey, 2001; Morrell, 1999; A. Scher, et al., 1995).

Sleep diaries are highly correlated with actigraphy compared to questionnaires, probably due to their higher level of detail. However, they are still not as accurate in measuring sleep quality. For instance, the number and duration of night awakenings and sleep onset latencies (Goodlin-Jones, et al., 2008; Sadeh, 1994, 1996; Tikotzky & Sadeh, 2001; Werner, Molinari, Guyer, & Jenni, 2008). In addition, long periods of diary recording may influence accuracy as parents become exhausted with the chore of maintaining the record (Sadeh, 1994, 1996).

Questionnaires are not as reliable as actigraphy for measuring sleep start and end times, duration and time spent awake (A. Scher, 2001a; Werner, et al., 2008). Parents typically overestimate the duration of their child's sleep at night by around 1 hour (Nixon, et al., 2008; So, et al., 2007). The test-retest agreement rates are sometimes low in infant questionnaires, due to the frequent changes in infant and children's behaviour. Therefore questionnaires need to be more time specific to avoid ambiguous answers (Werner, et al., 2008).

Sadeh (2004) developed the Brief Infant Screening Questionnaire (BISQ) which has the advantage that it relates to the past week's sleep, creating less ambiguity around answers. Sadeh performed two studies to validate the use of the BISQ. One validated its use in large samples over the internet, and the other validated its ability (compared to sleep diaries and actigraphy) to discriminate between clinical and control groups of 5 to 29-month olds.

The BISQ was demonstrated to be robust, with significant test-retest results for sleep timing and duration (r = 0.82 – 0.95). Parental reports from the BISQ were significantly correlated with actigraphy for defining sleep onset time and the number of awakenings (r = 0.42 – 0.54). However, reported sleep duration was not as highly related to actigraphy sleep duration (r = 0.23). Compared to diaries, the BISQ correlated well for sleep onset time and amount of night waking (r = 0.61 – 0.83), and was also significantly related to nocturnal sleep latency and sleep duration (r = 0.27 – 0.36). Through assessing the clinical and control groups whilst controlling for age and gender, Sadeh (2004) derived guidelines for identifying problem sleepers (i.e. those who should be considered for clinical referral) using the BISQ. Using these guidelines, 80% of the sample were correctly identified as either clinical or control subjects. This classification rate was higher than using similar variables from actigraphy data. The BISQ has also been effectively used in a large internet sample in America and Canada (Sadeh, Mindell, Luedtke, & Wiegand, 2009).

In NZ the sleep of infants has not been measured objectively and studies of the maturation of infant sleep have been from parental report only (Wooding, et al., 1990). It was therefore of interest to use standardised questionnaires as well as objective monitoring to measure the sleep of NZ infants.

1.4 *What is 'Normal' Sleep in Infants?*

Definitions of 'normal sleep' in infants comes from many sources including research, guidebooks, professional opinions as well as principles created by society, culture, and learnt norms from personal and other's experiences. Table 1.2 summarises some of the key scientific literature concerning normal sleep of infancy.

Table 1.2

Normative Data Concerning the Sleep Quantity and Quality of Infants (Average and SD or range where available).

Author and date	Acebo (2005)	DeLeon & Karraker (2007)	Sadeh (1994)	Sadeh (1994)	Sadeh (2004)	Sadeh et al (1991)
Method	Actigraphy & parental report	Diary	Actigraphy & parental report	Actigraphy & parental report	BISQ	Actigraphy
N	169	41	50	50	438	63
Age	1 -5 years	9 months	9-24 months	9-24 months	7-12 months	11-27 months
Country	America	America	Israel	Israel	Israel	Israel
Specific data (if applicable)	1-year-olds data (n = 24)		Actigraphy data after intervention for sleep disturbance	Parental report after intervention for sleep disturbance		Control data (n = 34)
Day sleep duration (hrs)	-	2.7 (0.7)	-	-	2.6 (1.9)	-
Bedtime/ sleep onset	20:28	-	21:18 (0:54)	20:42 (0:36)	20:36 (1.3)	21:59 (1.1)
Sleep onset latency (mins)	-	-	-	-	-	-
Night sleep duration (hrs)	10.5	9.8 (0.9)	9.4 (0.9)	9.9 (0.9)	8.9 (1.8)	9.4 (1.2)
Sleep efficiency during night sleep	81.1%	-	86.0 % (4.5)	97.4 % (2.5)	-	90.9% (4.6)
Number of naps in day	-	-	-	-	-	-
Number of night awakenings	6.6	1.3 (1.0)	3.3 (1.2)	1.6 (1.2)	3.3 (1.9)	2.1 (1.2)
Time awake at night (mins)	-	58 (48)	-	-	74 (64)	-
Sleep duration per 24-hrs (hrs)	-	12.4 (1.1)	-	-	11.5 (1.9)	-

Table 1.2 cont.

Author and date	Sadeh et al. (2009)	A. Scher (2005a)	A.Scher (2005b)	So et al.,(2007)	Tikotzky & Sadeh (2001)	Wooding et al.(1990)
Method	BISQ	Actigraphy	Actigraphy & diary	Actigraphy & diary	Actigraphy & diary	Diary and questionnaire
N	5006	55	50	20	59	34
Age	0-3 years	8 months	10 months	1-12 months	4-6 years	12 months
Country	America & Canada	Israel	Israel	Australia	Israel	NZ
Specific data (if applicable)	12-17 month data (*n* = 720)			12 month data	Actigraphy data	
Day sleep duration (hrs)	2.5 (0.8)	-	-	2.5	-	3.0
Bedtime or sleep onset	-	20:59	21:02 (0.58)	-	21.44 (0.7)	19:00 – 21:00
Sleep onset latency (mins)	-	-	-	-	-	15.0
Night sleep duration (hrs)	10.3 (1.4)	9.6 (0.9)	9.6 (0.8)	5.8	8.6 (0.8)	11.0
Sleep efficiency during night sleep	-	94.2% (4.4)	95.0% (2.9)	-	91.1 % (5.1)	-
Number of naps in day	1.5 (0.55)	-	-	2	-	2-3
Number of wakes at night	0.9 (2.8)	1.9 (1.4)	1.5 (1.2)	<1	2.7 (1.4)	-
Time awake at night (mins)	22 (37)	-	-	-	-	-
Bedtime or sleep onset	-	20:59	21:02 (0.58)	-	21.44 (0.7)	19:00 – 21:00
Sleep duration 24- hrs (hrs)	12.8 (1.6)	-	-	-	-	13.0

Note. Unreported data indicated by -

In NZ, influential guidelines come from *Plunket*, a society offering support to parents of children from birth to 5 years of age. Truby King's (1937) publication 'Feeding and Care of Baby' acted as a core guide for parenting during this time and enforced the need for routine and punctual parenting. King made it very clear that sleep should "take place with clock-like regularity" (King, 1937, p. 234) he also emphasised that infants should have a bedroom of their own and not be excited before bed or fed during the night after 6 months of age.

More recent publications including Plunket's 'Thriving under five' (Plunket, 2008) and Tomson's 'New Zealand Baby and Toddler' (2000), offer key guidelines for infant care. For example recommendations to lower the risk of Sudden Infant Death Syndrome (SIDS) include putting infant to sleep on their back and avoiding co-sleeping. Independent sleeping and routine schedules are promoted in order to allow parents sufficient time to themselves and promote self-regulating behaviours in the infant.

Weaning the infant from night feeding is recommended from 6 months of age onwards to avoid training the child to signal when they wake (Tomson, 2000). For infants between 10 and 15 months, Tomson recommends a bedtime of 6 to 6.30 p.m. and waking for the day at around 6 a.m. Minimal attention to night awakenings should be practiced in order to promote self-soothing and overcome separation anxiety.

Normative data concerning NZ infants' sleep is lacking. The majority of research is focused on SIDS (e.g., Ford, Schulter, & Cowan, 2000; Mitchell, et al., 1992; Scragg, et al., 1996), specific practices such as sleeping position (e.g., Abel, Park, Tipene-Leach, Finau, & Lennan, 2001; Tuohy, Smale, & Clements, 1998), and clinical interventions for sleeping problems (e.g., Blampied & France, 1993; France & Hudson, 1993). It is clear that there is variability in sleeping practices within NZ, which has been related to personal preference and ethnic differences (see section 1.6.1). However, one study from the late 1980's used parental reports (through diaries and questionnaires) to determine sleep timing and habits of infants in order to determine what a 'normal' or 'good' sleeper was in NZ. Through analysing responses from 874 parents of infants aged 1 to 12 months, there was great variability for sleep duration and time awake between infants of the same age as well within individuals on a day by day basis (Wooding, et al., 1990). The 1-year-olds (n = 34) slept on average 11 hours per night (9-13 hours). Over a 24 hour period, the range of time spent asleep varied from 11 to 17 hours (M = 14 hours). Almost 80% of the 5 to 12-month-olds were having two or three sleeps per day, and the majority of sleep time was at night. This is consistent with the maturation of the sleep/wake cycle at this age.

In terms of routine, Wooding et al., (1990) found that from 6 to 12 months of age, infants were put to bed between 7 and 8 p.m. Seventy-four percent of the infants settled within 15 minutes, but 1-year-olds took slightly longer to settle compared to earlier ages. The place of sleep also changed throughout the first year of life, with 45% of infants sharing the parental bedroom during the first 3 months reducing to just 10% of infants remaining in the parental bedroom at 11 months of age. Over all ages, 72 to 81% of parents reported that their infant woke at least once per night. The number of awakenings generally decreased with age. This finding is most likely associated with a decrease in night feeding, a consolidation of the circadian and homeostatic processes, as well as the shift from the parental bedroom into a separate space, where the chances of disturbing their parents sleep are decreased.

1.5 *Sleep Problems in Infancy*

Sleep problems of varying nature and intensity are reported in over one-third of infants from 6 to 12 months of age (Armstrong, Quin, & Dadds, 1994), and in approximately 20 to 30% of children between 1 and 5 years of age (Goodlin-Jones, et al., 2008; Rona, Li, Gulliford, & Chinn, 1998; Sadeh, et al., 2009; A. Scher & Asher, 2004). Sleep problems are one of the leading concerns that lead parents to consult with a paediatrician (J. A. Mindell, Moline, Zendell, Brown, & Fry, 1994). The International Classification of Sleep Disorders (ICSD) coding manual (1990) categorises sleep problems by three groups:

Dyssomnias are disorders related to the amount, maintenance and timing of sleep and include insomnia, narcolepsy, sleep disordered breathing and disturbances of sleep timing associated with the circadian rhythm. These disorders, although not completely absent from infancy, are rare and difficult to detect until childhood or adolescence (Moore, Allison, & Rosen, 2006; G. Rosen, 2006). This is due to fragmented sleep being a common occurrence during the first year (Herman, 2006; Kotagal, 2005). Snoring is common in infants and children (10-27%) but is not necessarily problematic (McColley, 2005), the prevalence of obstructive sleep apnoea (OSA) being 2% among children 2 to 6 years of age (Halbower & Marcus, 2003). In infancy, SIDS is a very real problem and associated risk factors alter the way parents put their infant to sleep. Although SIDS has been considered a disorder of breathing or arousal during sleep (Halbower & Marcus, 2003; Kahn, et al., 2006), the mechanisms involved are not further discussed in the present thesis.

Parasomnias are sleep disorders related to arousal, partial arousal, or sleep/wake transitions. These disorders include sleepwalking, talking and nightmares. Although commonly reported in childhood and adolescence, these disorders are difficult to identify in infancy (Moore, et al., 2006; S. D. Rosen, King, & Nixon, 1990; Sheldon, 2005a). This is again, due to the common occurrence of fragmented sleep as well as the inability of infants being able to report such experiences.

Secondary sleep disturbances are sleep problems related to underlying factors, for example psychiatric or medical conditions. For example, in adults sleep is often disturbed for those suffering from post-traumatic stress disorder, (Pillar, Harder, & Malhotra, 2006), or pain (Gögenur & Rosenberg, 2006). In the case of infants, it is less easy to describe a sleep problem as being directly related to another factor. However, research has shown associations between sleep disturbances and conditions such as asthma (Camhi, Morgan, Pernisco, & Quan, 2000; Diette, et al., 2000), food allergies (Kahn, Mozin, Rebuffat, Sottiaux, & Muller, 1989), colic (Weissbluth & Weissbluth, 1992), and skin disorders (Dahl, Bernhiselbroadbent, Scanlonholdford, Sampson, & Lupo, 1995).

In the case of infants, sleep problems are defined in terms of sleep disturbances which include sleep onset difficulties, sleep maintenance difficulties or mixed onset and maintenance difficulties (Sadeh, 2001; Sadeh & Anders, 1993). Prevalence rates vary between research studies due to the differing definitions of problem sleep. For example, some look at the time taken to settle, others the number of awakenings or time spent awake (e.g., Adair, Bauchner, Philipp, Levenson, & Zuckerman, 1991), the sleep efficiency (e.g., Tikotzky & Sadeh, 2001), or the degrees of attention elicited at night (e.g., Rona, et al., 1998). Although definitions have become more precise with studies using clinical versus control groups (e.g., Richman, 1981; Sadeh, 2004), infants meeting the criteria for a sleeping problem by the researchers' standards do not necessarily have a problem by the parents' standards (Blampied &

France, 1993). Therefore it is important to consider both sides, as parents may not be aware of a sleep disturbance, but may still experience the side effects (e.g., stress, and poor temperament and behaviour of the infant). Likewise, if a parent has concerns, then the infants sleep requires investigating regardless of scientific or clinical definitions.

1.5.1 Problems of Sleep Onset and Maintenance

Problems with going to bed, initiating sleep and re-settling are common in infancy and childhood. Such problems are often secondary to biological or psychological factors (Moorcroft, 2006, see Section 1.6). These problems are prevalent in 15 to 20% of infants between the ages of 6 months and 3 years and are usually transient in nature (ICSD, 1990; Jenni, Fuhrer, et al., 2005; Zuckerman, Stevenson, & Bailey, 1987). During the first year, problems with settling are common around the time of developing gross motor skills such as crawling and walking (A. Scher, 2005a). The ICSD criteria for having severe sleep onset association disorders include having prolonged sleep latency and waking three or more times per night at least five times per week. Chronic problems are defined once symptoms have persisted for 3 months or more in regards to bedtime refusal, and 6 months or more for night awakenings (ICSD, 1990).

Scher (2001a) describes the majority of infants as 'night wakers'. Electroencephalography recordings show that 3-month-olds typically wake nine times per 24-hours, decreasing to four or five times at the age of 1 year (Fagioli, et al., 2002). Waking with the need of parents' attention is common in approximately 24 to 34% of children between the ages of 1 and 2 years, who wake between one and three times per night (Richman, 1981; A. Scher, et al., 1995).

Estimating a true norm for night waking is difficult, due to discrepancies in defining an awakening. For example, EEG looks for a change in frequencies and amplitude of wave forms, actigraphy defines an awakening by movement, and observations use behavioural signs. Parental reports of awakenings will vary dependent on the infant's signalling behaviours. Therefore parents typically report less awakenings than are recorded objectively (Anders, 1979; Sadeh, 2004; Sadeh, Acebo, et al., 1995).

In terms of having a sleep problem, it is not necessarily the fact that the infant is waking (as this is typical of this age group). The problem lies with the infant being more likely to signal to the parent and not being able to self-soothe themselves back to sleep. Therefore older infants are not necessarily 'sleeping through the night' or waking less often, but have simply learnt to self-soothe (Goodlin-Jones, et al., 2001). Kleitman (1963) distinguished between waking by necessity (e.g., the physiological needs of maintaining airway patency, adjusting position, or nutrition), and waking by choice or habit often related to emotional issues. Video observations reveal that at 1 year of age, 50% of infants require a parental intervention to get back to sleep (Goodlin-Jones, et al., 2001). Infants who are unable to self-soothe have been found to have approximately 1 hour less continuous sleep per night, as well as a lower proportion of quiet sleep compared to self-soothers (Goodlin-Jones, et al., 2001; Jenni, Fuhrer, et al., 2005; Sadeh, 2004). These are aspects of sleep which have been related to developmental stage in infancy (Anders, Keener, & Kraemer, 1985, see section 1.6.3).

1.5.2 Healthcare Gaps in Identifying Sleep Problems in Infancy

An American survey in 2001 revealed that only 46% of paediatricians were confident in screening for sleep problems, despite acknowledging their importance to health and daytime performance. Just 34% felt confident in evaluating sleep disorders in infants and 25% were confident in treating them (Owens, 2001). Knowledge of infant sleep disorders was poor, especially concerning breathing related sleep disorders and excessive daytime sleepiness. Forty-one percent of the practitioners estimated that 25 to 50% of their patients from newborn to 2 years of age had a sleep problem. However, approximately 15% of the sample did not routinely screen for such problems (Jenni & O'Connor, 2005). These findings highlight that the lack of normative data makes identifying sleep problems with confidence a difficult job. There is need for further research and dissemination of results to health care practitioners.

1.6 *Predictors and Impact of Sleep Problems in Infancy and Childhood*

Factors associated with sleeping problems during infancy are bidirectional and dynamic between the infant and their surroundings. Sadeh and Anders (1993) proposed a transactional model of the factors affecting infants' sleep. The factors are mediated by the context of the parent-child relationship, and are distal or proximal in nature, as well as intrinsic or extrinsic, as outlined in the following quote:

> It can be speculated that sleep/wake regulation is mediated by parent-infant relationships and interactions but influenced mostly by the infant intrinsic context (temperament and biomedical factors) in interaction with the proximal extrinsic parental context. The more

> distal environmental, family, and cultural contexts have their influence on the parent context and affect the infant's sleep only secondarily. However, once present, the effects of a sleep problem are circular, affecting the relationship-interaction context, parental well-being, the harmony of the family and even, perhaps the temperament of the infant (Sadeh & Anders, 1993, p. 19).

The transactional model of infant sleep is outlined in Figure 1.7. Each factor mentioned in the model shall be described in more detail below.

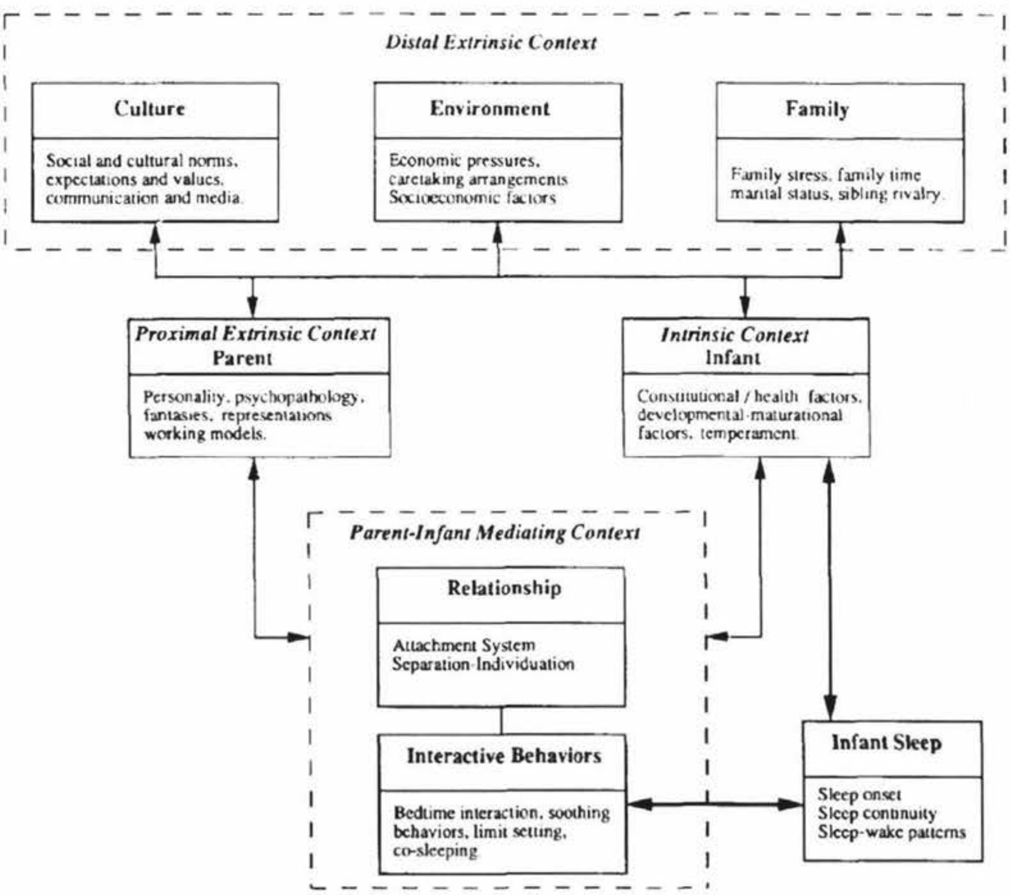


Figure 1.7. Infant sleep from a transactional perspective: Intrinsic and extrinsic factors affecting infant sleep (Sadeh & Anders, 1993, p. 20).

1.6.2 The Distal Extrinsic Context: Culture, Environment and Family

Social and cultural norms.

It is important when examining the factors that affect sleep, to assess the interplay between the biology and the culture of sleeping. How we sleep and what was considered normal has changed considerably over the last century. For example, in the 19^{th} century infants and children would typically co-sleep, however moving into the 20^{th} century, infants were more often left to go to sleep alone. This transition has been associated with the stand-alone crib replacing the cradle, as well as parents isolating the infant from noisy, brighter environments (Stearns, Rowland, & Giarnella, 1996). Another historical trend is that adults are getting less sleep (National Sleep Foundation, 2009). Children are being subjected to more stimulating night time activities (Borlase, 2001), and their bedtime is also becoming later by up to 2 hours (Iglowstein, Jenni, Molinari, & Largo, 2003; Kohyama, Shiiki, Ohinata - Sugimoto, & Hasegawa, 2002). Like their parents, children of all ages appear to be getting less sleep than previously recorded or recommended (Carskadon, 2007).

As with historical changes, beliefs and expectations from family, society and culture affect how and when an infant sleeps (Jenni & O'Connor, 2005). The most notable differences between cultures include parenting styles as well as sleeping routines and environment. Western society has adopted a monophasic pattern of sleep; one 7 to 8 hour sleep is the norm and is strived for in children's development. However, Mediterranean, Chinese and South American cultures typically have two sleeps per day, and the Japanese may have several naps. Although these traditions are under threat from industrialisation, such routines are not considered abnormal in adults or children in these cultures (Steger & Brunt, 2003).

Adult attitudes towards children play a role in sleeping arrangements between cultures. In Italy, children are much more involved with the adult night time events, often going to sleep in the parental bed much later and having a shorter sleep than children in America, where night time is for adults only (New & Richman, 1996; Ottaviano, Giannotti, Cortesi, Bruni, & Ottaviano, 1996). Chinese school children also have a shorter sleep duration than their American counterparts, which has been linked to crowded housing and health rather than social participation (Liu, Liu, & Wang, 2003).

Wolf, Lozaff, Latz, & Paludetto (1996) compared the child rearing practices and sleep management of 363 families with infants aged 6 months to 2 years across America, Japan and Italy. The Caucasian American group were identified as those with the most defined bedtime routine (Wolf, et al., 1996). For this group, individualism is sought and parents are encouraged to sleep apart from their infant. Such behaviours are also encouraged for NZ parents (Tomson, 2000). However this westernised norm of separating from the infant at night is an exception rather than an international rule (Jenni & O'Connor, 2005). Sleeping alone increases the used of transitional objects for infants to settle to sleep in westernised societies (Gaddini, 1970). Italians appear to have no set bed times or particular routine for their children and traditionally the mother co-sleeps with her child, enabling easier feeding and soothing in the night. This finding is independent of how many bedrooms are available. In Asia, co-sleeping is more commonly practised due to a greater stress on developing interpersonal relationships (Wolf, et al., 1996), and it is a practice that remains prevalent into school age (Liu, et al., 2003).

Differing practices and parental attitudes also have an effect on how parents perceive sleeping problems (Jenni & O'Connor, 2005; Zuckerman, et al., 1987). For example bedtime resistance will only be identified if the child is 'put to bed'. Infants who are not subjected to strict routines may have fewer reported problems compared to cultures where a routine is enforced. Reports of night awakenings, and how parents attend to such awakenings, also differ between cultures due to variation of beliefs and co-sleeping. For example in the west, leaving an infant to cry is considered an important part of developing autonomy and the ability to self-soothe, whereas in African cultures crying is considered to be a behaviour which should never be ignored. In fact the child is seldom left alone, so upon awakening they are immediately attended to (Stork, 1993, as cited in Giganti & Toselli, 2002).

Historical and cultural differences in NZ.

The majority (68%) of the NZ population are of European descent and many of the practices surrounding child rearing originate from westernised ideals. However it is important to consider the practices of the Māori and Pacific Island population in NZ who make up 15 and 8% of the population respectively (Statistics New Zealand, 2006). Most of the research into ethnic differences within NZ focuses on the sleeping environment and position of sleep (e.g., Abel, et al., 2001; Tuohy, et al., 1998), with a stress on the risks for SIDS (e.g., Mitchell, Scragg, Stewart, & al, 1991; Scragg, et al., 1996). Studies seeking to understand sleep during the first years of life, have included predominantly infants of European (Pākehā) descent (Wooding, et al., 1990).

The family structure and parenting styles of the indigenous Māori people varies from Pākehā. Traditionally living in a tribal format, the Māori family (whānau) consisted of approximately 30 members of extended family who would eat, sleep and live together, forming a large support network (Higgins & Morrfield, 2004; Ritchie & Ritchie, 1978). The western and Pākehā views of the child needing to become independent differs from the traditional Māori view, which maintains that the child requires greater interdependence with the parents and whānau and is therefore more likely to co-sleep and be attended to in the night.

In an early 20th century publication, Cowan described the communal habits of the Māori as "still strong; and in eating, working, and sleeping the Māori likes plenty of company"(1910, p. 145). However, it appears that through colonisation and industrialisation, these traditional social and family structures are becoming more difficult to maintain (Te Hoe Nuku Roa Research Team, 1999). The Māori child does not appear to be surrounded by their family in the traditional sense. The term whānau often now refers to the family in the nuclear sense or neighbours and friends rather than generations of the kin group (M. Reilly, 2004).

Pacific Islanders also have a more holistic approach to parenting, with an emphasis of communal care and attention. Therefore it is common practice for infants of Pacific Island ethnicity to stay up late into the night (especially at social or religious events) and to co-sleep with their mother (Gledhill, 1974; Holmes, 1980). These practices are much like their Italian counterparts (Wolf, et al., 1996).

Over two-thirds of infants between 1 month and 1 year of age share the parental bedroom. Infants of Māori and Pacific Island descent are almost twice as likely to be sharing the parents' bedroom during this time compared to Pākehā infants. Bedroom sharing is a behaviour which has been related to reducing the risk of SIDS (Scragg, et al., 1996) as evidenced by lower rates in Pacific Islanders (Schluter, Carter, & Percival, 2006). During the second half of the first year, when

SIDS is no longer as high a risk, 10 to 15% of NZ infants are sharing the parental bedroom (Wooding, et al., 1990).

Approximately 17% of NZ infants between 3 and 6 months of age routinely co-sleep with their parents (Tuohy, et al., 1998). Pacific Islanders have the highest incidence of co-sleeping (30-40%) followed by Māori (20%) and then Pākehā infants (5-6%). However, the exact place of sleep varies, with Pacific Island infants more likely to be placed in a raised position which is thought to reduce some of the risks related to SIDS (Mitchell, et al., 1992). Interviews of focus groups revealed that high incidences of co-sleeping in Pacific Islanders was due to cultural traditions and beliefs (including a belief that poor health or death may be caused by not providing the protection offered through bed sharing). Pacific Islanders also reported on the practicalities of co-sleeping, in being able to attend to the infant's physical needs, as well as the psychological and spiritual benefits for both infant and mother (Abel, et al., 2001). In contrast, Pākehā parents deemed it standard practice to sleep separately in order to increase independence and reduce the risks of SIDS. Māori parents adopted more varied approaches, with more westernised rather than traditional ideologies and practices. Differences of Māori family practices were dependent on geography and degrees of separation from the iwi (tribe).

The family context.

Parents' work commitments require them to have control over when they go to sleep and get up, often requiring children to follow a similar schedule. In western society where both parents are often working, family time can be reduced. Insufficient family time and poor routines may play a part in children resisting going to bed, as well as increasing the likelihood of sleep onset association disorders (e.g., the need for a blanket or teddy to go to sleep) and inability to self-soothe after a night awakening (Sadeh & Anders, 1993).

Family stress and marital status also play a role, with co-sleeping more common with single parents or those suffering marital difficulties (Lozoff, Wolf, & Davis, 1984). In NZ there is a general rise in divorce and single parent families, resulting in variability in the structure and support networks that the child experiences. Single parenting appears to be ethnically related, with Māori (38%) and Pacific Island (32%) families having approximately 10% more single mothers than Pākehā (22 %, A. B. Smith, 1998). Less than half of all children over 5 years of age have full time mothering, due to an increase of mothers returning to work. Therefore local support mechanisms are heavily used especially by Pākehā families who appear to have greater accessibility to social and health support systems (Abel, et al., 2001).

Environmental context.

Socioecomnonic status (SES) and educational level of parents, the number of bedrooms, bedroom sharing, and irregularities of schedules have all been related to sleep disruption. New experiences in the daytime can lead to overstimulation and cause subsequent sleeping problems for infants. During the first year of life, such environmental factors may include moving from a shared bedroom to sleeping alone and the anxieties related to this movement, or 'life-events' such as adapting to no longer breastfeeding.

Socioeconomic status and parents' education and marital status have not been consistently related to infants' sleeping problems (Acebo, et al., 2005; Armstrong, O'Donnell, McCallum, & Dadds, 1998; Rona, et al., 1998; A. Scher, et al., 1995; Zuckerman, et al., 1987), but have been associated with infants' place of sleep and sleeping positions. Single parents or those with lower levels of education and SES are generally more likely to co-sleep or place the infant to sleep in the prone (tummy) position (Lozoff, Askew, & Wolf, 1996). These findings have been replicated in NZ. Regardless of The NZ Cot Death Association and Plunket advice, there is still variance in sleeping positions (Mitchell, et al., 1991). Differences have been associated with ethnicity, SES, and educational differences (Tuohy, Counsell, & Geddis, 1993). Nevertheless, Tuohy et al., identified a significant change, in that *most* parents were reportedly not putting their infant to sleep prone, whereas prior to nationwide education, almost half of infants were being placed to bed in this position (Hassall & Vandenberg, 1985).

Stressful daily events are reported to occur at least once every 4 days for 67% of infants during their first year. The occurrence of such events has not been related to soothing styles adopted by parents, and they are considered normal in this age group (Anders, et al., 1985). The effects of such events on the duration and quality of sleep have yet to be investigated.

A large survey of infants' sleep across Japan found that sleep timing differed between three geographical areas. Later bedtimes were considered to be related to the timings of sunrise and sunset, as well as lifestyle differences associated with living in cities compared to the countryside (Ma, et al., 1993). Thus, living in rural versus urban areas can have an affect on the parents and thus infant's sleep timing.

Older children exhibit clear differences in sleep timing and duration between weekday and weekend sleep. School aged children typically having later bedtimes and shorter sleep at the weekends (Goodlin-Jones, et al., 2008; Nixon, et al., 2008; Werner, et al., 2008), and adolescents having shorter sleep on school days (Borlase, 2001; Dorofaeff & Denny, 2006). Whether there are significant differences as early as the age of 1 year remains to be determined. If differences exist, they are likely to be related to parental routines.

Childcare has also been shown to have an effect on the sleep of pre-schoolers, with children's wake up time in the morning being directly related to the start of kindergarten and half of the sample being woken by a family member (Werner, et al., 2008). The affects of childcare on the sleep timing of infants is not currently known.

1.6.3 Proximal Extrinsic Context: Parental Factors

The personality, parenting style and psychopathology of parents can have significant effects on the relationship with the infant and therefore play a role in their sleep. Mothers of infants with sleep problems are more likely to suffer from depression and/or psychological distress compared to those of 'good sleepers' (Armstrong, et al., 1998; Fauroux, Aubertin, & Clément, 2008; Goodlin-Jones, et al., 2008; Hall, Zubrick, Silburn, Parsons, & Kurinczuk, 2007; Zuckerman, et al., 1987). Retrospective reports have also found that sleepiness during pregnancy and postnatal depression is related to the sleeping problems of infants during the first 2 years (Armstrong, et al., 1998; Lam, Hiscock, & Wake, 2003). A less supportive relationship with their partner is common among depressed women (Richman, 1981), which can lead to conflicted parenting styles and current as well as future problem sleep for infants (Hall, et al., 2007).

Parental well-being does not appear to be related to infants' ability to develop self-soothing behaviours (Goodlin-Jones, et al., 2001). However shorter sleeps and more parental interventions are reported by depressed mothers. This is reflected by more night time awakenings of the infant (A. Scher, 2001b; Zuckerman, et al., 1987). It may well be that depressed parents perceive their infant's behaviour differently, or are more likely to also be awake at night, and therefore report more sleep problems than non-depressed mothers (Richman, 1981). Depression has not been considered to be a consequence of the infant's sleeping problem, nor does it appear to be a consistent predictor of persistent sleeping problems among infants (Zuckerman, et al., 1987).

1.6.4 Intrinsic Context: Individual Differences between Infants and Across Time

No consistent gender differences have been found for the sleep of infants (Adair, et al., 1991; Anders, 1979; Jenni, Molinari, & Remo, 2005; A. Scher, et al., 1995; Thünstrom, 1999; Touchette, et al., 2005). Although it does appear that girls develop the ability to self-soothe faster than boys (Goodlin-Jones, et al., 2001). This may lead to an increased number of parental interventions at night for boys.

First-born infants have been found to wake less in the night (Rona, et al., 1998; Wooding, et al., 1990), and have a later bedtime than subsequent children (A. Scher, et al., 1995). However, the development of a mature sleep cycle (Jenni, Borbely, & Achermann, 2004), or reports of sleep problems are not related to birth order (A. Scher, et al., 1995; Wooding, et al., 1990).

Premature infants have been found to have shorter sleep durations, more awakenings and less quiet sleep compared to term born infants. This is due to the ongoing development of the neurosensory and motor systems during this time (Gossel-Symank, Grimmer, Korte, & Siegmund, 2004; Graven & Browne, 2008; Sadeh, Dark, & Vohr, 1996; Skellern, Rogers, & O'Callaghan, 2001). By 2 to 4 years of age, premature birth is no longer a significant predictor of sleep differences (Touchette, et al., 2005; Wolke, Meyer, Ohrt, & Riegel, 1995).

As noted in section 1.2, the sleep/wake cycle and cycle of sleep stages change rapidly in the first years of life, so what may be considered 'problematic' at one point in time may quickly resolve. However, problem sleep in infancy has been found to significantly predict persistent problems into childhood (Hall, et al., 2007). Therefore sleep deserves careful consideration at all ages.

Breastfeeding does not appear to affect the development of the sleep/wake cycle (Jenni, et al., 2006). However, later into the first year, breastfeeding increases the likelihood of frequent and longer awakenings (DeLeon & Karraker, 2007; Sadeh, et al., 2009; A. Scher, et al., 1995; Touchette, et al., 2005; Zuckerman, et al., 1987), and higher incidences of reported sleep problems. Infants breastfeeding at 8 months of age are more likely to wake at night (32%), compared to other infants (15-16%, Zuckerman, et al., 1987), and the time for the infant to fall back to sleep after waking is significantly longer for those breastfeeding later into the first year (A. Scher, et al., 1995). Moreover, breastfeeding at the age of 1 year has been found to be a predictor of sleep problems at 3 years of age (Hall, et al., 2007). By the second half of the first year, the waking problem is related to the feeding patterns and parenting style rather than signs of malnutrition (Anders, 1994, as cited in Giganti & Toselli, 2002). Indeed, too frequent feeding in the first weeks of life (over 11 incidences a day) is likely to contribute to fragmented sleep at 3 months of age due to the infant becoming accustomed to feeding as a method of soothing (Nikolopoulou & James-Roberts, 2003). Problems with feeding (Thünstrom, 1999), as well as teething, have also been correlated with problem sleeping during the first 2 years. However these problems are not significant predictors of persistent sleep problems at 3 years of age (J. A. Mindell, Kuhn, Lewin, Meltzer, & Sadeh, 2006; Zuckerman, et al., 1987).

Behaviour and temperament.

Infant temperament has been related to sleep/wake regulation and the parental perception of sleep problems. In NZ, Truby King (1937) highlighted this link: "Children who do not have sufficient rest and sleep are difficult to manage and often described as naughty and quarrelsome" (p.144). Tantrums, poor mood and difficult-to-manage behaviours (based on behavioural screening questionnaires) have been related to more reports of sleep problems (Lam, et al., 2003; Zuckerman, et al., 1987), and longer durations of daytime sleep (Spruyt, et al., 2008). Excessive crying in infancy is thought to be related to poor development of the sleep/wake cycle, specifically a misalignment of the homeostatic drive to go to sleep at a circadian phase of high alertness (Jenni & LeBourgeois, 2006).

Poor temperament is more likely to elicit parental presence at bedtime and at times of night waking. Scher (2001a) found that 'fussiness' was related to mothers' report of awakenings and night time re-settling. These findings could be due to parents being overly attentive to their 'difficult' infant (Seymour, Brock, During, & Poole, 1984), which in turn leads to overstimulation and problems settling back to sleep (France & Hudson, 1993).

At pre-school age, children with sleep problems are more likely to have behavioural and emotional problems (as reported by questionnaire). After controlling for maternal depression, sleep problems in pre-schoolers were significantly correlated with more aggressive behaviours (Hall, et al., 2007). In the case of school children, hyperactivity during the day has been associated with fragmented sleep and sleep-walking. Furthermore, behaviour management and emotional problems have been related to bedtime resistance (Bos, et al., 2009). Further objective monitoring is required in these age groups to corroborate these relationships.

Development.

Sleep has been found to be important for brain plasticity. Brain plasticity is a term referring to "the capacity to change, adapt, and learn in response to environmental experiences and new needs" (Graven & Browne, 2008, p. 174). Deprivation of the sleep of adults has been associated with significant learning and performance deficits (e.g., C Smith & MacNeill, 1994), related to the relationship between sleep and cerebral cortical functioning (Harrison, Horne, & Rothwell, 2000). Therefore in the case of sleep disordered patients (e.g., those with OSA), cognitive functioning and mood is often negatively affected (Incalzi, et al., 2004; Ulfberg, Carter, Talback, & Edling, 1996). The relationship between learning and sleep is key for infants and children because of the fast stages of development and potentially fragmented sleep at this time. Better quality sleep and higher percentages of total sleep occurring at night have been associated with increased development, daytime performance and emotional regulation of infants and children (Goodlin-Jones, et al., 2008; A. Scher, 2005b; Spruyt, et al., 2008).

At birth (full-term), the quantity of REM sleep occurring within the sleep cycle is double that of adults (Jenni & Carskadon, 2005). This stage of sleep has been associated with the development of sensory systems in the foetus and infant and the consolidation of learning and memory in adults (Penn & Shatz, 1999 as cited it Graven & Browne, 2008; Plihal, 1996; Stickgold, 2005). For example, Paul and Dittrichova (1974, as cited in C. Smith, 2001) found that infants who had learnt a head turning response had a significant increase of REM sleep compared to infants who failed to learn the response. Adult learning of cognitive procedural tasks as well as emotionally charged declarative memories have been found to be particularly related to higher proportions of REM sleep (Wagner, Gais, & Born ,2001, & Kuriyama, Stickgold, & Walker, 2004, as cited in C Smith, 1995; Stickgold, 2005). Corroborating these findings are studies using neuroimaging of the brain. Such studies have found that particular brain activities present during task training, reoccur during the REM sleep of trained participants compared to controls (Maquet, Laureys, Peigneux, Fuchs, Petiau, Phillips et al., 2000, as cited in Walker, 2008).

By the age of 1 year, sleep cycles become more maturely distributed and the proportion of NREM sleep is higher. Non-REM sleep is also thought to play a role in brain plasticity, and has been specifically linked to the learning of language, motor, and visual tasks (Graven & Browne, 2008; Walker, 2008; Walker, Brakefield, Morgan, Hobson, & Stickgold, 2002). For example, Smith and MacNeill (1994) found that the performance of college students on a motor task was significantly poorer in those selectively deprived of stage two sleep compared to controls. Furthermore an increased density of sleep spindles during stage two sleep has been associated with the learning of particular tasks (Clemens, Fabo, & Halasz, 2006). The relationship between NREM sleep and learning processes is also supported through neuroimaging studies, revealing that hippocampal activity observed during learning is reactivated during SWS. Furthermore, higher degrees of hippocampal activity during sleep appears to be associated with higher extents of improvement on a virtual maze task the following day (Peigneux et al., 2004, as cited in Walker, 2008). These findings indicate that the process of learning directly modifies the physiology of sleep.

Studies using actigraphy and developmental scales reveal that at 10 months of age, sleep efficiency is positively correlated with cognitive development (A. Scher, 2005b). However, a negative relationship has been reported between the development of motor skills and sleep. Comparing the sleep of crawling and pre-crawling infants (using actigraphy and questionnaires), crawling was associated with longer sleep duration, more night awakenings and a higher incidence of parentally reported sleep problems (A. Scher, 2005a; A. Scher & Cohen, 2005). These findings could be related to an increase of energy expenditure in the day (J.Horne, 1998, as cited in A. Scher, 2005a), and higher levels of emotion creating greater need of active soothing (Campos, Kermoian, & Zumbahlen, 1992; Paret, 1983, as cited in A. Scher & Cohen, 2005). Motor development in infancy is also thought to be related to increased amounts of REM sleep, which has been related to the consolidation of learning but also more movement during infants' sleep (Kavanau, 1997, as cited in A. Scher, 2005a).

Sleeping position has also been related to motor development, with infants sleeping in the supine (back) position being more likely to have delays in gross motor development compared to infants sleeping in the prone position (Majnemer & Barr, 2006). This is a key point, as there is an increase in the number of infants being put to sleep in the supine position to the risk of SIDS.

Children with neuro-developmental disabilities have a much higher prevalence of circadian rhythm disturbances and poor sleep onset and maintenance, as well as more parentally-reported sleep problems (Goodlin-Jones, et al., 2008). Specific neuro-developmental disorders and the mechanisms associated with disrupted sleep are not discussed further in the present thesis, Stores and Wiggs (2001) provide a detailed review.

1.6.5 Mediating Context: Parent-Infant Interactions and Relationships

Bowlby's theory of attachment states that infants are predisposed to form a bond with their caregiver, and parents are naturally inclined to provide security and comfort which reinforce this bond (1969, as cited in A. Scher, 2001a) . By the age of 1 year, when the child begins to create a sense of self, the anxiety of being separated from the caregiver develops. Therefore, the naturally occurring separation at bedtime can become a stressful situation. Infants who are more dependent are reported as significantly more difficult to settle to sleep initially, and after a night awakening (DeLeon & Karraker, 2007; A. Scher, 2001a; A. Scher & Asher, 2004). Actigraphy studies reveal that more dependent infants do not wake more often than non-dependent infants, but the nature of parents attending to the infant and their perceptions of problem sleep differ and are related to settling problems (A. Scher, 2001a).

The routines and interactions surrounding sleep are key in developing good quality sleep and self-regulating sleep habits. A parent being present when the child goes to sleep has been found to be independently associated with night awakenings, possibly due to the learned association between parental presence and falling asleep (Adair, et al., 1991; DeLeon & Karraker, 2007; Touchette, et al., 2005). Between 8 and 12 months of age, around one-third of parents report being present when their infant goes to sleep (Adair, et al., 1991). As mentioned above, variations between methods of sleeping and soothing may have different implications between cultural contexts. Through analysing questionnaires and sleep diaries from 294 mothers with infants aged 1 to 1.5 years (average 13.8 months), Morrell and Cortina-Borja (2002) found that the most frequent settling techniques with 1-year-olds in the UK were active or physical comforting (such as feeding or rocking to sleep), or behaviours encouraging autonomy (such as leaving to cry or putting music on).

Active and physical methods of comforting between 6 months and 2 years are associated with higher frequencies of current and persistent sleeping problems. In particular, longer settling times as well as more frequent and longer night awakenings (Morrell & Cortina-Borja, 2002; Morrell & Steele, 2003; Sadeh, 2004; Sadeh, et al., 2009; Thünstrom, 1999). These findings have been replicated using actigraphic recordings. Infants capable of self-soothing have a higher sleep efficiency and fewer night awakenings than infants requiring parental intervention (A. Scher & Asher, 2004). Despite the associations with active and physical comforting, large internet surveys from Israel and America found that just 22% of infants (birth to 3 years of age) were being left to self-soothe (Sadeh, 2004; 2009).

Infants who are unable to self-soothe are more likely to be put to bed already asleep, which may cause stress for the infant related to waking up alone and being unable go back to sleep without parental intervention. Infants who cannot self-soothe are therefore more likely to be considered problem sleepers and co-sleep with their parents (DeLeon & Karraker, 2007; Lam, et al., 2003; A. Scher & Asher, 2004; Thünstrom, 1999). This relationship is bidirectional, as co-sleeping has been related to increased separation anxiety and temperament problems which, in turn, relate back to sleeping problems (Jenni, Fuhrer, et al., 2005; Lozoff, et al., 1996). Moreover, frequent co-sleeping has been associated with poorer sleep quality, due to a reduction of the amount of quiet sleep and the number of awakenings at night (as recorded by video observations, Mao, Burnham, Goodlin-Jones, Gaylor, & Anders, 2004).

1.6.6 Conclusions from the Transactional System Model

The factors described by the transactional system model (Sadeh & Anders, 1993) and further outlined above make it clear that sleep problems in infancy often need to be evaluated in terms of infant factors, parental factors and mediating factors associated with relationships and interactions. Sadeh and Anders consider sleep/wake regulation as a mode of transaction, and the factors affecting sleep problems are dynamic and often bidirectional in nature.

Studies consistently find that the strongest predictor of persistent sleep problems throughout childhood is the presence of a problem at an earlier age (Hall, et al., 2007; Morrell & Steele, 2003; Stein, Mendelsohn, Obermeyer, Amromin, & Benca, 2001; Touchette, et al., 2005; Zuckerman, et al., 1987). Over 60% of infants who have a problem at age 1 year are still likely to have a sleeping problem when they are 2 years old (Morrell & Steele, 2003), and over one-third of children who have sleep problems at 8 months still have problems at 3 years of age (Zuckerman, et al., 1987). Morrell and Steel (2003) used sleep diaries and questionnaires to identify the most important factors predicting the persistence of sleep problems in infants. After previous sleep problems, the next most significant factor was parents using active or physical comforting to settle their infant to sleep. These comforting techniques were, in turn associated with poor temperament and parenting strategies. Separation anxiety was also an independent predictor of persistent problems, while maternal depression was related to a current sleep problem but was not a significant predictor of continued problems. Such finding have been replicated by Lam et al. (2003).

1.7 *Sleep as a Risk Factor for Weight Gain*

1.7.1 Rise in the Prevalence of Obesity

Obesity is increasing worldwide, a phenomenon that has been termed an epidemic by the World Health Organisation (2009). Polls run by the National Sleep Foundation reveal that between 2005 and 2009 there has been a 5% rise in obesity in adults in America, with almost a third of adults defined as obese (National Sleep Foundation, 2009). In NZ, 25% of a cohort at age 21 years were overweight and 5% obese (Williams, 2001). At age 32, 50% of this cohort were defined as overweight, 18% were obese (Landhuis, Poulton, Welch, & Hancox, 2008). A significant predictor of being overweight as an adult is being overweight as a child (Williams, 2001). However, using this factor alone is insufficient to reliably identify risk.

1.7.2 Weight and Sleep Duration in Children

Studies consistently show that approximately 10% of pre-schoolers and 25% of school aged children are defined as overweight across America and Europe (Agras, Hammer, McNicholas, & Kraemer, 2004; Ogden, et al., 2006; J. J. Reilly, 2005; Taveras, Rifas-Shiman, Oken, Gunderson, & Gillman, 2008); a prevalence that has risen considerably since the 1990's (when the prevalence of being overweight in America was 14%, Wang, 2001, as cited in Lee, 2007). New Zealand children are also exhibiting increased body mass, with 14 to 20% of school aged children being overweight (Tyrrell, et al., 2001; Williams, 2001). Pacific Island and Māori children have a significantly higher prevalence of obesity compared to their Pākehā peers (Gordon, et al., 2003; Tyrrell, et al., 2001).

Obesity in children is becoming an increased cause for concern due to the associated risk factors for health (e.g., diabetes, hypertension, and OSA, Lee, 2007). There are clear links between continued obesity into adulthood (Charney & Lauer, 1993, as cited in Lee, 2007; Williams, 2001), as well as an association between overweight parents and their children's risk of also becoming overweight (Agras, et al., 2004; Locard, et al., 1992; Sekine, et al., 2002). In a large longitudinal cohort in England, J.J Reilly (2005) identified eight early life (4 months to 3 years of age) risk factors for being overweight at the age of 7 years. Through using multivariate analysis of 25 potential risk factors, the significant predictors (in order of highest odds ratio) were:

1. Body mass at 4 years of age.
2. Parental obesity.
3. Weight at 8 months.
4. Weight at 18 months.
5. Hours spent watching television at age 3 years.
6. Sleeping less than 10.5 hours at night at age 2.5 years.
7. Weight gain over the first year.
8. Birth weight.

The odds ratio comparing less than 10.5 hours of sleep per 24-hours with 12.5 hours or more was 1.45 (95% CI: 1.10, 1.89). Other longitudinal studies support this relationship. For example, Agras et al. (2004) found that 3 to 5-year-olds sleeping an average 30 minutes less per 24-hours had a greater risk of being overweight at 9 years of age.

When controlling for a variety of confounding variables (e.g., activity levels, parental BMI, smoking), parentally reported sleep problems in pre-school children have also been independently linked to obesity in adulthood. Those experiencing sleeping problems had an average of almost one unit increase in BMI at the age of 21 years compared to those not experiencing sleep problems (odds ratio = 1.06, 95% CI: 0.32, 1.79, Al Mamun, et al., 2007). In NZ, short sleep duration (reported by parents) at 11 years of age has been independently related to adult (32 years) BMI. When controlling for confounding variables, childhood sleep duration remains significantly correlated with adult BMI, $r = -.11$ (Landhuis, et al., 2008), a predictive value comparable to that of diet and physical activity (Berkey et al., 2000, as cited in Landhuis, et al., 2008).

The study of Taveras et al. (2008) is the only longitudinal research linking sleep duration of infants to future weight. In this American study, sleeping less than 12 hours per 24-hours at the ages of 1 and 2 years independently increased the risk of being overweight at 3 years of age. The sleep duration in this study was measured through parental report. Future research using objective measures of infants sleep is required to confirm this relationship.

Studies have also identified short sleep duration as a risk factor for *current* weight in children (e.g., Locard, et al., 1992; Sekine, et al., 2002), with an average odds ratio of 1.89 (1.46 – 2.43) between studies (Cappuccio, et al., 2008). The association between sleep duration and weight is greater in children than in adults (average odds ratio = 1.55 respectively, Cappuccio, et al.), probably due to the larger amount of confounding variables and risk factors in adults (Cizza, Skarulis, & Mignot, 2005).

In NZ, short sleep (less than 11 hours per 24-hours) was significantly correlated with BMI at ages 7, 9 and 11 years (but not at 5 years). However the percentage of body fat has not been significantly related to sleep duration (Duncan, Schofield, Duncan, & Rush, 2008). These findings may be related to the nature of the measures. Many studies looking at this relationship use the BMI or weight rather than body fat. These findings demonstrate that the specific measures used and the potential mechanisms linking sleep duration and obesity need to be carefully considered.

1.7.3 Mechanisms Behind the Sleep/Weight Relationship

Potential explanations as to how short sleep could lead to weight increase are outlined in Figure 1.8. Sleep restriction has been associated with hormonal changes, specifically reduced amounts of leptin, (an appetite suppressor), and increased ghrelin (which increases appetite, Chaput, Despres, Bouchard, & Tremblay, 2007; Spiegel, Tasali, Penev, & Van Cauter, 2004; Taheri, Lin, Austin, Young, & Mignot, 2004). In a cross-sectional study, people reporting 5 hours or less of habitual sleep had higher amounts of ghrelin (15% more) and reduced leptin (15% less, Taheri, et al., 2004). Therefore appetite regulation becomes disrupted and calorie intake increases. However, studies of children have not found any independent association between sleep duration and caloric intake and eating habits (Agras, et al., 2004; J. J. Reilly, 2005).

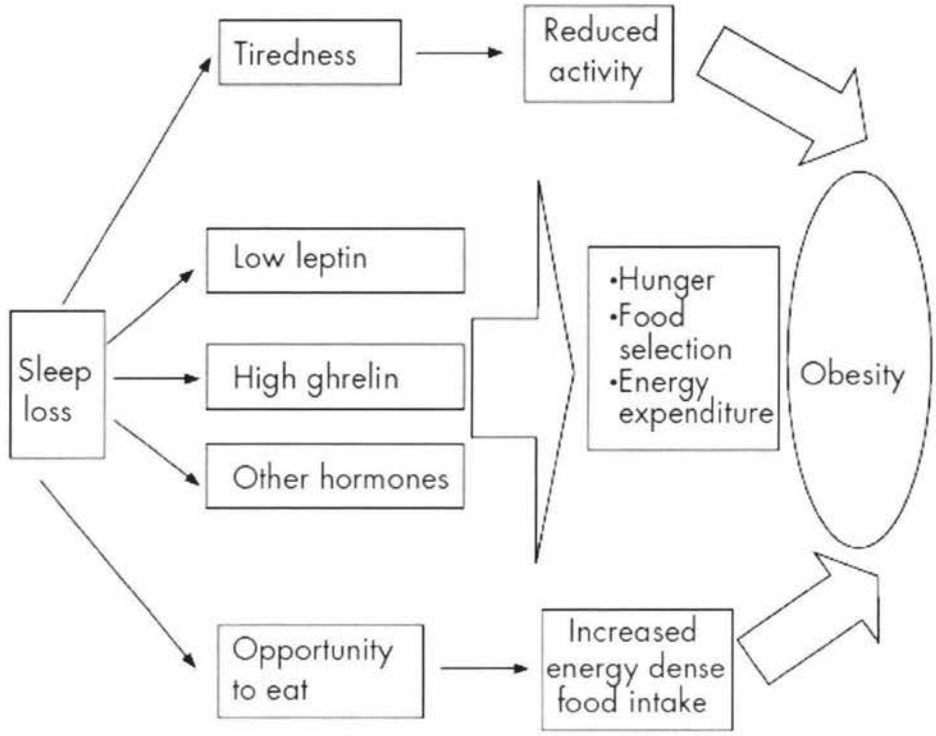


Figure 1.8. The potential mechanisms through which short sleep could cause obesity (Taheri, 2006, p. 883).

More time awake may be related to a reduction of activity and an increase of eating opportunities. Agras et al. (2004) found that daytime sleep reduction was specifically associated with weight increase. These children also had low activity levels and reduced caloric expenditure, therefore Agras et al. concluded, reduced sleepiness. During infancy, more time awake may be related to an increased number of feeds throughout the day, possibly in the attempt to soothe problem infants back to sleep.

Alternatively, daytime sleepiness may reduce physical activity. One American study found the 40% of 12 to 16-year-old's were waking up tired (Knutson, 2005). A similar percentage of NZ adults never/rarely reported waking refreshed (Gander, 2003; Harris, 2003). Feeling unrefreshed could lead to low levels of energy and increased caloric intake (Dinges, et al., 1997). However, the association between sleep duration and weight remains significant after controlling for physical activity (Bénéfice, Garnier, & Ndiaye, 2004; Gupta, Mueller, Chan, & Meininger, 2002; Sekine, et al., 2002).

Bearing in mind the strong association between parental BMI and child's weight (Locard, et al., 1992; J. J. Reilly, et al., 2005; Williams, 2001), there may well be shared family characteristics that expose the child to factors promoting obesity. For example, SES or behaviours such as high food intake late in the evening, physical and genetic predisposition, as well as poor sleep routine. Such behaviours need to be carefully studied and controlled for in order to identify the accurate predictors and mechanisms for weight gain.

The majority of studies looking at the sleep and weight of children use subjective reports of sleep as well as retrospective information and self-reported heights and weights (Patel & Hu, 2008). In many cases this is due to the large size of the samples making the use of actigraphy and time-linked physical measurements impractical. Past studies using objective monitoring of sleep in relation to weight of children and adolescents have had limited periods of recording (e.g., 1-4 days, Bénéfice, et al., 2004; Gupta, et al., 2002; Nixon, et al., 2008). However, these studies confirm that objectively monitored sleep duration is independently related to weight in childhood (ages 7 and 13). Such data are yet to be collected in infants.

A key limitation of studies investigating sleep duration and obesity is that definitions of 'overweight' and 'short sleep' vary between studies and ages (Patel & Hu, 2008). For infants, there is disagreement about definitions of 'overweight' or 'obesity'. Past studies tend to use the 85th or 95th percentile of BMI, but the relevance of these percentiles is questionable, as weight changes so substantially throughout childhood. Through a meta-analysis of international data, Cole, Bellizzi, Flegal and Dietz (2006) defined international thresholds for defining overweight and obesity in children from 2 to 18 years, however, in infants the BMI is not typically used. The ponderal index[1] (the cube root of weight divided by length, multiplied by 100) has been shown to be appropriate for tracking body size from birth into late adolescence (Pietilainen, et al., 2001)[2]. This calculation identifies infants whose soft tissue mass is not normal for their stage of skeletal development. The sum of ponderal index reduces with age and increases with higher tissue mass. Unlike the BMI, the ponderal index does not differ by ethnicity or gender. It is a useful measure for identifying growth retardation, as it gives a proportional measure of mass independent of length whereas using length or weight alone is not as accurate (Fayyaz, 2005; Lehingue, Remontet, Munoz, & Mamelle, 1998).

1.7.4 Conclusions Concerning Sleep and Weight

A large amount of evidence supports a link between reduced sleep and increased risk of weight gain and obesity. The relationship is better established in children than adults, but for infants, little data is currently available. Studies using objective monitoring of the sleep of children are few. Such methods are recommended in order to investigate at what age the relationship between sleep duration and weight becomes evident.

[1] Also known as the Rohrer's Index

[2] Also multiplied by 1000 in some instances

1.8 *Aims of this Thesis*

Due to gaps in knowledge of infants' sleep and the predictors of sleep problems, standardised measures need to be developed and normative data collected to offer guidelines for identifying and managing sleep problems.

Study aims.

1. To gather normative data of the sleep of 1-year-olds in NZ.
2. To identify factors that affect infants' sleep at this age.
3. To pilot methodology for a future cohort study.

Objectives.

1. To collect 1 week of actigraphic sleep data from a pilot group of 50 1-year-old infants.
2. To gather diary data to corroborate actigraphy measurements and identify factors which affect sleep.
3. To gather questionnaire data from parents in order to characterise the sample and identify additional factors which affect sleep.
4. To collect feedback from parents concerning the study design and their experience as a participating family.

Hypotheses.

Based on the literature review the following hypotheses were proposed:

1. Infants identified by the parents as problem sleepers will have shorter sleep duration, poorer quality sleep, and less total sleep time at night compared to non-problem sleepers.

2. Infants of a higher ponderal index ($^3\sqrt{}$weight/length)100 will have a shorter sleep duration, and a lower proportion of total sleep being spent at night.

3. Shorter sleep duration and poorer sleep quality will be negatively associated with daily mood and temperament ratings.

4. Reports of problem sleep will be negatively associated to breastfeeding.

5. Stage of development will be positively related to sleep duration, quality of sleep and the proportion of total sleep that occurs at night.

6. Sleep on the weekdays will be shorter than sleep on weekend days (Friday and Saturday nights) due to earlier get up times on weekdays.

7. Sleep on days with childcare will be shorter than on days without childcare due to earlier rise times on childcare days.

2. Methods

2.1 *Measures*

The tools and materials used in this study were selected because they had either been validated previously for research with infants or were deemed appropriate and practical to use with this group. Questionnaires were used to gather demographic details as well as data concerning the infant's environment, sleep and development. Infants' sleep was objectively monitored for 7 days using actigraphy, supplemented by a sleep diary kept by the parents. The diary served to validate times that the infant was put down to sleep as well as periods when the actigraph was removed. The diary also served to identify daily factors that may have an influence on sleep. Each of these measures is described in detail below.

2.1.1 Questionnaire

The questionnaire used in this research (Appendix A1) was adapted from the BISQ (designed and validated by Sadeh, 2004), as well as from the *Environmental Exposures and Asthma Risk in Infants Questionnaire* used by the Centre for Public Health Research (CPHR), Massey University.

The BISQ was designed as a standardised clinical screening tool for identifying infant sleep problems, as well as a valid questionnaire for paediatric sleep research. It correlates highly with actigraphic monitoring and sleep diaries (Sadeh, 2004). Additional questions concerning body habitus, feeding and the home environment of the infant were included from the CPHR questionnaire. These variables were added in light of the literature review.

Demographic items.

Demographic information included the names of the parent completing the questionnaire and the infant, address and contact details, as well as the gender and date of birth of the participating infant.

Body habitus.

Parents were asked to report on the weeks of gestation at birth of their infant, as well as their length, weight and head circumference at birth. Parents were reminded that this information should be recorded in the *Plunket Well-Child* book. Parents' height and weight were measured and recorded by the researcher as was the infant's current length, weight and head circumference. The final part of this section asked whether or not the participating infant was the parents' first child and whether or not it was a single birth.

Feeding details.

This section of the questionnaire asked whether the infant was currently being breastfed or had been in the past and if so, when they started and stopped breastfeeding. Whether or not they were waking for feeding was recorded and if so, how often they were waking. Finally, parents reported (yes or no) whether their infant was currently teething.

Infant's sleep.

This section of the questionnaire was used to understand the environmental factors surrounding each infant's sleep and also to document parental perceptions of their infant's sleep. Parents were asked to select one option describing:

1. Where their infant slept in the last week (five options).
2. Which position they were sleeping in most of the time (front, back or side?).
3. How their infant normally fell asleep (five options, e.g., whilst feeding, or alone in bed).

Parents were required to comment on the average timings of their infant's sleep (in the last week), questions included:

1. Sleep duration at night (7 p.m. – 7 a.m.).
2. Sleep duration in day (7 a.m. – 7 p.m.).
3. Number of awakenings at night (10 p.m. – 6 a.m.).
4. Time spent awake in the night (10 p.m. – 6 a.m.).
5. Length of time to settle infant to sleep (in the evening).
6. The time at which infant had been falling asleep for the night.

Parents were also asked to record on how many nights (in the past week) their infant had snored or had noisy breathing (this question was not applicable to infants who were unwell at the time of study). Finally, parents were asked to rate the extent to which their infant's sleep was a problem, the options being:

1. A very serious problem.
2. A small problem.

3. Not a problem at all.

The home and infant's bedroom.

This section of the questionnaire asked for information on the number of people living in the home, how many children or adults shared the room in which the infant slept and the kind of bed in which the infant slept. Parents were also asked to recall how many people typically come and go during the infant's usual sleep time and how often this occurs. Health conditions of household members which may affect the infant's sleep were noted as were the number of hours spent in childcare per week.

2.1.2 The Ages and Stages Questionnaire (ASQ)

The Ages and Stages Questionnaire (ASQ) is a standardised set of questionnaires designed to assess the developmental stage of children from 4 to 48 months of age and has been found to be a reliable predictor of future developmental outcomes (Bricker & Squires, 1999). Given the research aim of developing a future cohort to study longitudinally, the ASQ was deemed the most appropriate tool.

The original ASQ (known as the Infant/Child Monitoring Questionnaires) had a test-retest agreement of around 90% (Bricker & Squires 1989, as cited by Squires, Bricker & Potter, 1996, p.315), with generally high agreement between parents and trained assessors as to whether clinical assessment was required (76-92%). A revised edition of the ASQ was subsequently shown to have test-retest reliability of 94% (across successive weeks), with a high agreement rate between parents and trained assessors (94%, Squires et al., 1996). The ability for the ASQ to detect developmental delay has a sensitivity of 75% across ages, and 86% specificity

(Bricker & Squires, 1999). The ASQ is useful compared to clinical assessments of development because:

1. It is considered cost affective; families do not need to attend specialist clinics for routine screening.
2. It acts as a basic screening tool which highlights areas that may need further assessment.
3. Parents have been shown to be accurate judges of the behaviours of their children, and it is important that they are involved with the screening of their infant.
4. Parents find the ASQ relatively easy and not too time consuming to complete.
5. It allows parents to express any concerns they may have with their child's development.

There are 11 ASQ's that are tailored for a given age group. The 12 month questionnaire (applicable for 11 to 13 months of age) was used in this study and can be found in Appendix A2. The ASQ collects information on contact details and date of birth (including the corrected date of birth if the infant was born prematurely), and then includes 30 simply-worded questions focusing on development, divided into five developmental domains:

1. *Communication* for example: "Does your infant shake his head when he means "no" or "yes"?"
2. *Gross Motor* for example: "Does your infant stand up in the middle of the floor by himself and take several steps forward?"

3. *Fine Motor* for example: "Does your infant help to turn the pages of a book?"
4. *Problem Solving* for example: "After he watches you hide a small toy under a piece of paper or cloth, does your infant find it?"
5. *Personal-Social* for example: "When you dress her, does your infant lift her foot for the shoe, sock or pant leg?"

The optional answers to these questions are 'yes', 'sometimes' or 'not yet', indicating the level at which the child is performing the behaviour. Each answer is then scored using a point system; 10 for 'yes', 5 for 'sometimes' and 0 for 'not yet'. Each domain is scored separately and compared to validated age specific thresholds (Squires, et al, 1997). If an infant scores below the threshold for "doing well at that time", then further evaluation of that domain is recommended. In the present study, an experienced paediatrician reviewed instances where infants scored below developmental thresholds and advised that as delay was only ever found in one domain, additional follow-up was not necessary for any of the affected infants at this time. No parents expressed delay about their child's development.

The final section of the ASQ includes general questions concerning whether the infant hears and sees well, uses both hands equally, stands properly, and any other medical concerns. Parents are given space here to document any observations or concerns about their child's development. Answers from this section were not included in statistical analysis but were collected to help assess whether further assessment was required.

2.1.3 Actigraphy

Actigraphy has been demonstrated to be reliable for measuring sleep in adults (Signal, et al., 2005), and infants after the third month of life (Gnidovec, et al., 2002). Compared to the gold standard for sleep measurement (PSG) actigraphy has high agreement rates (see section 1.3). Ease of use and comfort were primary considerations throughout the development of the actigraphy band and data collection protocol.

The actigraph used for this study was the *Actiwatch Mini Mitter-64*™ (AW64; Respironics® & Mini Mitter Inc., Bend, Oregon.). The AW64™ has been validated against PSG recordings of infants, as well as against observations and measures of energy expenditure (Finn & Specker, 2000; Puyau, Adolph, Vohra, & Butte, 2002; Sadeh, et al., 1991; So, et al., 2005). The AW64™ is a light weight (16 grams) activity monitor worn on the wrist or leg that automatically collects and scores activity counts from an accelerometer. It is sensitive to 0.01 g, sampled at a rate of 32 hertz, and has a non-volatile memory of 64KB's. There is an event marker on the actigraph for participants to press, marking times of significance (e.g., at bedtime). Figure 2.1 shows the actigraph on an adult wristband.

Figure 2.1. The *Mini Mitter Actiwatch-64*™ (source-www.cpapaustralia.com.au).

Specialised actigraph band.

In studies that have validated actigraphy for the study of sleep of infants, the device has been worn on the ankle or lower calf, whereas in adults it is typically worn on the wrist. A specialist band was designed for the study with the aims of being easy for parents to use and being made of materials that would not irritate the skin. Such designs have been implemented in past studies of infants (e.g., So, et al., 2007).

Calf measurements were taken (with the permission and in the presence of a parent or caregiver) from infants aged 4 to 18 months at social events (e.g., music groups and library sessions). Calf measurements were taken from 30 infants and varied from 15 to 23 centimetres. Among the 12 infants falling into the age group of interest (11 to 13 months), calf measurements ranged from 18 to 23 centimetres. Due to this large range, three band sizes were made (small, medium and large) rather than making adjustable straps (as this would involve more bulky materials).

The bands were made from a double layer of *Tubigrip* (Medlock Medical Ltd., UK) with a pocket in which to hold the actigraph. The band was fastened using snap-lock buttons on elasticised ribbing material, allowing for further stretch. An iron-on motif was placed on the actigraph pocket over the event marker, so parents could simply press the motif when they wanted to mark a point in time. The band is shown in Figures 2.2 and 2.3 overleaf. Each family were given two bands with a description of the material content and washing instructions. The bands were intended to be used once, parents were not expected to wash or return them.

2.1.4 Sleep Diaries

Sleep diaries were provided to be filled out during the week of actigraphy data collection. The diary was adapted and based on those previously used in the Sleep Wake Research Centre (SWRC) in many populations (Gander, van den Berg, & Signal, 2005; Signal, et al., 2007), and also incorporated elements of a diary designed by Sadeh (2001) to collect information on temperament .

The aim of the diary was to help interpret the data from the actigraph as well as provide additional information concerning the infant's routine, mood and sleep. Sleep timing data was not analysed directly from the diary, as typically this data is not as accurate as objective measures (see section 1.3.1). Keeping the diary also gave parents the opportunity to note any factors particular to that day that may have affected their infant's sleep. An example day of the sleep diary can be found in Appendix A3. Each area of the diary is explained in more detail below.

Figure 2.2. Specialist band with bumble bee motif [3].

Figure 2.3. Participating infant with actigraph and band in place [4].

[3] The assistance of Perrine Boy is gratefully acknowledged for the design and manufacture of the specialist bands.

[4] Photograph taken with the kind permission of Allison Clark.

Sleep timing.

Parents were asked to record in the diary the times of 'intended' and 'unintended' sleeps on a series of 24-hour time lines. Intended sleeps were defined as times when the parent had planned for the infant to go to sleep, for example their usual bedtime or a time when parents initialised sleep. Unintended sleeps were defined as times when the infant fell asleep unexpectedly, for example whilst in the car. Note that these are times when the infant was put into bed and got up rather than the times they actually fell asleep or woke up. Parents were asked to record any sleep that was 10 minutes or longer. Times when the monitor was removed were also marked on the dairy timelines so that these periods could be excluded from analysis, rather than being mistaken for times spent asleep (i.e. with no movement). *Excluded Intervals* are described in further detail below (section 2.4.4).

Daily diary questions.

For each day parents rated general factors about their child's sleep, mood and temperament on a series of three-point scales (adapted from Sadeh, 2001) as follows:

"How did your child wake up in the morning?" options:

1. Woke by themselves.
2. With parental initiative.
3. Other.

"To what degree is s/he alert this morning?" options:

1. Not at all.
2. Somewhat.

3. Very.

"Mood in the morning?" options:

1. Good.
2. Moderate.
3. Bad.

"Compared to other days, this was a:

1. Low,
2. Typical,
3. High

...activity day".

" To what extent were there problems putting your child to sleep?" options:

1. None.
2. Some.
3. Many.

"To what extent did your child appear to be tired at bed time?" options:

1. Not at all.
2. Somewhat.
3. Very.

"Mood at bedtime?" options:

1. Good.

2. Moderate.

3. Bad.

Parents were also asked whether or not the infant was in another person's care during that day, and if so between which times. This was of interest because caregivers other than parents had not formally agreed to, or been briefed on the study procedures. Time spent separated from the parents may also have resulted in stress or anxiety that could potentially affect sleep. Childcare days might also involve specific time constraints with potential effects on the sleep routine. Finally, to provide additional contextual information, on each day of the diary parents had space to write any notes, for example if their infant was unwell, been away from home, or to parties.

2.1.5 Feedback Questionnaire

As this research aimed to pilot methodology and a protocol for studying infant's sleep, it was vital to seek feedback from the participating families. Therefore a short (six question) feedback form was designed (Appendix A4).

Parents were asked how they heard about the study, whether they had sufficient information prior to beginning, and whether any queries they had had been answered satisfactorily (yes/no).

Parents were then asked to rate (options: easy, OK, difficult):

1. Using the monitor and band.

2. Completing the sleep diary.

3. Completing the questionnaires.

For each item, space was also available for written comments. Finally parents were asked for any general comments concerning the study.

2.2 *Ethics*

Approval for the study was obtained from the Massey University Human Ethics Committee (Application number – 08/26). A copy of the letter of ethical approval can be found in Appendix B1. Participating in the study was voluntary and based on written informed consent. Participants were informed that they had the right to withdraw from the study at any point. Copies of the letter of invitation, information sheet and consent form can be found in Appendix B2.

A free-call mobile telephone number and email address were available throughout the study for any questions or comments. Parents were advised that, should any developmental concerns arise from the ASQ, a follow-up consultation with the study paediatrician, Dr Dawn Elder, could be arranged. They were also informed that they had the right to withdraw from the study at any time.

2.2.1 Recruitment of Participants

Families were recruited through advertisements in public places that parents with infants were likely to visit (e.g., local libraries, crèches, and community halls, see Appendix B3). Recruitment also took place via direct communication to groups of parents through email or newsletters (e.g., North Wellington Parents Centre and local schools), and through the researcher attending community groups to promote the study (such as library sessions). Families who found out about the study from other participants were also recruited.

Inclusion/exclusion criteria.

This was a convenience sample for a pilot study. The only inclusion criteria were that infants were in good health and aged 11 to 13 months at the time of their participation, and lived within a 40 km radius of central Wellington. Because of the limited sample size (planned N=45) no attempt was made to stratify the sample by ethnicity, gender or SES.

2.3 *Procedure*

Information sheets and consent forms were given or posted to families interested in the study, together with a prepaid envelope to return the signed consent form to the researcher. One week after receiving these documents, if a consent form had not yet been returned, potential families were followed up by email or telephone.

The researcher visited each participating family in their home at an agreed time when the infant was awake. Although the option to have a courier deliver the materials was offered, no family opted for this method. At the visit, questionnaires and instructions for using the actigraph were provided, the infant was fitted with the appropriate size actigraphy band, and height and weight measurements were taken from the parent(s) and infant. Home visits took approximately 20 to 30 minutes.

2.3.1 Use of the Actigraph

Each actigraph was initialised at the SWRC and a log was created linking the participants ID number with the actigraph's serial number. A label with the contact name and telephone number of the researcher was attached to the back of each monitor in case of misplacement.

Actigraphs were set at an epoch length of 1 minute. This is the typical time frame used in actigraphy, unless being used alongside PSG recordings (in which case a 30 second epochs are typically used for ease of comparison). Use of 1 minute epochs makes the conversion of activity counts into minutes and hours of the day much easier. This epoch length allows for lengthier continuous monitoring whilst maintaining a high level of resolution, as well as being the typical length used in actigraphic studies (Acebo, et al., 2005; Littner, et al., 2003; Sitnick, et al., 2008). Some research with school aged children has considered 1 minute epochs to be too long due to the chance of misrepresenting short bursts of activity (Trost, 2001, as cited in Trost, et al., 2005). Although shorter epochs have been used in some research with infants (e.g., Gnidovec, et al., 2002), there is no consensus about the most appropriate epoch length for this age group.

Parents were told that the actigraph measures movement only and were shown the event marker. Infants were fitted with an appropriate sized actigraphy band and wore the monitor for the duration of the home visit to ensure that it did not affect the skin or trouble the infant. Whether or not particular placement of an actigraph is superior to another is yet to be established (Ancoli-Israel, et al., 2003; Littner, et al., 2003; Sitnick, et al., 2008). In a study of school aged children, actigraphy recordings had high agreement rates between the hip and ankle (Puyau, et al., 2002) as well as between wrist and waist (Paavonen, Fjällberg, Steenari, & Aronen, 2002). In the present study, actigraphs were positioned on the outer side of the infant's calf. This position is recommended due to the nature of infants' movements, smaller size of upper limbs, and for providing greater comfort and validity (i.e. the infant is less likely to notice or excessively handle the device, Acebo, et al., 2005). Furthermore, this position has been used in previous research with this age group (Jenni, Fuhrer, et al., 2005; Sadeh, Acebo, et al., 1995; Sitnick, et al., 2008; Spruyt, et al., 2008).

Parents were requested to use the event marker on the actigraph to mark times of putting the infant down to sleep and again when getting them up (for any sleep of 10 minutes or longer). They were also instructed to leave the monitor on at all times except when likely to get wet. The event marker was to be pressed at the beginning and end of times when the monitor was removed to enable exclusion of these intervals from analyses. Parents were informed that the actigraph was not any form of surveillance or a respiratory monitor.

Taking into account days that may be lost (e.g., due to technical difficulties or illness), approximately 28% of a week's recording from children or adolescents should be expected to be unacceptable for analysis (Acebo, et al., 1999). In order to achieve reliable day to day results, 4 to 9 days of recording are required, with the recommendation being for a full 7 days (Acebo, et al., 1999; Sadeh & Acebo, 2002; Trost, et al., 2005). Parents of the present study were instructed to have their infant wear the actigraph for a full week.

Based on the review of Trost et al. (2005), the following strategies were put in place to increase the reliability of actigraphy recording:

1. A supplementary instruction sheet was given (see Appendix B4) reminding parents of the actigraphy and diary protocol.
2. An example of the output that the monitor would give was shown. To encourage compliance, parents were promised that a copy of their infant's

results (in the form of an actogram) would be sent to them at the end of the study.

3. Halfway through the study week, the researcher contacted the family by phone or email to ensure that all was going well. This contact served as a reminder to have the infant wearing the monitor at all possible times and to use the event marker. This time was also used to discuss any problems that the family might have been having with the actigraphy recording.

2.3.2 Use of the Daily Diary

Once the parents were comfortable with the use of the actigraph, the diary was explained using an example page. The importance of the diary data for interpreting the actigraphy was enforced. Parents were advised that they did not have to wait for their infant to fall asleep, but to simply mark the times that they were in bed. Likewise, in the morning they were to mark the time that the infant was taken out of bed rather than estimating a time they may have woken up. These times were defined as *rest intervals*. If the infant woke or was tended to in the night (e.g., for a nappy change or feed) for more than 10 minutes, then the parents were asked to mark the end of a rest interval and beginning of any subsequent rests on the timeline.

The daily diary questions were discussed, parents were requested to circle just one answer per question to rate their infant's mood and temperament. Finally any queries concerning the diary were answered and a supplementary information sheet was given (see Appendix B4). The diary took approximately 5 to 10 minutes to fill out per day.

2.3.3 Use of the Questionnaires and Measurements of Body Size

The sleep questionnaire was shown to the parents and the researcher described each section, giving the parents opportunity to ask any questions they had. They were told that the questionnaire would take approximately 20 minutes to complete and they were left to complete this in their own time.

The height and weight of the parent(s) were measured by the researcher (when possible or applicable), as well as the infant's length, weight and head circumference. Weights were measured using a mechanical set of scales on a flat surface. Heights of parents were measured with a metal tape measure whilst standing on a flat surface against a wall. Infant's length was measured using a measuring mat and head circumference was taken with a fabric tape measure.

Finally, parents were shown the ASQ. They were told that it would take 15 to 30 minutes to complete. Instructions were given in the ASQ covering sheet as well as brief verbal instructions at the home visit. Parents were encouraged to complete the questionnaire in their own time, physically attempt each activity covered in the questionnaire, and give an answer for each question. They were assured that if their infant appeared to be delayed in any domains, a paediatrician working on the study would evaluate whether clinical follow-up was necessary.

2.3.4 Completion of the Home Visit

Once all areas of the research were covered, parents were free to ask any further questions. The fitting of the actigraphy band was checked and the event marker pressed to mark the start of the study. Parents were left with a prepaid package to post the equipment back to the researcher at the end of their study week.

It was confirmed that families had the contact details of the researcher and they were encouraged to call or email at any point. Parents were reminded that they had the right to withdraw from the study at any time.

On the receipt of the equipment and successful download of the actigraph, families were posted a copy of their infant's actogram with a letter briefly annotating the findings (see Appendix B5). A feedback form and freepost return envelope was also sent on completion of the study. These were sent back anonymously in order to encourage frankness.

2.4 *Data Analysis*

Data were analysed using SPSS 13.00 software (SPSS Inc. Chicago, Illinois, United States of America). Graphs were created using Prism 4.0 software (Graphpad Software, United States of America). Kolmogorov-Smirnov analysis of normality was run on all variables of interest (results can be found in Appendix Tables C1 and C2). Descriptive data is reported as the median and range, or the frequency. For all tests, a p value of less than .05 was considered to be statistically significant. Each area of analysis is described below.

2.4.1 Analysis of Parental Reports

Sleep questionnaires.

Missing data from the questionnaire were due to parents missing or not correctly answering questions. On these occasions, families were contacted with regards to the missing information, however some were unable to be reached before analysis took place.

Data from the sleep questionnaire included nominal, ordinal and interval scales. The age of the infants was calculated as the difference between the birth date and the date of the first day of data collection. No analyses were undertaken to compare preterm to full term infants as, although significant differences have been reported (e.g., Gossel-Symank, et al., 2004), only seven of the present study's infants were premature and they were all close to full term (therefore their ages were not adjusted).

Height and weight data were reviewed against normal centile ranges used by the local paediatric service at Wellington Hospital to determine the proportion of infants being overweight. Parents BMI's were reviewed against the World Health Organisation's categorisation of overweight and obese (2006). The ponderal index $((\sqrt[3]{\text{weight}}/\text{length})100)$ was calculated for each infant.

Frequency distributions and descriptive statistics were calculated for each domain of the questionnaire. Variables from the sleep questionnaire were dichotomised to enable categorical analyses (Results section 3.1, Table 3.8). Infants' were categorised as to whether or not they were *problem sleepers*. This was determined three ways:

1. Snoring:

   Parents answered the question – *How many nights of the last week did your infant have snoring or noisy breathing?* (The option *'not applicable as infant was unwell'* was given in order to gather only valid data).

2. Sadeh's (2004) problem criteria:

   - Sleeping less than 9 hours per 24-hours.
   - Waking more than three times per night.
   - Spending more than 1 hour awake per night.

3. Parentally-defined:

   Parents answered the question – *Do you consider your child's sleep a problem* (options were: *a very serious problem, a small problem, not a problem at all*).

Statistical analysis of the sleep questionnaire.

Chi-square tests were used to examine whether problem sleepers and non-problem sleepers (by parental definition) were differently represented in the categories of each of the other dichotomous variables defined by from the sleep questionnaire. These analyses could not be done for problem sleep defined by snoring or the Sadeh definition because too few infants were classified as problem sleepers by these definitions.

Mann-Whitney tests for independent groups were used to compare the parentally reported sleep timings and durations between the problem and non-problem groups. The relationship between maternal BMI and infants' ponderal index was investigated using bivariate correlation analysis.

2.4.2 Analysis of Diaries

Times marked on the timeline of the sleep diary were used for the analysis of the actigraphy data only. Responses to diary questions were averaged for each infant due to the variance in the number of complete days of data. Responses to the daily diary questions were dichotomised (Results section 3.21, Table 3.12).

A separate file was created with the daily diary ratings of mood and temperament split and averaged for each infant depending on whether it was a weekend or weekday. Weekends were defined as Saturday or Sunday as the ratings were relevant to the effects of the daytime experience of the weekend. Averages were also calculated for each infant for childcare and non-childcare days (as indicated by the parent in the diary).

Statistical analysis of diary data.

Chi-square tests were used to examine whether parentally-defined problem sleepers and non-problem sleepers were differently represented in the categories of each of the other dichotomous daily diary ratings. McNemar tests were used to assess whether there were significant sleep or dairy rated changes between week days and weekend days, or between childcare and non-childcare days. Since these were pair-wise comparisons, only infants with data for both occasions of interest were included.

2.4.3 Analysis of the Ages and Stages Questionnaire

The ASQ gave data on a scale from 0 to 60. Infants were also categorised according to whether nor not they scored below the respective age related threshold for each of the five domains.

Statistical analysis of the ASQ.

Linear regression was used to evaluate whether there was a positive relationship between age and ASQ scores (Sokal & Rohlf, 1973). Mann-Whitney tests for independent groups were used to compare the ASQ scores between gender, as well as parentally-defined problem sleepers and non-problem sleepers.

2.4.4 Analysis of Actigraphy Data

Scoring of raw actigraphy data.

Once the actigraphs were returned to the SWRC they were downloaded using the Actiware® 5 software (Respironics ® Mini Mitter, Bend, Oregon, United States of America). The data is initially presented as an actogram. The actogram in Figure 2.4 runs from noon to noon. Black vertical lines represent activity (underscored by a horizontal red line). Periods of low activity represent times at rest or times when the monitor may have been taken off.

Determination of sleep and wake.

The Actiware® 5 software includes a validated algorithm that categorises each 1 minute epoch of the recording as either sleep or wake. The software considers not only the particular epoch, but the weighted fractions from the two epochs before and after (Figure 2.5).

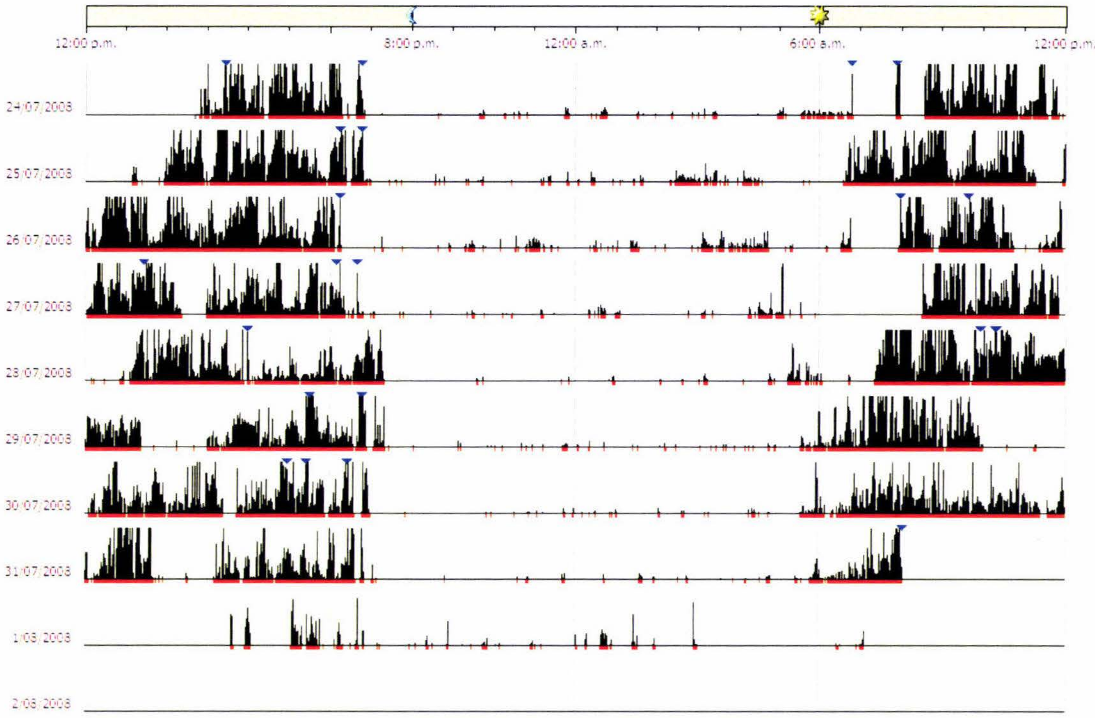


Figure 2.4. An example of 1 week of actigraphy recording from a participating infant.

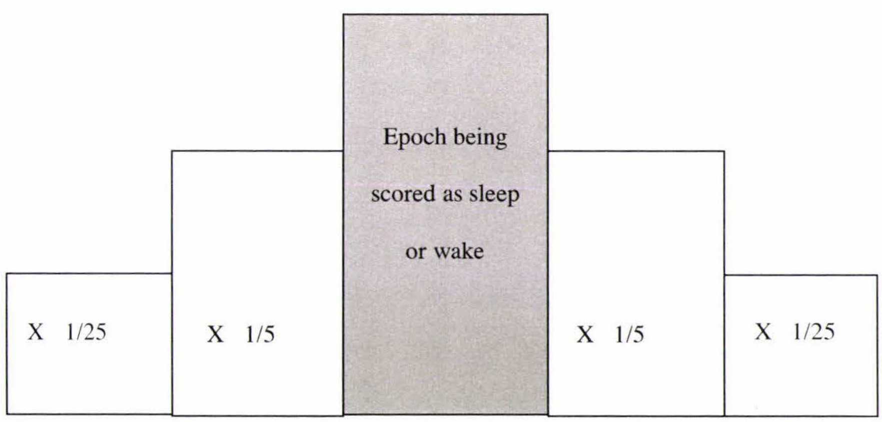


Figure 2.5. Actiware® 5 algorithm for calculating the sum of activity counts for a 1 minute sampling epoch in order to score as sleep or wake.

The sum of the activity counts from the epoch of interest plus fractions of the activity counts from the surrounding epochs is compared to a set threshold for wake (*low [20]*, *medium [40]*, or *high [80]*). If the sum of activity counts exceeds the threshold then the epoch is scored as wake. If the total count is below the threshold, then it is scored as sleep.

In the present study the threshold for defining wake was set to high (80 activity counts per minute). Previous research has shown this to give high agreement rates with PSG for predicting sleep of infants from 5 months of age into childhood (Hyde, et al., 2007; So, et al., 2005). Using the high threshold means that it takes more movement to define an epoch as wake. Table 2.1 shows an example of how the epoch of 19:00 (in this case) is scored as wake.

Table 2.1

Example for Calculating the Actiware® Definition for the 1 Minute Epoch of 19:00.

Time	Activity data
18:58	50
18:59	39
19:00	92
19:01	32
19:02	65

The equation for the total activity count for the 19:00 epoch in Table 2.1 would equal: 50(0.04) + 39(0.20) + 92 + 32(0.20) + 65(0.04) = 110.8. This value exceeds that of the high threshold and therefore the epoch would be scored as wake. Actigraphy alone cannot distinguish between sleep and still wakefulness or the actigraph not being worn. Manual scoring is also necessary and for this purpose the diary data are essential (Sadeh, Hauri, et al., 1995).

Manual scoring of actigraphy intervals.

Rest intervals and *excluded intervals* were identified manually, based on three sets of information:

1. The sleep diary kept by parents, indicating times in bed and times the monitor was removed or fell off.
2. The event marker should have been pressed at the beginning and end of bedtimes and removed times, which results in an arrow-like marker being plotted in the actogram.
3. A change in activity around times of rest and times when the monitor was off.

In an ideal world, the note in the sleep diary would coincide with the event marker and a change in activity, but this was not always the case so a set of scoring rules was developed (Appendix C2).

Two different types of intervals were identified by manual scoring. Rest intervals were defined as the time the infant spent in bed. Within a rest interval, the software directly applies the *Sleep Interval Detection Algorithm*, which defines a *sleep interval* within the rest interval (see below). Excluded intervals were defined as any time that the infant was not wearing the actigraph, for example bath times or when the actigraph fell off or was removed. These intervals are excluded from any analyses.

Times when the actigraph came off were not always noted in diaries (due to forgetting etc). Therefore a protocol for excluding periods of time was created in order to give the most valid and reliable data for statistical analysis:

1. Any periods of time with no activity for 1 hour or more and not already noted as a rest interval.
2. Times prior to the study beginning and when the actigraph was in transit back to the SWRC.
3. Any rest intervals containing an excluded interval (e.g., if the actigraph slipped off in the night) were omitted from analysis.
4. Any days with a high proportion (over 1 hour) of total excluded time were omitted altogether.

Reliability of manual actigraphy scoring.

Twenty percent of the manually defined intervals were double scored to ensure that data were reliable, 266 rest and excluded intervals were rescored. Any discrepancies of more than 15 minutes for either start or end times were flagged and re-analysed accordingly. Of the total time points (532) there were 70 discrepancies which gave an agreement rate of 86.8% (agreement rates ranged from 72.9% to 100% per participant).

Software defined intervals.

Once rest and excluded intervals have been identified manually, the Actiware® 5 (Respironics® Mini Mitter) software defines all other times as *active intervals,* and applies the algorithm to define sleep intervals within the manually scored rest intervals. Active intervals are times when the activity levels indicate that the infant is awake and engaged in physical activity. These times are the remainders, i.e. the infant is not identified as resting (and therefore not asleep) and the actigraph is on.

The sleep intervals are times between sleep onset and final wakeup as determined by the algorithm. Sleep onset is defined as the first of 10 consecutive epochs scored by the algorithm as sleep. The final wakeup time is scored as the first of 10 consecutive epochs scored by the algorithm as wake. Note, sometimes the infant is put down with the parent's intention for them to sleep (a rest interval) however they do not fall asleep according to the algorithm criteria. Therefore not all days have the same number of sleep intervals and rest intervals.

2.4.5 Defining Actigraphy Variables

The actigraphy intervals as identified above were further categorised as night time or daytime as follows:

- A *night interval* was defined as any interval starting after 7 p.m. or any interval starting before 7 p.m. for which >50% of the interval occurred after 7 p.m.
- A *day interval* was defined as any interval starting after 7 a.m. or any interval starting before 7 a.m. for which >50% of the interval occurred after 7 a.m.

For each participant, for each day of recording, descriptive statistics were calculated for the variables of interest for day, night and 24-hour time frames (Table 2.2). Figure 2.6 shows an example day from an actigraphy recording.

Table 2.2

Descriptions of the Variables Calculated from the Actigraphy Records and used for Statistical Analysis.

Variable	Description	Timeframes
Mean activity during active intervals (act count per min) [a]	The average of all activity counts for active interval epochs divided by the interval length	Day
Bedtime (hrs: mins)	The time that infant was put to bed (the beginning of the rest interval)	Day & night
Sleep onset time (hrs: mins)	The time that the infant fell asleep for the night (from the Actiware® algorithm)	Night
Sleep onset latency (mins) [b]	Time between the beginning of the rest interval and sleep onset	Day & night
Sleep duration (hrs)	Total time between sleep onset and wake up (from the Actiware® algorithm)	Day, night, & 24-hrs
Sleep efficiency during the rest interval	The proportion of the rest interval time spent asleep (as defined by the Actiware® algorithm)	Day & night
Sleep efficiency during the sleep interval	The proportion of the sleep interval time spent in actual sleep (as defined by the Actiware® algorithm)	Day & night
Final wake up time (hrs: mins) [c]	The time that the infant woke up (end of sleep interval)	Night
Wake-rise time (mins) [d]	Time between wakeup and the rest interval ending (time spent awake before being taken out of bed).	Day & night
No. of rest intervals	The number of times the infant was put to bed (diary defined)	
No. of sleep intervals	The number of times the infant went to sleep (from the Actiware® algorithm)	Day, night & 24-hrs
Percentage of sleep occurring at night	The proportion of total sleep per 24-hrs that occurs between 7 p.m. - 7a.m. An indication of the development from multiphasic sleep to consolidated sleep at night (researcher defined)	

a Any active intervals containing an excluded interval were removed from analysis.

b Sleep onset latency at night was taken from the first night rest interval only.

c Final wake up time taken from the last night time interval only.

d Wake - rise time at night taken from the last night time rest interval only.

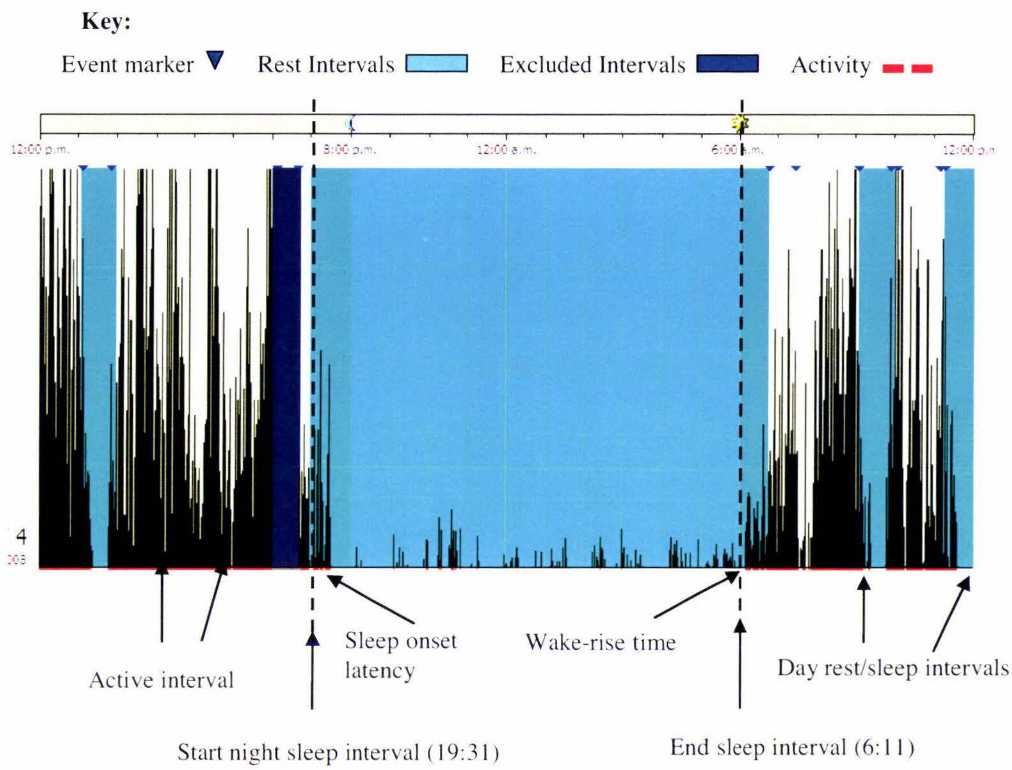


Figure 2.6. A screenshot of 24 hours of infant actigraphy indicating the variables of interest and their relationships to one another.

Figure 2.6 shows (from left to right) a marked rest interval (light blue, manually scored) during the afternoon (13:06 – 13:59), then an excluded interval (dark blue, manually scored) just before bed time (18:01 – 18:44). These intervals were noted in the diary and the event marker was pushed (as can be seen by the blue arrows at the top of the diagram). There are also clear reductions in activity levels, as indicated by breaks in the bottom red line.

Although the event marker is not pressed at the evening bedtime, the diary indicated that the infant was put down for sleep at 19:00, and was taken out of bed in the morning at 6:47 (which corresponded to the diary and pushing of the event marker). This gives the infant night time rest duration of 707 minutes (11.8 hours).

The red line underscoring the actigraph indicates that there is still some activity at the beginning and end of the rest interval. These are times when the infant was awake in bed. In the above instance, the sleep interval begins at 19:31, giving a sleep onset latency of 31 minutes. The sleep interval ends at 6:11 when the infant clearly became more active, giving a wake-rise time of 36 minutes. The night time sleep duration in the above example is 640 minutes (10.7 hours).

Within the sleep interval, points of activity can be seen (marked by the black vertical lines with corresponding horizontal red markers underneath), these are recorded as wake bouts. There is a total of 14 minutes spent awake during the night time sleep interval. The number of wake bouts were not used for analysis, the meaningfulness of this statistic is questionable as the software algorithm scores each individual epoch (1 minute) of wake as an awakening. Past research has designed and used smoothing algorithms in order to identify longer periods (e.g., 3 consecutive minutes or more of wake) as wake bouts (Acebo, et al., 2005; Goodlin-Jones, et al., 2008; A. Scher, 2005b).

Note that two measures of sleep efficiency were used for analysis; the *sleep efficiency during the sleep interval* (a representation of the continuity of sleep), and the *sleep efficiency during the rest interval* (a representation of the amount of time in bed during which the infant was asleep):

- The sleep efficiency within the sleep interval = 100 – ((time awake in sleep interval/time spent in asleep in sleep interval)100). In the above example this is equal to:

  100-((14/640)100) = 97.8 %.

- The sleep efficiency of the rest interval = 100 – ((time wake in sleep interval + sleep latency + wake–rise time)/duration of rest interval) 100). Which in the above example this is equal to:

  100-((14+31+36)/707)100) = 88.5%.

2.4.6 *Statistical Analysis of Actigraphy Data*

Once invalid actigraphy days were removed (as described in section 2.4.4), actigraphy data were averaged for each day of monitoring so that statistics could be matched with sleep diary data. As the number of valid actigraphy days varied between infants, the averages for each variable per infant were calculated and then averaged across the whole sample. Since many actigraphy variables were not normally distributed, non-parametric statistics were used throughout.

A purpose-built algorithm was used to calculate the percentage of infants likely to be asleep at each given hour of the 24 hour day. Data used to calculate sleep propensity were the first 4 days of data from all infants with 4 or more days of valid actigraphy data.

Linear regression was used to assess whether the relationship between the percentage of total sleep occurring at night was positively related to age. Regression analysis was also used to test whether the night time sleep duration, sleep duration per 24-hours, or the percentage of sleep occurring at night, were positively related to ponderal index (Sokal & Rohlf, 1973).

Mann-Whitney tests for independent groups were used to compare actigraphy variables between genders, high or low ponderal index (defined by a median split), as well as parentally-defined problem sleepers versus non-problem sleepers.

Actigraphy and diary data.

The actigraphy data were compared between dichotomised daily diary ratings of mood and temperament using Mann-Whitney tests for independent groups.

The actigraphy data were split depending on whether it was a weekend or weekday, and childcare or non-childcare days, then averaged and re-entered for each participant. Two definitions were used for the analysis of childcare days; firstly the wake-up time from the night's sleep interval of the night preceding childcare was compared with that of nights' not preceding childcare in order to assess any differences in routine. Secondly the actigraphy variables pertaining to the full 24-hours of the day of care (including the night following care) were compared with non-care days using Wilcoxon signed-rank tests. Twenty-four-hour actigraphy variables included: activity counts per minute in daytime active intervals, daytime sleep duration, sleep efficiency during daytime rest and sleep intervals, bedtime at night, sleep onset latency, night time sleep duration, sleep efficiency during night time rest and sleep intervals, wake-rise time in the morning, the number of rest and sleep intervals per 24-hours, and durations of rest and sleep per 24-hours.

The weekend was also defined in two ways in order to assess the full effects of this time of week. The first set of Wilcoxon signed-rank tests compared the weekend as defined as Friday and Saturday nights to weekdays (Sunday to Thursday nights). The actigraphy variables concerned the night time only; bedtime, sleep onset latency, night time sleep duration, sleep efficiency during the night time rest and sleep intervals, time of final wake up in the morning, wake-rise time, were compared within subjects. The second set of tests used the weekend defined as Saturday and Sunday (compared to Monday-Friday). These analyses included the full 24-hour day (as noted above) in order to assess any changes of routine.

Actigraphy and developmental progress.

The scores from the five ASQ domains were ranked and Spearman's correlation coefficients were calculated to investigate the relationship between ASQ scores and actigraphy data. Variables of interest were the night time sleep duration, sleep duration per 24-hours, the sleep efficiency during the night time sleep interval and the percentage of sleep occurring at night.

Infants categorised by whether or not they scored below one or more developmental threshold(s) were compared using Mann-Whitney tests for independent groups to assess whether there were any differences in actigraphy variables.

2.4.7 Mixed ANCOVAs of Actigraphy Variables

Mixed analysis of covariance (ANCOVA) for repeated measures was used to investigate the influence of stages of development, the ponderal index, age and gender on the actigraphic sleep variables. In these analyses, sleep data were treated as the repeated measure. The Mixed ANCOVAs were performed in the SAS system for Windows (version 9.0)[5].

The mixed linear model is an extension of the general linear model, allowing for the controlling of fixed and random effects. Fixed effects are those established to be related to the variable, whereas the random effects are additional variables suspected to also have an impact on the variability of the data. The mixed model has three assumptions that need to be met:

1. The data residuals are normally distributed.
2. The expected relationships are linear.
3. The variance's and covariance's exhibit a structure matching one of those available in the modelling procedure.

Assumptions of normality, linearity and homoscedasity were checked by analysing the residuals of each model (Tabachnick & Fidell, 2007). Histograms, normality plots and Shapiro-Wilk statistics were produced to assess the structure of residuals and to determine whether or not the data were significantly skewed. If the residuals were not normally distributed, outlying residuals were identified and the corresponding cases (days) were systematically removed starting with the most extreme cases. Transformations (square root [SQRT] and log to the base 10 [log10]) were also applied to reduce the impact of excessive data removal (in this case, if more than 10 outliers were in need of removal) and to improve normality. Some distributions substantially differed from normal with a negative skew. In these cases the data were *reflected* prior to SQRT or log10 transformations (Tabachnick &

[5] Dr Sarah-Jane Paine is gratefully acknowledged for her assistance with mixed modelling.

Fidell, 2007). Some distributions required transformation as well as subsequent removal of outliers to create a normal distribution. The process of removing outlying residuals and/or applying transformations was applied until the Shaprio-Wilk statistic indicated that the residuals were normality distributed.

In the present research, mixed models ANCOVAs for repeated measures were used to investigate two sets of data:

1. The first set of models investigated the relationship between actigraphy variables and the ASQ scores as well as the age and gender of the infants. Age was categorised by 2 week intervals. The five ASQ domains were assessed and infants were also compared according to whether or not they scored below one or more developmental threshold. The actigraphy variables used in the models were: night time sleep duration, sleep duration per 24-hours, sleep efficiency during the night time sleep interval, and the percentage of total sleep occurring at night.
2. The second set of models investigated the relationship between actigraphy variables and ponderal index. Gender was included as a fixed factor. Mother's BMI was included as a covariate, as past research has found maternal BMI to be significantly correlated to infants body habitus (J. J. Reilly, et al., 2005). The actigraphy variables included in the analyses were night time sleep duration, sleep duration per 24-hours and the proportion of sleep occurring at night.

Tables 2.3 and 2.4 outline each model including the number of outliers removed and data transformations which were necessary to meet the assumptions of the mixed model.

Table 2.3

Dependent and Independent Variables for the Mixed Model ANCOVAs Related to Developmental Progress.

Model	Dependent variable	Fixed factors in the model [a]	Data transformations	Outliers removed
1	Night sleep duration	ASQ Communication, age group, gender		5
2	As above	ASQ Gross motor, age group, gender	Reflect SQRT	1
3	As above	ASQ Fine motor, age group, gender	Reflect SQRT	2
4	As above	ASQ Problem solving, age group, gender		5
5	As above	ASQ Personal social, age group, gender		3
6	As above	ASQ Categories - above or below threshold, age group, gender		5
7	Sleep efficiency during night time sleep	ASQ Communication, age group, gender	Reflect log10	Nil
8	As above	ASQ Gross motor, age group, gender	Reflect log10	Nil
9	As above	ASQ Fine motor, age group, gender	Reflect log10	Nil
10	As above	ASQ Problem solving, age group, gender	Reflect log10	Nil
11	As above	ASQ Personal social, age group, gender	Reflect log10	Nil
12	As above	ASQ Categories - above or below threshold, age group, gender	Reflect log10	Nil
13	Sleep duration per 24-hrs	ASQ Communication, age group, gender		5
14	As above	ASQ Gross motor, age group, gender		1
15	As above	ASQ Fine motor, age group, gender		3
16	As above	ASQ Problem solving, age group, gender		2
17	As above	ASQ Personal social, age group, gender		3
18	As above	ASQ Categories - above or below threshold, age group, gender		4
19	Percentage of sleep occurring at night	ASQ Communication, age group, gender		3
20	As above	ASQ Gross motor, age group, gender		2
21	As above	ASQ Fine motor, age group, gender		2
22	As above	ASQ Problem solving, age group, gender		2
23	As above	ASQ Personal social, age group, gender		2
24	As above	ASQ Categories - above or below threshold, age group, gender		2

a ASQ domains were included as continuous variables (0-60). ASQ categories were defined as either those who scored below one or more threshold or above thresholds. Age groups were categorised into four age groups defined by 2 week cut-offs.

Table 2.4

Dependent and Independent Variables for the Mixed Model ANCOVAs Related to Ponderal Index ($[\sqrt[3]{weight/length}]100$).

Model No.	Dependent variable	Fixed factors in the model [a]	Covariate	Outliers removed
25	Night sleep duration	Ponderal Index, gender	Mother's BMI	4
26	Sleep duration per 24-hrs	Ponderal Index, gender	Mother's BMI	5
27	Percentage of sleep occurring at night	Ponderal Index, gender	Mother's BMI	1

a Ponderal index was included as a continuous variable (2.67-3.08), Mother's BMI was also included as a continuous variable (17.4-43.4).

The initial process for the mixed models was unstructured, however the software could not manage the large data set. Therefore in all mixed model ANCOVAs presented here, the covariance was modelled using the compound symmetry structure. This structure assumes that multiple measures have the same variance and that all pairs of measures from an individual have the same covariance. It also assumes that the covariance of repeated measures is due to the individual and not to relationships over time (Littell, Henry, & Ammerman, 1998).

Where fixed effects were statistically significant, post-hoc *t*-tests were used to investigate the relationships of interest. Based on the study hypotheses, the specific relationships of interest were:

1. Whether a positive relationship exists between sleep duration, propensity and efficiency with the stages of infants' development, after controlling for age and gender.
2. Whether a negative relationship exists between sleep duration and propensity with the body ponderal index of the infant, after controlling for gender and mother's BMI.

2.4.8 Analysis of Parental Feedback

Descriptive statistics from the nominal questions in the feedback form were calculated. Qualitative feedback was categorised and is also summarised in the results section.

3. Results

Fifty-eight families expressed interest in the study and 52 were recruited. Those who withdrew from the study did so due to their infant having a medical issue, which the parents felt would be affected by taking part (e.g., eczema), or discovering that the family did not have the time to dedicate to the study prior to their infant turning 14 months of age. Three families who expressed interest were not included in the study due to the data collection being completed prior to their infant turning 11 months of age.

Research results are presented below in five sections: the findings from the questionnaire data, followed by diary findings, and developmental scores (from the ASQ). Fourthly, the findings from the actigraphy recordings are presented. The relationships between actigraphic sleep data with questionnaire and diary data are investigated. Finally the outcomes from the feedback form are outlined.

3.1 *Description of the Sample Based on Questionnaire Data*

The seven page questionnaire was completed by the parents of all infants in the study (N=52). A description of the questionnaire can be found in section 2.1.1, and copy in Appendix A1. Findings from each area of the questionnaire are presented below.

3.1.1 Sample Characteristics

Among the 52 participating families, 33 of the infants were boys, and 19 were girls. About two-thirds (65.4%) of the infants were the first child for the parents. One set of fraternal twins were included in the study, the rest being single births. The infants ages ranged from 11 to 13.9 months (*Mdn* = 12.1 months).

The majority (88.5%) of infants were living in a household with two adults. However, for the other 11.5% up to six adults were reported to be living in a household. Two-thirds (65.4%) of the infants were the only child (under 17 years of age) to be living in the home, 23.1% were living with one other child, and 11.5% shared the home with two to five siblings. Forty percent of the infants spent time in childcare, varying from 2 to 45 hours per week (*Mdn* = 20 hours; *Mode* = 16 hours). Most of the infants had been breastfed (92.3%), and 38.5% were still breastfeeding at the time of data collection. Two-thirds (67.3%) of the infants were reported to be teething around the time of data collection.

Sixteen infants were considered to be unwell by the parents during the study week (31% of the sample), however, any infants whose medical condition would interfere with their taking part in the study were not recruited. None of the infants were considered by Dr Dawn Elder, the paediatrician on the study team, to require clinical follow up for either developmental or sleep-related concerns.

3.1.2 Body Habitus

Table 3.1 describes the body habitus of the infants and parents who took part in the study. Missing data were due to information being either unknown or not applicable. Circumstances included adopted infants, current pregnancy of the mother, or information simply not being known or accessible at the time of data collection.

There were 7 infants born prematurely, however, as can be seen in Figure 3.1, the minimum period of gestation was 35 weeks. Following the advice of the study's paediatrician, the infants' ages were not adjusted for subsequent data analysis. Figures 3.2 and 3.3 show that the weight of the sample was approximatley normally distributed at birth, as well as at the time of study.

Table 3.1

Descriptive Statistics for Body Habitus Results (Questionnaire Data).

	N	Median	Range
Gestation (weeks)	49	40.0	35-42
Infant age (months)	52	12.1	11.1 – 13.9
Head circumference (cm)	52	47.0	44 – 50
Weight (kg)	52	10.0	8 – 13
Length (cm)	52	76.5	76 – 82
Ponderal index (($\sqrt[3]{\text{weight}}$/length)100)	52	2.86	2.67 – 3.08
Weight at birth (kg)	51	3.50	2.2 - 4.6
Weight gain (kg)	51	6.98	4.2 – 9.1
Mother's BMI (kg/m ^{2})	49	23.38	17.4 – 43.4
Father's BMI (kg/m ^{2})	42	25.93	19.8 – 45.8

Note. Medians and ranges are reported as the data was not normally distributed.

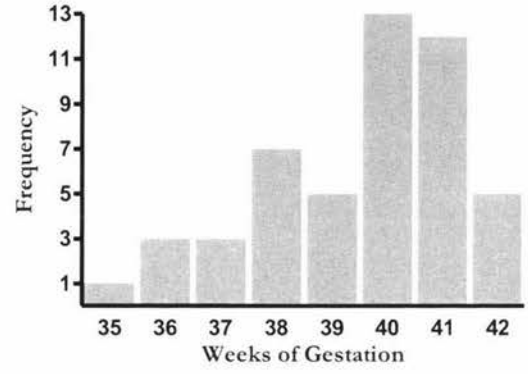


Figure 3.1. Frequency distribution of weeks of gestation of infants (n = 49).

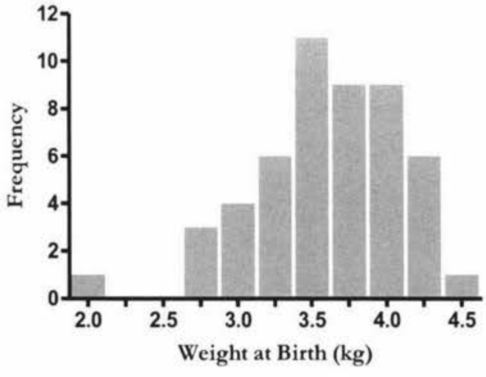


Figure 3.2. Frequency distribution of infants' weight at birth (n = 49).

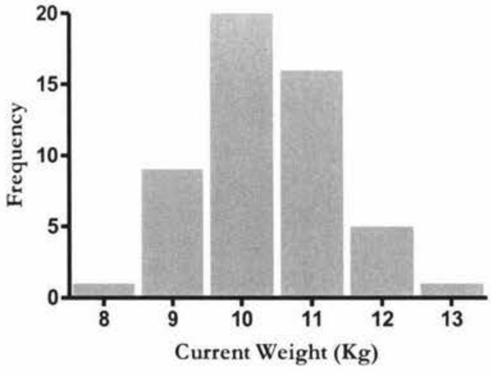


Figure 3.3. Frequency distribution of infants' weight at the time of study (n = 52).

None of the infants were in the range for growth retardation at 12 months. The infant who weighed below the 3rd percentile at birth (weighing 2.2 kg) weighed within the normal range (9 kg) the age of 1 year. At the time of study, 7 of the boys were over the 90th centile for weight and 1 was over the 97th centile. The girls were all under the 90th centile of weight for their age. Frequency distributions of length and weight by gender and centile curve can be found in Appendix Figures C1 and C2.

Twenty-nine percent of the mother's were classified as overweight (BMI $\geq$25 kg/m^2), and 14.3% as obese (BMI $\geq$ 30kg/m^2). Two-thirds of the fathers were overweight (66.7%), and 11.9% were obese. There was no significant relationship between the mothers' BMI and the infants' ponderal index, $n = 49$, $r = -.052$, $p = .361$.

The ponderal index could not be accurately calculated at the time of birth as the birth length was only recorded for 35% of the sample. As Figure 3.4 shows, there was a gender difference for ponderal index, with the girls being significantly higher (*Mdn* = 2.91) than boys (*Mdn* = 2.83, $U = 189.5$, *p*, one-tailed <.05, see Appendix Table C3).

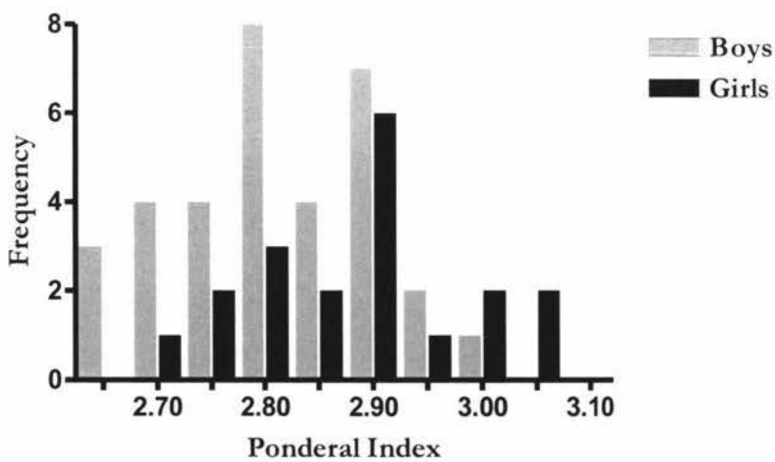


Figure 3.4. Ponderal index by gender (boys n = 33, girls n = 18).

3.1.3 Infants Sleep

Most of the infants were sleeping in a cot or bed in a bedroom separate from their parents or siblings. Only one infant was sharing the parental bed (Table 3.2). The majority were left to go to sleep alone compared to any other methods of soothing (Table 3.3). The infants were mainly sleeping in a prone position (46%), but many were also sleeping on their sides or in the supine position (Table 3.4). Parentally reported sleep timings, durations and awakenings, are summarised in Table 3.5.

Infants were reportedly sleeping an average 2.5 hours in the day and 11 hours at night. Over two-thirds (67.3%) of parents reported that their infant, on average, woke at least once per night for approximately 10 minutes. Over one-third (34.6%) of infants were waking in the night to feed. Sixty-one percent of those waking to feed were also infants who were still breastfeeding. The average time the infants were reported to fall asleep at night was 7 p.m., and they took approximately 5 minutes to settle. However, as illustrated in Figures 3.5 to 3.7, there was considerable variance in reported bedtimes, settling times and time spent awake at night.

Table 3.2

The Distribution of the Usual Place of Sleep (as Reported by Parents).

Where infant sleeps	Frequency	Percentage
Cot/bed separate room	44	84.6
Cot/bed parents room	4	7.7
Cot/bed siblings room	3	5.8
Parents bed	1	1.9

Table 3.3

Distribution of How Infants were Usually Settled to Sleep (as Reported by Parents).

How infant is settled	Frequency	Percentage
Alone in bed	44	84.6
Whilst feeding	4	7.7
In bed near parent	2	3.8
Being rocked	1	1.9
2 or more methods	1	1.9

Table 3.4

Distribution of the Infants' Usual Sleeping Position (as Reported by Parents).

Sleeping position	Frequency	Percentage
Supine	17	32.7
Prone	24	46.2
Side	11	21.2

Table 3.5

Descriptive Statistics for Sleep Timing Variables as Reported by Parents in the Sleep Questionnaire.

	N	Median	Range
Bed time (hrs: mins)	52	19:00	18:15 – 21:00
Settling time (mins)	51	5	0 – 75
Day sleep duration [a] (hrs)	52	2.5	1 – 5
Night sleep duration [b] (hrs)	52	11	7 – 12.75
Time awake [c] (mins)	50	10	0 – 120
Number of awakenings [c]	52	1	0 – 3
Wake for feed	52	0	0– 3

[a] Day sleep = 7 a.m. – 7 p.m.

[b] Night sleep = 7 p.m. – 7 a.m.

[c] Awake between 10 p.m. – 6a.m.

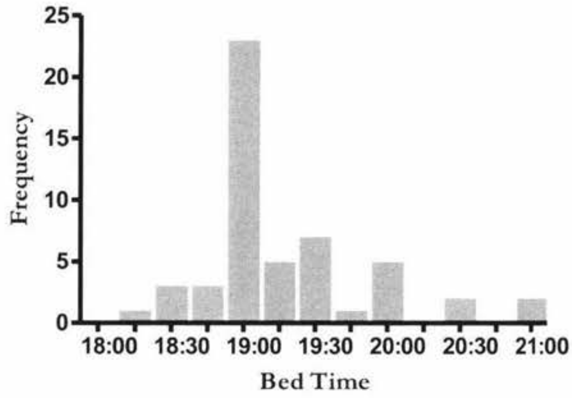


Figure 3.5. Frequency distribution of bedtime at night (parental report, N = 52).

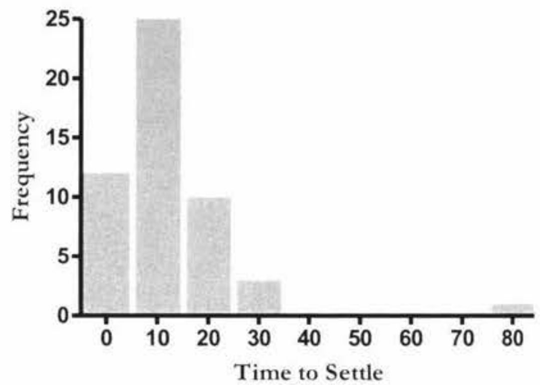


Figure 3.6. Frequency distribution of time to settle at night (parental report, n = 51).

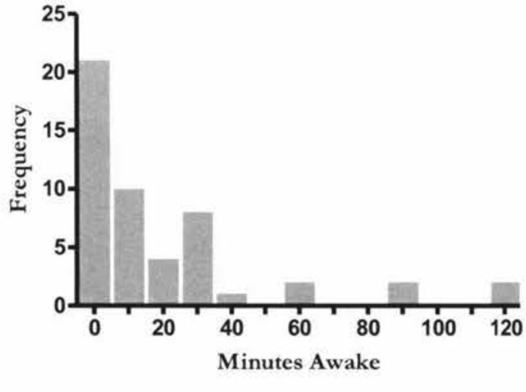


Figure 3.7. Frequency distribution of time spent awake during the night from 10 p.m.-6 a.m. (parental report, n = 50).

Although the majority of infants took 5 minutes or less to settle (58.8%), some (19.2%) were taking 20 minutes or more (up to 75 minutes) to settle to sleep at night. Reported time awake at night was also variable. Although many parents reported that their infant spent no time at all awake (36%), over one-third (38%) reported 20 minutes or more of wake between 10 p.m. and 6 a.m. (Figure 3.7).

Kolmogorov-Smirnov tests for normality were run on all questionnaire variables, as summarised in Table 3.6 (see also Appendix Table C1). As a large proportion of the questionnaire variables were not normally distributed, non-parametric tests were used in all analyses of the questionnaire data.

Table 3.6
Variables from the Questionnaire by Normality of Distribution.

Normally Distributed Variables	Skewed variables
Infants' age	Weeks of gestation
Birth weight	Infants' current weight
Ponderal index	Infants' current head circumference
Weight gain from birth	Mothers' BMI
Infants' length	Fathers BMI
Hours per week in childcare	Bedtime
	Minutes to settle to sleep
	Hours sleep at night
	Hours of sleep in day
	Number of awakenings
	Minutes awake in night
	Waking to feed
	Number of nights snoring
	Percent of study week in childcare

3.1.4 Problem Sleep

Problem sleep was defined from the parental questionnaire in three ways: firstly the report of snoring, secondly Sadeh's (2004) definition, and thirdly parents' perception of problem sleep (see section 2.4.1). Problem sleepers identified by each of these definitions are considered in more detail below.

Snoring.

Infant snoring or noisy breathing was reported to occur at least once per week by 17.3% of the parents. Half of the parents (51.9%) recalled no instances of snoring or noisy breathing (Figure 3.8). The remaining infants included the 16 deemed unwell during the study week (so the snoring question was not applicable), and one case of missing data.

Table 3.7 compares body habitus, sleeping variables (by parental report), and gender by snorers (one or more nights per week) and non-snorers. Due to the small size of the snoring group (n = 8) no statistical comparisons between the groups were carried out.

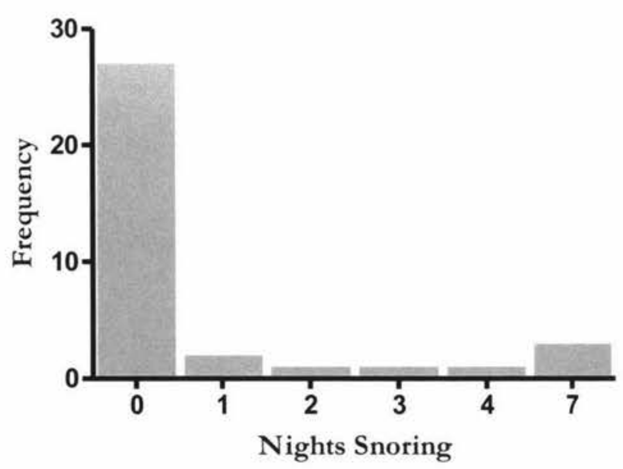


Figure 3.8. Frequency distribution of nights snoring (parental report, n = 35).

Table 3.7

Descriptive Statistics of Parentally-Defined Snorers (n = 8) and Non-Snorers (n = 27).

	Snorers		Non-Snorers	
Variable	Average	Range	Average	Range
Ponderal index (($\sqrt[3]{}$weight/length)100)	2.93	2.81 – 3.08	2.86	2.67 –3.01
Duration of night sleep (hrs)	10.50	7 – 12	11.00	10 – 12.75
Time to settle (mins)	15.00	0 – 75	5.00	0 – 30
Most common sleeping position	Side (42.8%)		Prone (51.9%)	
% girls	28.60		71.40	
% boys	19.00		81.00	

Sadeh-defined of problem sleep.

Only one infant was reported by the parent to sleep less than 9 hours per 24-hours, no infants were reported to wake more than three times, and only 7.7% reportedly spent more than 1 hour awake during the night. In total, five infants were defined as problem sleepers by exhibiting one or more of the Sadeh (2004) criteria. Of the five infants who were deemed problem sleepers by Sadeh's definition (2004), three were also reported as problem sleepers by the parents, and two were snorers. Due to the small number of problem sleepers identified by the Sadeh criteria, no statistical comparisons to non-problem sleepers were carried out.

Parentally-defined sleep problem.

None of the parents considered their infant's sleep to be *a very serious problem,* while 34.6% reported *a small problem,* and the remaining 65.4% reported their infant's sleep as *not a problem at all.* Chi-square analysis revealed no significant differences between gender and parental perception of a sleep problem χ^2 (1) = 0.66, p = .79 (two-tailed, see Appendix Table C4). To compare parentally-defined problem sleepers and non-problem sleepers, a number of questionnaire variables were dichotomised for chi-square analysis, as described in Table 3.8. Results from chi-square tests can be found in Table 3.9.

Table 3.8

Categories for Dichotomised Questionnaire Variables.

Variable	Category 1	Percent	Category 2	Percent
Wake time during the night	< 20 minutes	44.0%	≥ 20 minutes	36.0%
Time to settle at night	< 20 minutes	80.8%	≥ 20 minutes	19.2%
Place of sleep	Cot/bed alone	84.6%	Other	15.4%
Soothing techniques	Alone in bed	84.6%	Other	15.4%
First born	Yes	65.4%	No	34.6%
Breastfeeding	Still	38.5%	No longer	61.5%
Wake to feed	Yes	34.6%	No	65.4%
Teething	Yes	67.3%	No	32.7%
Childcare	Yes	40.4%	No	59.6%
Sleeping position [a]	Supine	32.7%	Prone	46.2%

[a] Infants sleeping on their side omitted from analyses (21.2%).

Table 3.9

Comparisons of Parentally-Defined Problem Sleepers and Other Infants (Chi-Square Analysis).

Variable	No problem	Small problem	χ^2 (1)	*p* (two- tailed)
First born	73.5%	26.5%	2.88	.127
Not first born	50.0%	50.0%		
Still breastfeeding	45.0%	55.0%	5.97	.019
No longer breastfeeding	78.0%	21.9%		
Teething	65.7%	35.3%	0.05	1.00
Not teething	64.7%	34.3%		
Awake ≥20 mins	31.6%	68.4%	16.78	.000
Awake<20 mins	87.5%	12.5%		
Has childcare	61.9%	38.1%	0.19	.769
No childcare	61.8%	32.3%		
Supine position	82.4%	17.6%	2.65	.173
Prone position	58.3%	41.7%		

Note. Variables unable to be included due to the expected count being less than five in one or more of the cells: waking for feeds, place of sleep, time to settle, or settling technique.

Table 3.9 shows that parentally-defined problem sleepers were 2.5 times more likely to be currently breastfeeding rather than no longer breastfeeding, and 5.4 times more likely to spend 20 minutes or more awake rather than less than 20 minutes awake at night.

Data from the parental questionnaire revealed no significant differences between the reported sleep onset time, or the amounts of daytime sleep that problem sleepers were having compared to other infants. However problem sleepers had significantly less sleep at night (approximately 40 minutes less) compared to the other infants (Table 3.10).

3.2 *Description of the Sample Based on Sleep Diary Data*

A sleep diary for the week of data collection was completed for each infant. In addition to the daily timeline of sleep and wake (to corroborate objective monitoring), parents rated their child's mood, alertness, temperament and activities. The modes of ratings were determined for each participant, and then the frequency distributions were created for the whole sample (Table 3.11).

During their study week, most of the infants tended to wake by themselves (rather than being woken by their parents or by something else). They were usually very alert on waking in the morning (or at least somewhat alert), and also in a good mood on most mornings.The majority of the infants had 'typical' activity levels across the study week.

At bedtime, two-thirds of the infants were usually in a good mood, however not as many as in the morning. Most of the infants were somewhat to very tired at their bed times, but around one-third were reported to have problems being put to sleep.

Table 3.10

Comparison of Questionnaire Data for Sleep Timings (By Parental Report) Between Problem Sleepers (n = 18) and Non-Problem Sleepers (n = 38, Mann-Whitney Test).

	No problem		Small problem				
Variable	Median	Range	Median	Range	*U*	*p* (one-tailed)	*Effect size*
Day sleep [a] (hrs)	2.5	1-5	2.5	1-4	286	.697	-.04
Time of sleep onset	19:00	18:15-20:30	19:21	18:30-21:00	881	.348	-.06
Night sleep [b] (hrs)	11.5	10-12.8	10.8	7-12	166	.003	-.38

[a] Day sleep = 7 a.m.–7 p.m.

[b] Night sleep = 7 p.m –7 a.m.

Table 3.11

Frequency Distributions of Answers to Daily Diary Questions.

Category	1	%	2	%	3	%	% Multiple answers
How wake	By themself	98.1	Parents	0	Other	1.9	0%
Alert a.m.	Very	78.8	Somewhat	15.4	Not- at-all	0	5.8%
Mood a.m.	Good	78.8	Moderate	17.3	Bad	1.9	1.9%
Activity levels	High	5.8	Typical	82.7	Low	3.8	7.6%
Bedtime problems	Many	0	Some	21.2	None	67.3	11.5%
Tired bedtime	Very	28.8	Somewhat	53.8	Not-at-all	3.8	13.4%
Mood bedtime	Good	67.3	Moderate	26.9	Bad	0	5.7%

Note. How wake? (How did your child wake up this morning?), *Alert a.m.?* (To what degree is s/he alert this morning?), *Mood a.m.* (Mood in morning?), *Activity levels* (Compared to other days, was this a: low/typical /high activity day?), *Bedtime problems* (To what extent were there problems putting your child to sleep?), *Tired bedtime* (To what extent did your child appear to be tired at bed time?), *Mood bedtime* (Mood at bed time?).

3.2.1 Diary Data of Parentally-Defined Problem Sleepers

Chi-square analyses revealed no significant relationship between being very tired and having problems being put to bed (χ^2 (1) = 0.27, *p*, one-tailed = .416, Appendix Table C5).

Responses for each of the variables rated daily in the diary were dichotomised as in Table 3.12. Membership to these categories was then compared between infants identified by their parents as having a sleep problem, and infants without sleep problems (Table 3.13). Parentally-defined problem sleepers were 2.6 times more likely to be in a moderate to bad mood compared to a good mood at bedtime (χ^2 (1) = 6.54, $p<.05$).

Table 3.12

Categorisation of Daily Diary Ratings.

Variable	Category 1	Category 2
Alertness a.m.	Very	Somewhat - Not*
Mood a.m.	Good	Moderate - Bad*
Activity levels	High*	Typical - Low
Bedtime problems	None*	Some - Many
Tired bedtime	Somewhat - not*	Very
Mood bedtime	Good	Moderate - bad*

Note. * Indicates category in which participants with multiple modes fell.

Table 3.13

Comparisons of Daily Diary Ratings for Problem Sleepers (Parentally-Defined) And Non-Problem Sleepers (Chi-Square Analysis).

Variable	No Problem	Small Problem	χ^2 (1)	*p*(one-tailed)
Very tired at bedtime	52.4%	47.6%	2.63	.093
Somewhat – not tired	74.2%	25.8%		
Some - many bedtime problems	65.7%	35.3%	0.01	1.00
No bedtime problems	64.7%	34.3%		
Moderate – bad bedtime mood	41.2%	58.8%	6.54	.013
Good bedtime mood	77.1%	22.9%		

Note. Daily diary variables unable to be included in Chi-square analysis due to the expected count being less than five in more than one of the cells: mood in the morning, alertness in the morning and levels of daytime activity.

3.2.2 Diary Data Over Weekends and Childcare Days

Diary data for each infant over their study period (7-12 days data) were split to determine the proportion of the study time which was a weekend (Saturday or Sunday) or spent in childcare (Table 3.14). For these analyses weekends were classified as Saturday and Sunday as the daily diary ratings pertain to the effects of the daytime experience rather than routine and timings of sleep.

Overall 65.4% of the infants were cared for by someone else at some point during their study week. However the amount of days spent in childcare was quite variable (Figure 3.9). As this data is not normally distributed (D, 52 = .254, p <.001), non-parametric tests were used in all analyses.

Table 3.14

Percentage of Study Days that were Weekends, or Infants were in Another Person's Care (as Defined by the Sleep Diary).

	Median	Range
Percent of study days that were Saturday or Sunday	25.0	22.2 – 37.5
Percent of study days in care	12.5	0 – 62.5

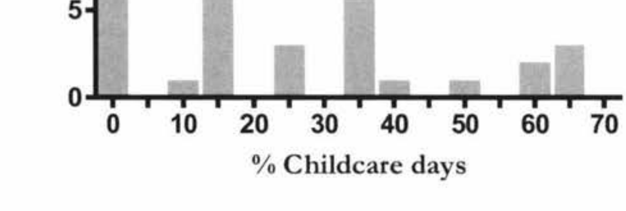


Figure 3.9. Frequency distribution of the amount of childcare (sleep diary data, N = 52).

McNemar tests were used to compare the daily diary ratings (as categorised in Table 3.12) by childcare versus non-childcare days (Table 3.15) and weekdays (Monday-Friday) versus weekends (Saturday and Sunday, Table 3.16). As these tests compare responses in a pair-wise fashion, only participants with a response on both occasions were included in the analyses.

Table 3.15

Changes in Daily Diary Ratings between Days With and Without Childcare (McNemar Test, n = 34 [a]).

Variable	% Same	%Better on care days	%Worse on care days	p(two-tailed)
Alertness a.m.	82.4	0.0	17.6	.031
Mood a.m.	76.5	11.8	11.8	1.00
Activity levels	66.7	21.2	12.1	.549
Bedtime problems	64.7	26.5	8.8	.146
Tired bedtime	55.9	17.6	26.5	.607
Mood bedtime	72.7	18.2	9.1	.508

[a] Activity levels and mood at bed time, $n = 33$.

Table 3.16

Changes in Daily Diary Ratings between Week Days (Monday to Friday) and Weekend Days (Saturday and Sunday, McNemar Test, n =52 [a]).

Variable	%Same	%Better on Weekends	%Worse on weekends	p(two-tailed)
Alertness a.m.	82.7	5.8	11.5	.508
Mood a.m.	61.5	5.8	32.7	.003
Activity levels	50.0	40.4	9.6	.002
Bedtime problems	59.6	9.6	30.8	.027
Tired bedtime	63.5	26.9	9.6	.064
Mood bedtime	64.7	9.8	25.5	.096

[a] Mood at bedtime , $n = 51$.

Although the majority of ratings for infants' mood and temperament did not change, parents were significantly more likely to rate their infants as less alert on childcare mornings compared to non-childcare mornings, with 17% of infants changing from very to somewhat-not at all alert (p, two-tailed <.05).

In approximately 30% of the sample activity ratings increased significantly from being typical or low on weekday to high on a Saturday or Sunday (*p*, two-tailed <.05). Over one-quarter of infants were more likely to be considered in a poor mood on a Saturday or Sunday morning compared to a weekday morning (*p*, two-tailed <.05). Almost one-third of infants were considered more problematic at bedtime on a Saturday or Sunday night, compared to week nights (*p*, two-tailed <.05).

3.3 *Developmental Progress*

The ASQ was completed by all (N = 52) parents. Frequency distributions for each ASQ domain can be found in Appendix Figures C3-C7. The distributions from all five domains were not normally distributed (Appendix Table C1), so non-parametric statistics were used.

Linear regression was used to evaluate whether ASQ scores were positively related to age, across the range of 11.1 to 13.9 months (Table 3.17). Developmental scores pertaining to gross motor skills, problem solving, and personal-social skills increased significantly with age. However, age only accounted for a small amount of the variance in ASQ scores.

Table 3.17

Relationships between Age (Months) and ASQ Results (Linear Regression Analysis).

Domain	R^2	*B*	*SEB*	*B*
Communication	.036	11.79	.291	.18
Gross motor	.084	11.67	.249	.29*
Fine motor	.051	10.81	.825	.23
Problem solving	.121	10.95	.471	.35*
Personal-social	.079	11.31	.418	.28*

Note: * = *p* <.05.

Table 3.18 outlines the ASQ scores for the infants split by gender. Table 3.19 highlights the proportion of boys and girls falling below the age-related thresholds for 'doing well at this time' (see section 2.1.2). Girls scored significantly lower than boys in the development of fine motor skills. There was also a trend towards less developed problem solving skills among the girls.

Table 3.18

Developmental Scores on the Five Domains of the ASQ Comparing Boys (n = 33) and Girls (n =19, Mann-Whitney Test).

	Boys	Girls			
Domain	Median (range)	Median (range)	*U*	*p*(two-tailed)	*Effect size*
Communication	40 (0-60)	45 (5-60)	290	.659	-.06
Gross motor	50 (0-60)	45 (0-60)	304	.853	-.03
Fine motor	55 (35-60)	50 (30-60)	158	.002	-.43
Problem solving	50 (20-60)	40 (15-60)	214	.056	-.27
Personal-social	45 (30-60)	45 (10-60)	250	.229	-.17

Table 3.19

Percentage of Infants Falling Below the Developmental Thresholds for Each ASQ Domain.

Domain	Boys	Girls
Communication	18.2	5.3
Gross motor	15.2	10.5
Fine motor	0	0
Problem solving	3	5.3
Personal-social	0	5.3

A higher proportion of boys fell below the age-related threshold for communication and gross motor skills, however these groups were too small for further analysis between genders. When assessing the percentage of infants falling below one or more threshold(s), there was no significant difference between boys (27.3%) and girls (26.3%), $\chi^2 = 0.01$, p (one-tailed) = .603. Likewise, there was no significant difference between the ASQ scores of parentally-defined problem sleepers versus non-problem sleepers (Appendix Table C6).

3.4 *Description of the Sample Based on Actigraphy Data*

Among the 52 families participating, four were asked to repeat the week of actigraphy and diary recording due to faulty equipment. One family repeated due to the family dogs eating the actigraph (see Appendix Figure C8)!

Active intervals or rest intervals containing any excluded time were omitted from analysis, as were days with more than 1 hour of total excluded time (section 2.4.4). A total of 267 days were deemed valid for analysis (65% of the total days recorded), with an average of 5 days per infant (Figure 3.10).

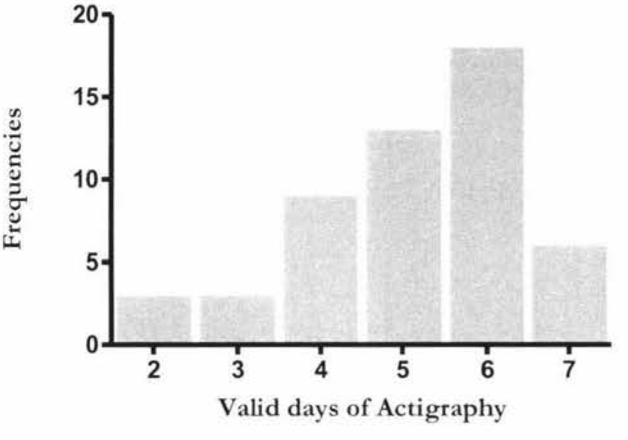


Figure 3.10. Frequency distribution of the number of days of valid actigraphy per infant (N = 52).

Data from the total valid days were averaged for each infant, and then across the group based on the day, night and 24-hour time frames (see Methods section, Table 2.2). Kolmogorov-Smirnov tests of normality indicated that the majority of the actigraphy variables were not normally distributed (Table 3.20, and Appendix Table C2). Non-parametric tests were therefore used for the statistical analysis for all variables. Table 3.21 gives descriptive statistics from the actigraphy data. Figures 3.11 to 3.20 show the frequency distributions for key actigraphic variables.

Table 3.20
Actigraphy Variables.

Normally distributed variables	Skewed Variables
Duration of rest intervals in day, night and per 24-hours	Activity counts/min - all active intervals
Duration of sleep intervals for day, night and 24-hour time frames	Number of rest intervals for day, night and per 24-hour timeframes
Sleep onset latency for daytime sleep intervals	Number of sleep intervals for day, night and per 24- hour timeframes
Sleep efficiency of daytime rest intervals	Bedtime at night
Sleep onset latency at night	Time of sleep onset at night
	Sleep efficiency during night rest interval
	Sleep efficiency during night sleep interval
	Wake-rise time for day and night timeframes
	Wake-rise time for day and night timeframes

Table 3.21

Descriptive Statistics for Actigraphic Sleep Data.

	Night time (7p.m.–7a.m.)		Daytime (7a.m.–7p.m.)		Per 24-hrs	
Variable	Median	Range	Median	Range	Median	Range
Activity counts/min - active intervals	102	20.6–638.5	406.1	235.1–884.8	388.7	219- 884.8
Number of rest intervals	1	1–3.5	2	1-3	3	1.5 - 5
Number of sleep intervals	1	1–3	1.5	0.5-2.5	3	2.0-4.5
Sleep onset latency (mins)	18	2.5 - 62.5	9.3	1.0-24.5		
Rest duration (hrs)	11.6	10.4–13.2	2.5	1.1-4.5	13.9	12.3 - 16.9
Sleep duration (hrs)	10.4	8.5–12.3	1.6	0.42-3	12.2	9.8- 14.4
Sleep efficiency during rest interval (%)	86.9	60.0–94.9	61.8	8.0 -90.8		
Sleep efficiency during sleep interval (%)	96.4	75.2– 99.5	97.8	19.6 -100		
Wake-rise time (mins)	24.5	2.0–111.5	8.3	0.9-36		

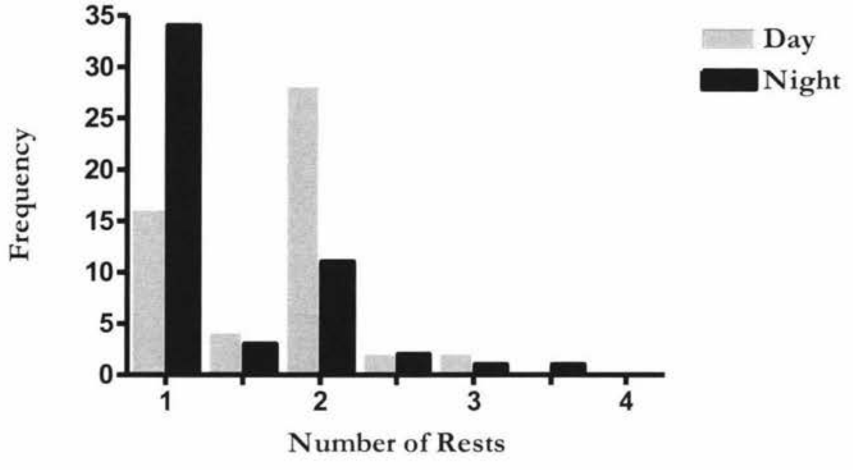


Figure 3.11. Frequency distribution for average number of rest intervals by day (7a.m.-7p.m.) and night time (7p.m.-7a.m.).

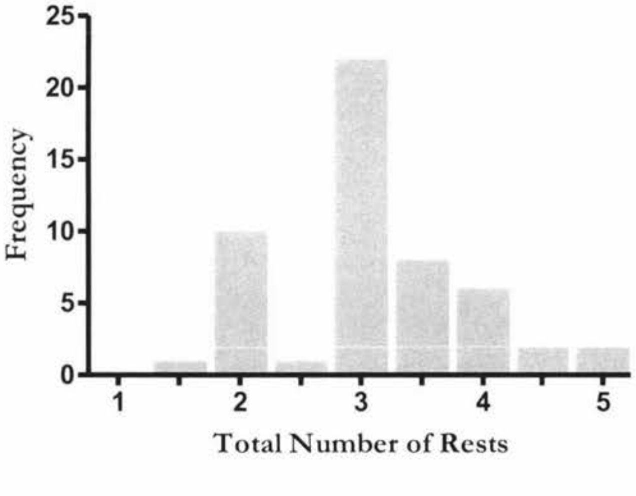


Figure 3.12. Frequency distribution for the number of rest intervals per 24-hrs.

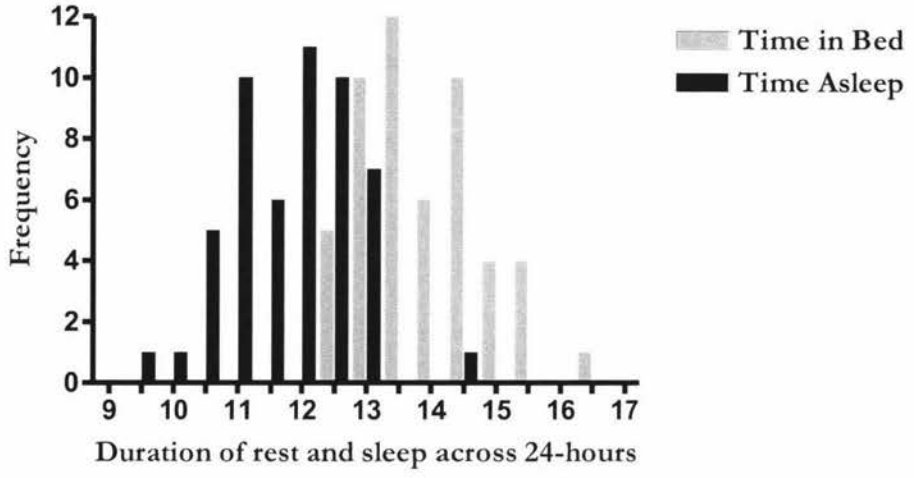


Figure 3.13. Frequency distribution for the average time in bed per 24-hrs (total duration of rest intervals, hrs) and time asleep per 24-hrs (total duration of sleep intervals, hrs).

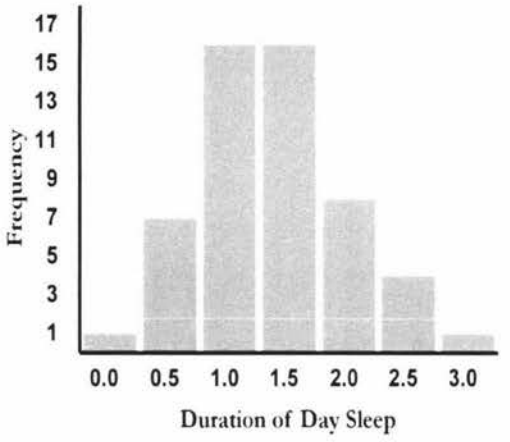


Figure 3.14. Frequency distribution for average duration of day sleep (hrs, 7a.m.-7p.m.).

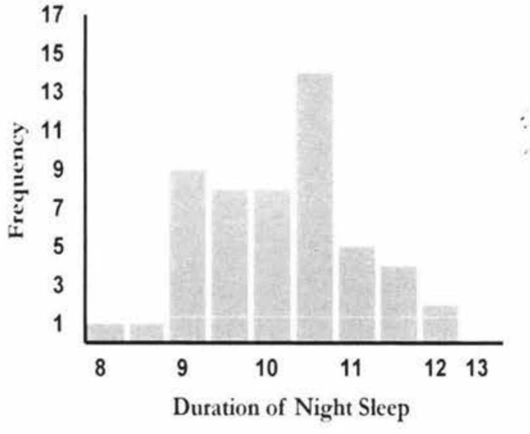


Figure 3.15. Frequency distribution for average duration of night sleep (hrs, 7p.m.-7a.m.).

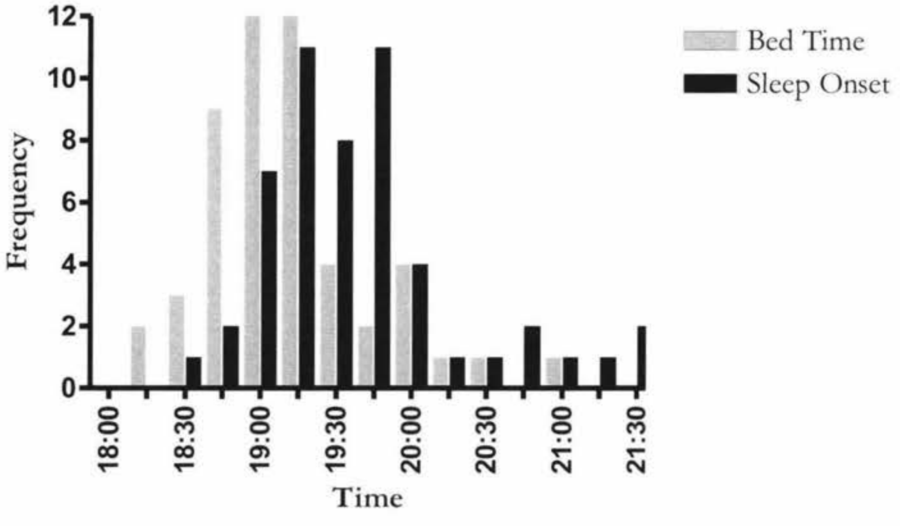


Figure 3.16. Frequency distribution for the average bedtime (time infants were put to bed/beginning of rest interval) and the average time of sleep onset (times infants fell asleep at night/beginning of sleep interval).

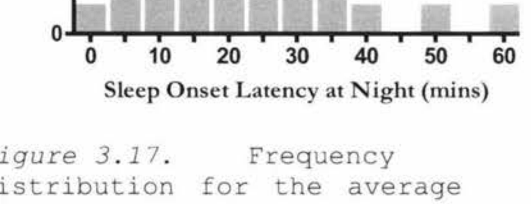


Figure 3.17. Frequency distribution for the average sleep onset latency (time between being put to bed and falling asleep) for the first night time sleep.

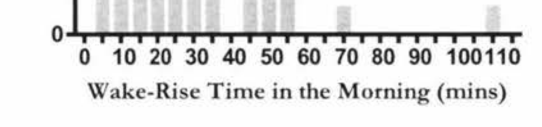


Figure 3.18. Frequency distribution for the average wake-rise time (the time between when infants' wake and when they are taken out of bed) in the morning.

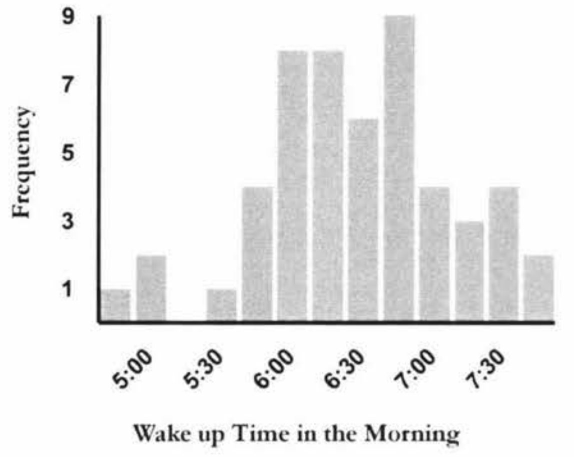


Figure 3.19. Frequency distribution for the average final wake up time in the morning.

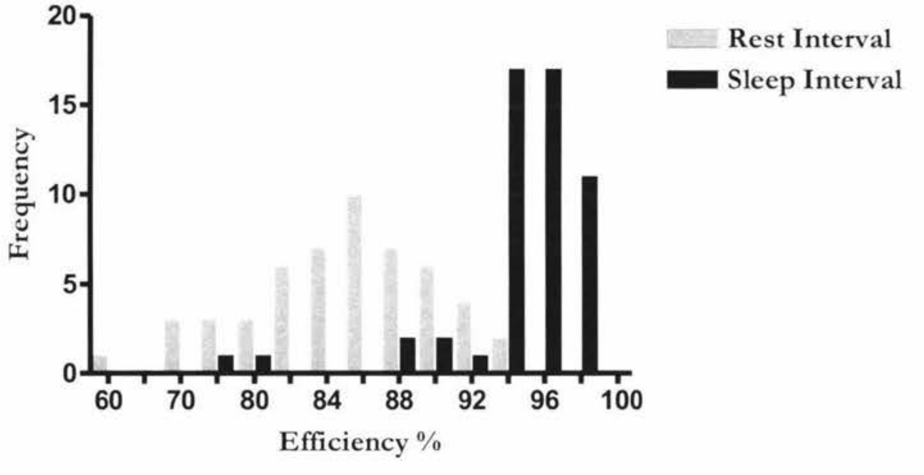


Figure 3.20. Frequency distribution of the average sleep efficiency during night time rest and sleep intervals.

Infants were being put to bed at an average time of 19:00 (18:15–20:55) and were falling asleep at an average time of 19:23 (18:26–21:20). They were waking up in the morning at an average time of 6:22 (4:49–7:45). Only four of the infants had an average sleep efficiency during the night time sleep interval of less than 90%. Sleep efficiency during the night time rest interval was more variable (Figure 3.20).

Mann-Whitney tests revealed no differences by gender for any of the actigraphic sleep variables (Appendix Table C7). Linear regression revealed that there were no significant correlations between the age of the infant and the duration of sleep at night or per 24-hours, nor was age related to sleep efficiency during the night time sleep interval (Appendix Table C8).

3.4.2 Sleep Propensity

As infants develop, sleep begins to consolidate to the night time, and the cessation of daytime naps is considered a milestone. The proportion of total sleep (per 24-hours) occurring at night (7p.m.–7a.m.) was calculated for each infant from the actigraphy data. None of the infants slept entirely at night (*Mdn* = 86.1%, *range* = 75.9%–95.8%) and there was great variability among infants in the distribution of sleep between night and day (Figure 3.21). Although there appears to be a linear relationship between age and the percentage of total sleep occurring at night (Figure 3.22), at the univariate level this relationship was non-significant (Appendix Table C8).

To estimate the overall distribution of sleep across the 24 hour day, data from the first 4 days from participants with 4 or more valid days of data were used to calculate the midnight-midnight sleep propensity curve in Figure 3.23 (n = 46 participants, 184 days). This shows that the majority of the infants were asleep from 19:00 through to 06:30. During the daytime approximately 20% of the infants were napping, except during two clear wakeful times, from 07:10 to 09:10 and from 15:40 to 18:10.

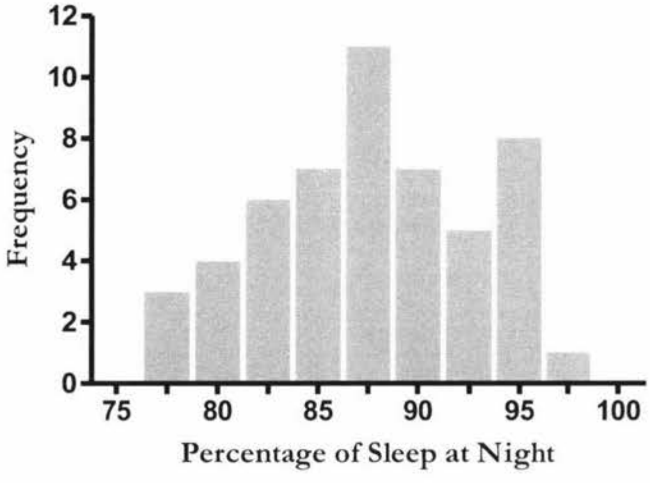


Figure 3.21. Frequency distribution of the percentage of total sleep time (24-hrs) which occurred at night (7p.m-7 a.m.).

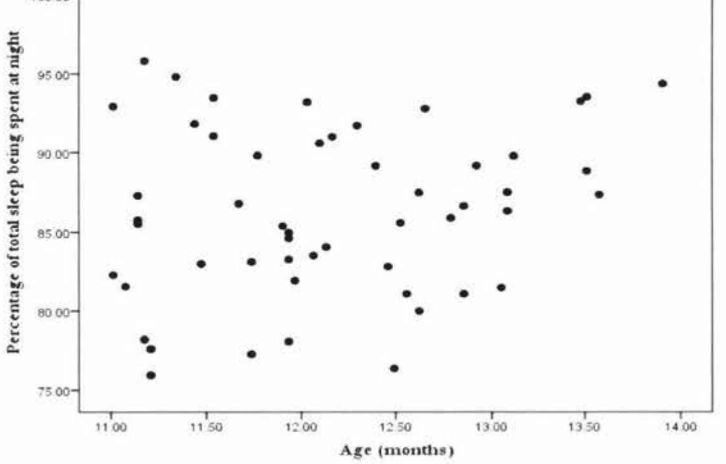


Figure 3.22. Scatterplot illustrating the relationship between age and the percentage of total sleep time occurring at night (7 p.m.-7 a.m.).

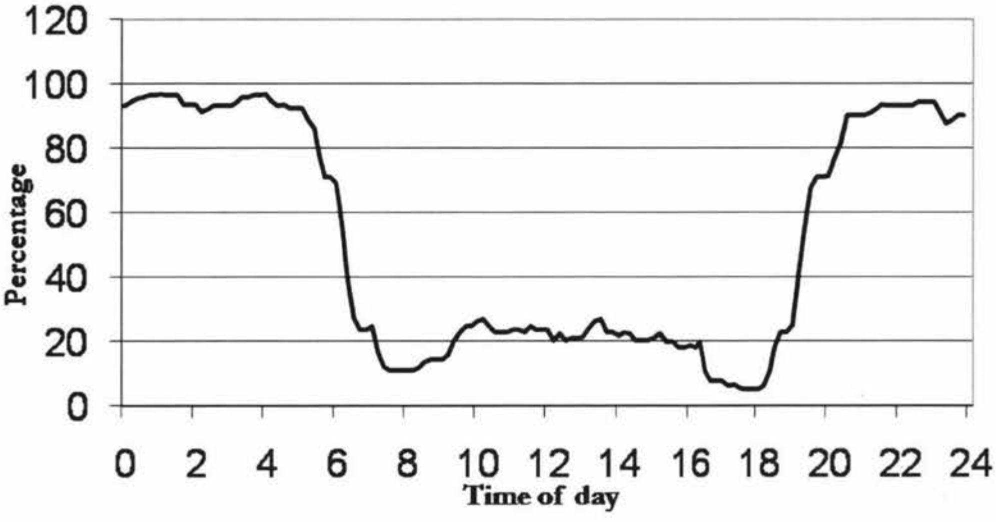


Figure 3.23. The percentages of infants asleep across the 24-hr day (n = 46).

3.4.3 Sleep and Body Habitus

Figures 3.24 to 3.26 show the relationships between ponderal index and sleep duration per 24-hours, hours of sleep at night, and the proportion of total sleep that occurred at night. Linear regression analyses confirmed that none of these relationships were significant (Appendix Table C9). The ponderal index distribution was bimodal (Figure 3.27), so the sample was split at the median (2.86). The data were split in this way rather than by infants above and below the 90th percentiles for weight as the numbers of infants measuring above the 90th centile were too few ($n = 7$).

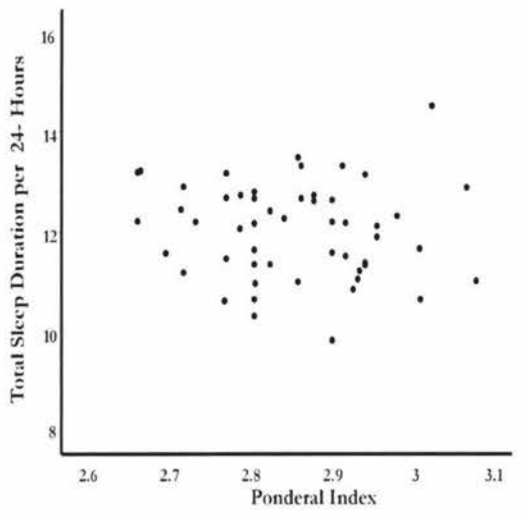


Figure 3.24. Scatterplot illustrating the relationship between ponderal index and sleep duration per 24-hrs (hrs).

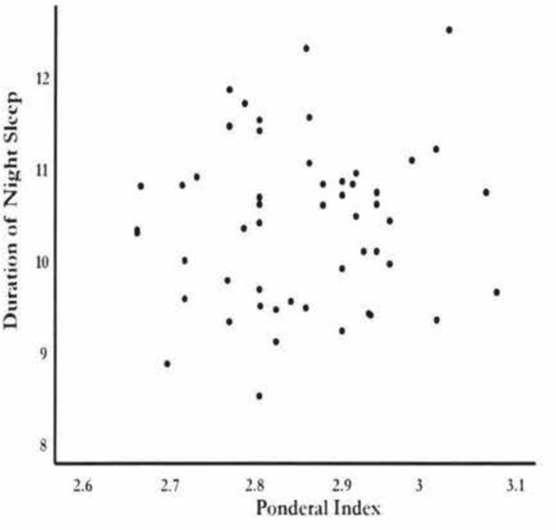


Figure 3.25. Scatterplot illustrating the relationship between ponderal index and duration of night time sleep (hrs,7p.m.-7 a.m.).

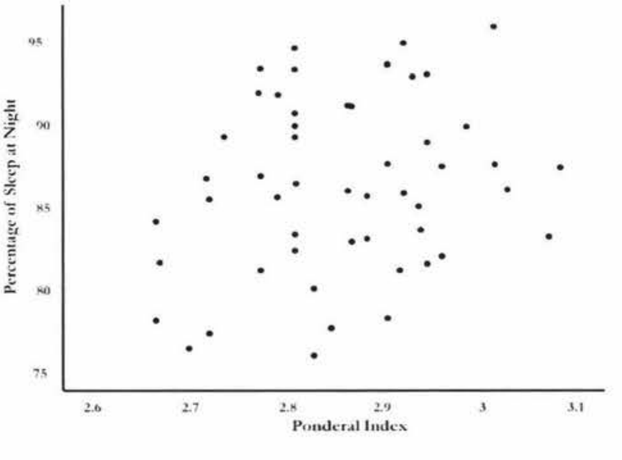


Figure 3.26. Scatterplot illustrating the relationship between ponderal index and the percentage of sleep occurring at night (7 p.m.-7 a.m.).

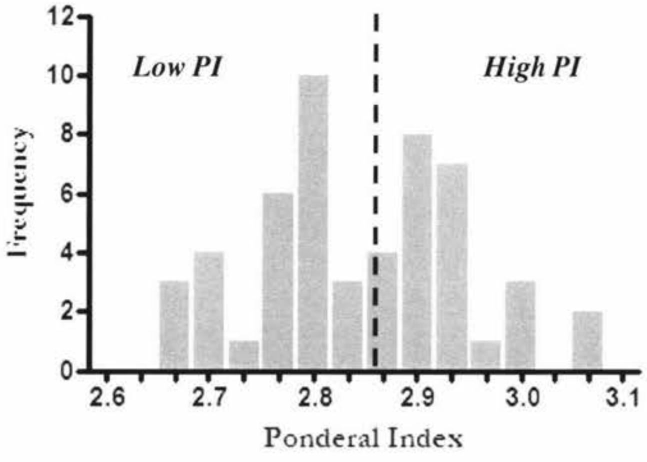


Figure 3.27. Histogram showing the bimodal split of high (n = 27) and low (n = 25) ponderal index.

Table 3.22 compares actigraphic sleep variables concerning the duration of rest and sleep intervals, as well as the sleep efficiency during night time sleep and the proportion of total sleep occurring at night. There were no significant differences between the high and low ponderal index groups.

3.4.4 Actigraphy of Parentally-Defined Problem Sleepers versus Non-Problem Sleepers

As noted in section 3.1.4, 35% of the infants were considered to have a 'small sleeping problem' by their parents. Actigraphic sleep variables for these infants were compared to those identified by their parents as having no sleep problems (Table 3.23). Parentally-defined problem sleepers slept approximately 1 hour less per 24-hours and had significantly more daytime rest intervals than other infants (p, one-tailed <.05). There was also a trend towards higher daytime activity levels in problem sleepers.

Table 3.22

Comparisons of Actigraphic Sleep Variables for High (n = 27) and Low (n = 25) Ponderal Index Infants (Mann-Whitney Test).

Variable	Low ponderal index Median (range)	High ponderal index Median (range)	*U*	*p* (two-tailed)	*Effect Size*
Night sleep duration (hrs)	10.3 (8.5 – 11.8)	10.6 (9.2 – 12.3)	283.5	.328	-.14
Sleep efficiency during night sleep interval (%)	96.5 (89.5 – 99.5)	95.8 (75.2 – 99.4)	269.0	.213	-.15
Number of rest intervals per 24- hrs	3 (2 – 4)	3.0 (1.5 – 5.0)	301.5	.497	-.09
Rest duration per 24-hrs	14.1 (12.3-15.9)	13.8 (12.3-16.9)	274.0	.251	-.10
Sleep duration per 24-hrs	12.2 (10.3 – 13.2)	12.1 (9.8 – 14.4)	336.0	.982	-.00
Percentage of total sleep occurring at night	85.5 (75.9 – 94.4)	87.3 (78.2- 95.8)	269.0	.215	-.17

Table 3.23

Comparisons of Actigraphic Sleep Variables for Parentally-defined Problem Sleepers (n = 18) and Non-Problem Sleepers (n = 38, Mann-Whitney Test).

Variable	No Problem Median (range)	Small Problem Median (range)	*U*	*p* (one-tailed)	*Effect Size*
Activity count per min-daytime active intervals	381.3 (235.1-884.8)	431 (252 – 781.6)	232.0	.079	-.20
Bedtime (average start of first night rest)	19:00 (18:15-20:17)	19:00 (18:26-20:55)	289.5	.378	-.04
Sleep onset latency at night (mins)	20.5 (6.0-62.5)	16.5 (2.5-36)	262.0	.202	-.12
Night sleep duration (hrs)	10.7 (9.2 – 12.3)	10.0 (8.5 – 12.5)	193.0	.015	-.30
Sleep efficiency during night rest interval (%)	86.8 (59.9 - 94.9)	86.9 (71.6 – 93.3)	274.5	.276	-.08
Sleep efficiency during night sleep interval (%)	95.8 (75.2 – 99.4)	96.5 (81.8 – 99.5)	275.5	.282	-.08
Time of final wake up in the morning	06:24 (05:30 – 07:45)	06:11 (04:49 – 07:32)	251.0	.148	-.15
Wake-rise time in morning (mins)	26 (2 – 111.5)	21.5 (5.5 – 70.9)	253.5	.159	-.14
Number of rest intervals per 24- hrs	3 (2 – 4.5)	3.5 (1.5– 5)	201.5	.018	-.29
Rest duration per 24-hrs (hrs)	14.1 (12.3 – 15.4)	13.6 (12.3 – 15.4)	244.0	.120	-.16
Sleep duration per 24-hrs (hrs)	12.5 (9.8 – 13.5)	11.4 (10.3 – 14.5)	169.5	.004	-.36
Percentage of total sleep occurring at night	86.1% (75.9 – 95.8%)	86.7% (76.4 – 93.2%)	296.0	.428	-.03

Note. Night intervals = 7 p.m. – 7 a.m.

3.4.5 Actigraphic Sleep Measures and Diary Ratings

Average daily diary ratings were compared to actigraphy measures of sleep. Infants who were typically rated as *somewhat alert* in the morning had significantly shorter sleep onset latency at night (approximately 9 minutes less) compared to *very alert* infants, (*p*, one-tailed <.05, Table 3.24).

Infants typically rated as in a *moderate* or *bad mood* in the mornings had significantly less hours sleep at night (by approximately 1 hour) compared to infants in a *good mood* (*p*, one-tailed <.05). Infants rated in poorer moods also woke up significantly earlier in the morning (by approximately 30 minutes) and had longer wake-rise times (over 15 minutes longer) compared to infants in a good mood in the morning (*p*, one-tailed <.05, Table 3.25).

Infants who were rated as *very tired at bedtime* had woken up significantly earlier in the morning (almost 30 minutes earlier) compared to infants who were *somewhat* or *not at all tired at bedtime* (*p*, one-tailed <.05, Table 3.26). None of the other daily dairy ratings were significantly related to actigraphic sleep variables (See Appendix Tables C10-C12).

Table 3.24

Comparisons of Actigraphic Sleep Variables for Infants Rated as Very vs. Somewhat Alert (as Rated Daily by Parents, Mann-Whitney Test).

	Very alert a.m.	Somewhat-not alert a.m.			
Variable	Median (range)	Median (range)	*U*	*p* (two-tailed)	*Effect size*
Activity count per min-daytime active intervals	407.2 (235.1–884.8)	355.6 (252.6– 657.0)	158.0	.135	-.21
Bedtime (average start of first night rest)	19:00 (18:15-20:17)	19:10(18:44–20:55)	163.5	.169	-.19
Sleep onset latency at night (mins)	21.0 (2.5 – 62.5)	12.5 (6.0 –34.0)	137.5	.048	-.27
Night sleep duration (hrs)	10.5 (8.5 – 12.3)	10.1 (9.4–11.2)	223.0	.960	-.00
Sleep efficiency during night rest interval (%)	86.9 (59.9 – 94.9)	87 (71.6–93.3)	220.0	.909	-.02
Sleep efficiency during night sleep interval (%)	96.5 (75.2– 99.5)	95.7 (81.8–99.4)	203.0	.623	-.07
Time of final wake up in the morning	06:21 (05:08 –07:45)	06:31 (04:49–07:32)	205.5	.662	-.06
Wake-rise time in morning (mins)	23.0 (2.0–111.5)	37.0 (8.5 – 70.9)	168.5	.207	-.18
Number of rest intervals per 24- hrs	3.0 (1.5–5.0)	3.5 (2.0–5.0)	178.5	.280	-.15
Rest duration per 24-hrs (hrs)	14.0 (12.3–16.9)	13.5 (12.8–15.9)	187.0	.400	-.12
Sleep duration per 24-hrs (hrs)	12.2 (9.8–14.4)	11.7 (10.7–13.3)	200.0	.577	-.08
Percentage of total sleep occurring at night	85.9 (75.9– 94.8)	86.4 (77.3–95.8)	206.0	.675	-.06

Note. Night intervals = 7 p.m.–7 a.m.

Table 3.25

Comparisons of Actigraphic Sleep Variables for Infants Rated as Good vs. Somewhat-Bad Mood in the Morning (as Rated Daily by Parents, Mann-Whitney Test).

	Good mood a.m.	Moderate - bad mood in a.m.			
Variable	Median (range)	Median (range)	*U*	*p* (two-tailed)	*Effect size*
Activity count per min-daytime active intervals	393.4 (235.5-884.8)	444.2 (286.9-774.4)	185.0	.375	-.13
Bedtime (average start of first night rest)	19:00 (18:26-20:55)	19:01(18:15-19:58)	214.5	.812	-.03
Sleep onset latency at night (mins)	18 (2.5 – 53)	22.5 (8 – 62.5)	172.5	.241	-.16
Night sleep duration (hrs)	10.6 (8.5 – 12.3)	9.6 (8.8 – 11.7)	118.5	.015	-.33
Sleep efficiency during night rest interval (%)	86.9 (59.9 - 94.9)	82 (74.2 – 90.6)	136.0	.045	-.28
Sleep efficiency during night sleep interval (%)	96.5 (75.2 – 99.5)	95.4 (92.9 – 98.2)	173.0	.246	-.16
Time of final wake up in the morning	06:25 (04:49 – 07:45)	05:57 (05:10 – 07:27)	139.5	.054	-.27
Wake-rise time in morning (mins)	21 (2 – 111.5)	38 (15 – 55.5)	123.5	.021	-.32
Number of rest intervals per 24- hrs	3 (1.5 –5)	3 (2– 4)	211.5	.751	-.05
Rest duration per 24-hrs (hrs)	13.9 (12.3 – 16.9)	13.9 (12.5 – 15.6)	219.0	.895	-.02
Sleep duration per 24-hrs (hrs)	12.2 (10.3 – 14.4)	11.6 (9.8 – 12.88)	165.0	.180	-.19
Percentage of total sleep occurring at night (%)	86.8 (77.3-95.8)	85.4 (75.9-93.6)	179.0	.307	-.14

Note. Night intervals = 7 p.m.–7 a.m.

Table 3.26

Comparisons of Actigraphic Sleep Variables for Infants Rated as Very Tired vs. Somewhat-Not Tired at Bedtime (as Rated Daily by Parents, Mann-Whitney Test).

	Very tired bedtime	Somewhat-not tired bedtime			
Variable	Median (range)	Median (range)	*U*	*p* (two-tailed)	*Effect size*
Activity count per min-daytime active intervals	417.1 (284.9 -884.1)	393.4 (235.1-884.8)	299.0	.152	-.20
Bedtime (average start of first night rest)	19:00 (18:15-20:08)	19:07(18:26-20:55)	272.5	.328	-.14
Sleep onset latency at night (mins)	12.5 (2.5 – 40)	22 (6 – 62.5)	244.0	.130	-.21
Night sleep duration (hrs)	10.3 (8.8 – 11.7)	10.6 (8.5 – 12.3)	283.5	.440	-.11
Sleep efficiency during night rest interval (%)	87 (74.2 - 94.3)	86.8 (60 – 94.9)	319.5	.915	-.02
Sleep efficiency during night sleep interval (%)	96.4 (89.5 –98.5)	96.5 (75.2 – 99.5)	289.5	.508	-.09
Time of final wake up in the morning	06:01 (04:49 – 07:27)	06:28 (05:08 – 07:45)	220.0	.049	-.27
Wake-rise time in morning (mins)	24 (5.5 – 55.5)	25 (2 – 111.5)	308.5	.757	-.04
Number of rest intervals per 24- hrs	3.5 (2 –5)	3 (1.5– 5)	239.5	.095	-.23
Rest duration per 24-hrs (hrs)	13.9 (12.3 – 15.3)	13.9 (12.5 – 16.9)	293.0	.554	-.08
Sleep duration per 24-hrs (hrs)	11.9 (10.6 – 13.3)	12.4 (9.8 – 14.4)	234.0	.089	-.24
Percentage of total sleep occurring at night (%)	85.6 (75.9-95.8)	87.4 (76.4-93.2)	281.0	.415	-.12

Note. Night intervals = 7 p.m.–7 a.m.

Wilcoxon signed-ranks tests were used to compare the actigraphy data of childcare with non-childcare days and weekends with weekdays. These tests compare responses in a pair-wise fashion, therefore infants without a response on both occasions were excluded from analysis.

Wake-up time on the morning of childcare days did not differ significantly from non-childcare days ($T = 13$, $Z = -.576$, p, one-tailed = .287). The data reported in Table 3.27 assesses the actigraphy during the day of, and night *after* care. The sleep efficiency during the night time rest interval was significantly higher on the nights after care compared to non-childcare nights, p, one-tailed <.05.

In order to assess the full effects of weekend activities, the data is split by two definitions of weekend. Weekend night time data were for Friday and Saturday nights (compared to Sunday-Thursday data), and the daytime data were for Saturday and Sunday days (compared to Monday-Friday data). There were no significant differences between the sleep (as defined by actigraphy) of Friday and Saturday nights compared to Sunday-Thursday nights. Infants had significantly longer sleep latency (an average of 5 minutes longer) on Saturday and Sunday nights compared to weekdays (p, one-tailed <.05). Consequently, sleep efficiency during the night time rest interval was significantly lower on Saturday and Sunday nights (p, one-tailed <.05, medium, Table 3.28).

Table 3.27

Comparisons of Actigraphy Data on Childcare (19.5% of Days) to Non-Childcare (80.5% of Days) Days (Wilcoxon Signed-Rank Tests).

		Childcare	Non-childcare				
Variable	*n*	Median (range)	Median (range)	T	Z	*p* (two-tailed)	*Effect Size*
Activity count per min-daytime active intervals	27	385.6 (188.5 – 885.5)	408.0 (240.0 – 878.2)	182.0	-.168	.878	-.02
Day sleep duration [a] (hrs)	28	1.4 (0.3 – 3.7)	1.7 (0.7 – 3)	165.0	-.865	.396	-.16
Sleep efficiency during day rest interval (%)	28	64.6 (6.5 – 91.8)	63.9 (13.9 – 86.2)	179.0	-.547	.396	-.10
Sleep efficiency during day sleep interval (%)	28	98.4 (19.3 – 100)	97.57 (19.6 – 99.4)	181.0	-.142	.859	-.04
Bedtime (average start of first night rest interval)	29	19:00 (16:38 – 20:45)	18:59 (18:22 – 19:54)	164.5	-.589	.566	-.10
Sleep onset latency at night (mins)	29	16 (3 – 86)	21 (0.5 – 66)	198.5	-.411	.689	-.08
Night sleep duration [b] (hrs)	28	10.7 (5.5 – 12)	10.1 (8.8 – 11.9)	127.5	-1.720	.087	-.32
Sleep efficiency during night rest interval (%)	28	87.7 (76.4 – 95.8)	86.3 (64.3 – 95.6)	107.0	-2.190	.028	-.41
Sleep efficiency during night sleep interval (%)	28	95.5 (81.3 – 99.7)	96. 0(83.2 – 99.6)	185.5	-.399	.699	-.07
Wake-rise time in morning (mins)	29	17.5 (1 – 84)	31 (6 – 75.1)	127.0	-1.730	.085	-.32
Number of rest intervals per 24- hrs	28	3 (2 – 5)	3 (2 – 5)	70.5	-.674	.545	-.09
Rest duration per 24-hrs (hrs)	28	13.9 (12.4 – 15.9)	14 (12.1 – 15.6)	191.0	-.273	.792	-.05
Number of sleep intervals per 24-hrs	28	3.0 (2.0 – 4.0)	3.0 (1.5 – 4.5)	44.0	-.533	.672	-.10
Sleep duration per 24-hrs (hrs)	28	12.1 (8.7 – 14.0)	12.2 (9.7 – 13.9)	185.0	-.410	.695	-.00

[a] Day intervals = 7 a.m.–7 p.m.

[b] Night intervals = 7 p.m. –7a.m.

Table 3.28
Comparisons of Actigraphy Data on Weekends to Weekdays (Wilcoxon Signed-Rank Tests)

		Weekend (Fri & Sat night)	Weekday (Sun- Thurs night)				
Variable	*n*	Median (range)	Median (range)	T	Z	*p* (two-tailed)	*Effect size*
Bedtime (average start of first night rest)	48	19:00 (17:39 – 20:49)	19:00 (18:16 – 21:01)	478.0	-.440	.665	-.06
Sleep onset latency at night (mins)	47	21 (0 – 100)	19(0 – 120)	489.0	-.322	.752	-.05
Night sleep duration [a] (hrs)	47	10.4 (5.9 – 12.7)	10.4 (8.7 – 12)	508.5	-.587	.562	-.09
Sleep efficiency during night rest interval (%)	47	86 (58.6 – 95.3)	86.7(59.9 – 95.7)	527.5	-.386	.704	-.06
Sleep efficiency during night sleep interval (%)	47	96.2 (70.6 – 100)	96.2 (66.3 – 99.6)	485.0	-.836	.411	-.12
Time of final wake up in the morning	47	06:16 (02:52 –08:36)	06:22 (05:05 –0 8:36)	522.0	-.439	.665	-.06
Wake-rise time in morning (mins)	47	28 (1 – 219)	25 (1 – 111.5)	508.0	-.355	.727	-.05
		Weekend (Sat/Sun daytime)	Weekday (Mon-Fri daytime)				
Activity count per min-daytime active intervals	45	432.1 (204.1 – 867.1)	412.5 (188.5 – 884.1)	420.0	-1.10	.276	-.12
Day sleep duration [b] (hrs)	49	1.7 (0 – 3.2)	1.7 (0.3 – 3.0)	579.0	-.092	.929	-.01
Sleep efficiency during day rest interval (%)	48	67.0 (7.7 – 88)	61.2 (0.9 – 93.9)	570.5	-.179	.861	-.02
Sleep efficiency during day sleep interval (%)	48	97.3 (19.7 – 100)	97.8 (19.6 – 100)	476.5	-.926	.362	-.13
Bedtime	48	18:56 (18:00 – 21:40)	19:01 (18:12 – 21:01)	445.0	-1.36	.220	-.19
Sleep onset latency at night (mins)	49	23 (2 – 206)	19 (0 – 62.5)	391.5	-2.02	.043	-.29
Night sleep duration (hrs)	49	10.5 (6.6 – 13)	10.6 (8.2 – 12.2)	605.0	-.075	.943	-.01
Sleep efficiency during night rest interval (%)	49	86.4 (39.3 – 95.6)	87 (62.4 – 95.7)	362.0	-2.49	.012	-.36
Sleep efficiency during night sleep interval (%)	49	96.1 (77.4 – 99.7)	96.6 (66.7 – 99.7)	459.5	-1.52	.129	-.22
Wake-rise time in morning (mins)	50	32.7 (1 – 95.5)	24 (1 – 111.5)	591.5	-.444	.661	-.06
Number of rest intervals per 24- hrs	49	3 (2-5)	3 (1-5)	178.0	-.579	583	-.08
Number of sleep intervals per 24-hrs	49	3 (1-5)	3 (2-5)	263.0	-.100	.999	-1.4
Rest duration per 24-hours (hrs)	49	14.2 (12.2 – 16.6)	13.9 (11.9 – 17.7)	534.0	-.781	.440	-.11
Sleep duration per 24-hrs (hrs)	49	12.3 (8.6 -14.7)	12.2 (10.05 – 14.5)	610.0	-.025	-982	-3.6

[a] Night intervals = 7 p.m.–7 a.m.

[b] Day intervals = 7 a.m.–7 p.m.

3.4.6 Actigraphic Sleep Measures and Developmental Progress

In order to assess the possible relationships between infants' sleep and stages of development, ranked correlations were performed between scores from each of the ASQ domains (see section 2.1.2) and the sleep duration and timing variables: hours of sleep at night, hours of sleep per 24-hours, sleep efficiency within the night time sleep intervals, and the percentage of total sleep that occurred at night (Table 3.29).

Table 3.29

Relationships between Sleep Variables and Developmental Scores on the ASQ (Spearman's Rank Correlation).

Sleep Variable ASQ domain	Night sleep duration	Sleep duration per 24-hrs	Sleep efficiency during night sleep interval	Percentage of total sleep occurring at night
Communication	-.210	.013	.138	-.031
Gross motor	.089	.142	.457**	-.126
Fine motor	-.207	-.036	.263*	-.274*
Problem solving	-.007	.094	.475**	-.138
Personal-social	.195	.141	.229	.124

Note. * p <.05 ** p <.001

There was a positive relationship between the average sleep efficiency during the night time sleep interval and infants' developmental scores for the gross motor (p, one-tailed <.001), fine motor (p, one-tailed <.05) and problem solving (p, one-tailed <.001) domains. The percentage of sleep at night was negatively associated with the development of fine motor skills, r_s=-.277, p (one-tailed) <.05.

Mann-Whitney tests were used to assess any differences in actigraphic sleep variables between infants who scored below one or more developmental threshold(s) (n = 14), and infants above developmental thresholds (n = 38, Table 3.30). Infants who were below one or more threshold(s) had significantly lower sleep efficiency during the night time sleep intervals than those above the ASQ thresholds, p, (one-tailed) =.001.

Table 3.30

Comparing Actigraphic Sleep Measures between Infants Above and Below ASQ Thresholds.

	Below threshold(s)	Above thresholds			
Variable	Median (range)	Median (range)	*U*	*p(one-tailed)*	*Effect size*
Night sleep duration [a] (hrs)	10.6 (9.2 – 11.5)	10.4 (8.5 – 12.3)	261.5	.465	-.01
Sleep efficiency during night sleep interval (%)	94.6 (75.2 –99.5)	96.8 (81.7 – 99.5)	124.5	.001	-.40
Sleep duration per 24-hrs (hrs)	12.2 (9.8 – 13.2)	11.6 (10.3 – 14.4)	237.0	.279	-.08
Percentage of total sleep occurring at night (%)	85.4 (77.3 – 95.8)	86.7 (75.9 – 94.8)	251.0	.384	-.04

[a] night interval = 7 p.m.–7 a.m.

3.5 *Mixed ANCOVAs for Actigraphy Variables*

Data from all 267 valid days (2-7 days per participant) of actigraphy recording were analysed using mixed model ANCOVAs for repeated measures. Mixed models were used to analyse the relationships between actigraphic sleep variables and developmental stage, age (categorised into six groups by 2 week intervals), and gender. Actigraphy variables examined were sleep duration at night and per-24 hours, as well as the sleep efficiency during the night time sleep interval and the proportion of total sleep that was occurring at night.

Significant relationships were found between sleep duration at night and age (when controlling for gender, development of problem solving and personal-social skills, and whether or not the infant fell below one or more developmental threshold(s), Table 3.31). Post-hoc t-tests revealed that the duration of night time sleep had, in general, a positive trend with age.

Sleep efficiency during the night time sleep interval was positively related to the development of problem solving skills as well as being in the above developmental thresholds group (Table 3.32). For example, after controlling for gender and age, the sleep efficiency during the night time sleep interval was approximately 15% higher (range = 0.89-29.4%) for infants who scored above developmental thresholds compared to those scoring below one or more threshold(s), $t\ (46.7) = -2.14$, $p < .05$. Sleep duration per 24-hours was not significantly related to development, age or gender (Table 3.33).

Table 3.31

Results from the Mixed Model ANCOVAs Examining Rlationships Between Night Sleep Duration and Developmental Progress, Age, and Gender.

Model No.	Fixed factor	(*df*) *F*	*p*	Fixed factor	(*df*) *F*	*p*	Fixed factor	(*df*) *F*	*p*
1	Communication	(12, 31.5) 0.75	.693	Age	(4, 30.4) 1.64	.189	Gender	(1, 31.2) 0.35	.558
2	Gross motor	(10, 34.6) 0.99	.469	Age	(4, 34.3) 1.18	.338	Gender	(1, 35.5) 0.39	.535
3	Fine motor	(6, 43.2) 0.79	.584	Age	(4, 34.6) 1.06	.390	Gender	(1, 36.2) 0.59	.446
4	Problem solving	(8, 34.8) 0.99	.461	Age	(4, 35.2) 2.60	.053	Gender	(1, 37.8) 0.99	.463
5	Personal-social	(8, 35.8) 1.49	.195	Age	(4, 33.0) 2.79	.042	Gender	(1, 34.0) 0.09	.767
6	Below threshold	(1, 39.1) 0.00	.996	Age	(4, 39.1) 2.57	.053	Gender	(1, 40.8) 0.00	.976

Table 3.32

Results from the Mixed Model ANCOVAs Examining Relationships Between Sleep Efficiency During the Night Time Sleep Interval, Developmental Stage, Age, and Gender.

Model No.	Fixed factor	(*df*) *F*	*p*	Fixed factor	(*df*) *F*	*p*	Fixed factor	(*df*) *F*	*p*
7	Communication	(12, 36.0) 0.75	.593	Age	(4, 35.0) 1.09	.378	Gender	(1, 35.3) 1.47	.234
8	Gross motor	(10, 39.4) 1.88	.078	Age	(4, 39.4) 1.09	.376	Gender	(1, 40.4) 1.57	.218
9	Fine motor	(6, 47.8) 3.45	.007	Age	(4, 39.9) 2.92	.033	Gender	(1, 41.5) 3.91	.055
10	Problem solving	(8, 38.9) 3.23	.006	Age	(4, 39.1) 0.89	.479	Gender	(1, 41.0) 0.94	.337
11	Personal-social	(8, 40.4) 0.67	.714	Age	(4, 38.6) 1.45	.236	Gender	(1, 39.0) 2.27	.714
12	Below threshold	(1, 46.7) 4.57	.038	Age	(4, 46.7) 0.78	.544	Gender	(1, 47.8) 2.63	.111

Table 3.33

Results from the Mixed Model ANCOVAs Examining Relationships Between Sleep Duration Per 24-hrs and Developmental stage, Age and Gender.

Model No.	Fixed factor	*(df) F*	*p*	Fixed factor	*(df) F*	*p*	Fixed factor	*(df) F*	*p*
13	Communication	(12, 29.6) 1.35	.245	Age	(4, 28.5) 0.59	.676	Gender	(1, 29.4) 0.59	.613
14	Gross motor	(10, 31.6) 0.95	.504	Age	(4, 31.4) 0.51	.371	Gender	(1, 32.7) 0.82	.371
15	Fine motor	(6, 43.3) 1.91	.100	Age	(4, 34.4) 0.60	.665	Gender	(1, 35.8) 2.28	.140
16	Problem solving	(8, 32.6) 1.05	.420	Age	(4, 33.0) 0.48	.747	Gender	(1, 35.1) 0.07	.786
17	Personal-social	(8, 34.1) 0.63	.744	Age	(4, 31.7) 1.07	.390	Gender	(1, 32.2) 0.02	.880
18	Below threshold	(1, 36.7) 0.02	.897	Age	(4, 36.1) 0.79	.537	Gender	(1, 37.6) 0.65	.426

The sleep efficiency during the night time sleep interval was also significantly related to fine motor development, however the trend of this relationship was negative. When controlling for this domain of development, age and gender were also significantly related to sleep efficiency. Therefore these relationships may have confounded the relationship between fine motor development and on sleep efficiency.

The percentage of total sleep occurring at night was positively related to the development of communication and problem solving skills (Table 3.34). For example, those scoring low in the problem solving domain (minimum score = 15) had a lower estimated proportion of sleep occurring at night (estimated difference - 11.12%, range = -0.17 - -20.51%) compared to those scoring the maximum (60) in this developmental domain, t (33.4) = -2.41, p <.05). A positive trend was also found between the percentage of total sleep occurring at night and age (when controlling for gender, and development of communication, fine motor, problem solving and personal-social skills).

Mixed model ANCOVAs were also used to investigate the relationship between actigraphic sleep variables (duration of sleep at night, duration of sleep per 24-hours and the proportion of total sleep that was occurring at night) with ponderal index, and gender whilst controlling for mother's BMI. As with the univariate analysis (section 3.4.2), the relationship between sleep and ponderal index was not significant (Table 3.35).

Table 3.34

Results from the Mixed Model ANCOVAs Examining Relationships Between the Percentage of Sleep Occurring at Night and Developmental Stage, Age and Gender.

Model No.	Fixed factor	(*df*) *F*	*p*	Fixed factor	(*df*) *F*	*p*	Fixed factor	(*df*) *F*	*p*
19	Communication	(12, 32.7) 3.43	.003	Age	(4, 31.5) 3.46	.019	Gender	(1, 32.4) 2.28	.141
20	Gross motor	(10, 36.8) 0.43	.922	Age	(4, 36.5) 1.51	.219	Gender	(1, 37.2) 0.01	.938
21	Fine motor	(6, 48.3) 2.19	.060	Age	(4, 40.1) 3.32	.019	Gender	(1, 41.7) 0.00	.962
22	Problem solving	(8, 36.3) 2.40	.035	Age	(4, 36.6) 3.78	.011	Gender	(1, 38.5) 0.57	.455
23	Personal-social	(8, 38.3) 1.50	.188	Age	(4, 36) 3.16	.025	Gender	(1, 36.8) 0.08	.775
24	Below threshold	(1, 43.2) 0.69	.412	Age	(4, 43.2) 2.42	.063	Gender	(1, 44.7) 0.69	.678

Table 3.35

Results of the Mixed Model ANCOVAs for Sleep Variables and Ponderal Index ((³√weight/length)100).

Model No.	Dependent factor	Fixed factor	(*df*) *F*	*p*	Fixed factor	(*df*) *F*	*p*	Covariate	(*df*) *F*	*p*
25	Night sleep duration	Ponderal index	(1, 40.4) 0.19	.668	Gender	(1, 42.5) 0.69	.411	Mother's BMI	(1, 39.5) 0.03	.865
26	Sleep duration per 24-hrs	Ponderal index	(1, 39.2) 0.04	.836	Gender	(1, 41.1) 0.12	.734	Mother's BMI	(1, 38.3) 0.16	.687
27	Percentage of sleep occurring at night	Ponderal index	(1, 45.1) 0.83	.367	Gender	(1, 46.5) 0.03	.861	Mother's BMI	(1, 45.1) 0.40	.529

3.6 *Parental Feedback on Study Procedures*

Of the 52 participating families, 43 returned feedback forms after completing the study. Table 3.36 outlines how the parents initially heard about the study. All of the participants felt they had sufficient information about the study prior to taking part, and 83.3% felt that any questions they had concerning the study were answered reasonably (the other 16.8% having no questions). Table 3.37 gives the frequencies of how families answered questions concerning the use of the actigraph, sleep diary, and questionnaires.

Table 3.36

Feedback on Recruitment: "How Did You Hear About This Study?"

Source	Percentage of families
Parents Centre	32.5%
Friend	30.2%
Library	16.0%
Other (notices, emails)	21.4%

Table 3.37

Frequencies and Percentages of How Parents Found Data Collection.

	Easy	OK	Difficult
Actigraph use	20 (46%)	16 (37%)	10 (23%)
Diary use	28 (65%)	14 (32%)	0
Questionnaire use	28 (65%)	14 (32%)	0

3.6.1 Comments

For each area of the feedback form, parents were free to comment on the research. Below is an outline of this feedback:

Actigraphy comments:

1. Forgot or found it difficult to press event marker (n = 13).
2. Actigraph band fault (n = 10).
3. Monitor slipped/infant moved out of place (n = 9).
4. Accidently left off /forgot to replace after bathing (n = 5).
5. Concern that car trips may look like sleep due to less activity (n = 1).

Diary comments:

1. Confusion around definitions e.g. unplanned sleep and mood (n = 4).
2. More space required (n = 4).
3. Remembering to do it (n = 3).
4. Additional codes (n = 3):
    1. 'Aborted sleep' if parent forced the infant out of bed.
    2. 'Arousal' if infant wakes before end of sleep period.
    3. How infant was settled?' could be recorded daily.

Questionnaire comments:

1. Took a long time (n = 3).
2. Question on whether infant was walking suggested (n =1).

3. Unclear if 'last week' referred to monitoring week or week before (n =1).
4. Answers could change one day to the next (n =1).
5. Some things had to be looked up, e.g. in Plunket book (n =1).

General comments.

Parents had space to write further comments at the end of the feedback form. Many of these included praise for the research process as a whole. Parents enjoyed participating and through doing so it *"made us more aware of his sleeping patterns"*. However some participants did confess that they had thought it would be easier and less time consuming (n = 2).

Suggestions included having a longer study *"to observe before and after teething"* or *"two practice days"* and also including questions concerning parenting styles (e.g., day-to-day feeding and routines). Parents also noted that, due to it being hard to know if/when their infant was awake at night, the event marker was not always pressed.

4. Discussion

The main aims of this study were to pilot the methodology for the objective recording of infants' sleep in NZ and to gather data concerning the factors that affect their sleep. This was achieved through collecting actigraphic data from 52 infants in the Wellington region, together with questionnaires and sleep diaries. Feedback on the study's methods and protocol were gathered from the participating families in order to refine methodology for future studies.

The present findings give a first glimpse of how NZ 1-year-olds are sleeping. Results are generally in support of past research from western cultures. Hypotheses concerning problematic sleep, temperament and stage of development were supported. However relationships between sleep duration and ponderal index, as well as the day of the week, were not supported, possibly due to the age of the infants or the small size of the sample.

Data concerning the sleep of NZ infants' have, up to this point, been subjective in nature. The present findings help to define the range of normal sleep which is useful for parents as well as clinicians. This study adds to the body of research concerning infants' sleep through the use of objective monitoring to investigate risk factors highlighted in past research.

This chapter provides an overview of the main study findings within the context of relevant past literature. Strengths and limitations of the study are highlighted and discussed, and suggestions for future research are made.

4.1 *The Sample of Infants and the Ecology of Sleep: Recruitment and Parental Reports*

4.1.1 Limitations of Recruitment

The sample in the present research were recruited through advertisements disseminated in public places, as well as via email to Parent Centre groups and by word-of-mouth. The majority of participating families reported hearing about the study either through the library or Parent Centre. This method of recruitment did not result in a representative sample of Wellingtonian infants. Families accessing and using these services are more likely to be of a higher SES and of Pākehā ethnicity (Abel, et al., 2001).

The sample was not structured to enable comparisons by ethnicity or socioeconomic deprivation. Parents' levels of education or medical and psychiatric well-being were also not assessed. Such factors should be controlled for in future studies, due to the links between these distal extrinsic factors with infants' sleep (Acebo, et al., 2005; Armstrong, et al., 1998; Lam, et al., 2003; Morrell & Steele, 2003; Rona, et al., 1998; Sadeh & Anders, 1993). Somatic illnesses of the infants were not recorded. Illnesses such as asthma and allergies have been related to sleep quantity and quality (Dahl, et al., 1995; Diette, et al., 2000; Kahn, et al., 1989; Weissbluth & Weissbluth, 1992). Therefore, future studies may consider using the presence of such conditions as exclusion criteria in recruitment. Such criteria were not used in the present study due to the relatively small sample size and because the main aim of the study was to pilot methodology.

Past literature highlights differences in sleeping practices between ethnicities in NZ (Abel, et al., 2001; Gledhill, 1974; Scragg, et al., 1996; Tuohy, et al., 1998).

Furthermore, in Japan, differences of sleep timing have been identified between geographical regions (Ma, et al., 1993). It is important that future research investigates whether such cultural differences remain in NZ and likewise, whether there are differences between rural and urban lifestyles. Future research should aim to use multiple methods of recruitment in order to reach a more representative sample of families, thereby obtaining more reliable data on the sleep ecology and timings of NZ infants.

There were a disproportionate number of boys compared to girls recruited. Future studies should stratify the sample in order to have an equal gender balance. Premature birth was not controlled for in analyses as only seven premature infants were recruited and the earliest was born at 35 weeks of gestation. Although the marital status of the parents was not requested in the questionnaire, most of the infants were living in a household with at least two adults. Future studies may consider recruiting a sub-sample of single parent families in NZ, in order to assess whether there are differences in sleep ecology, timing and quality, as have been found in past studies in other countries (e.g., Wolf, et al., 1996; Zuckerman, et al., 1987).

The prevalence of parents classified as overweight or obese in the present study was comparable to studies of American adults (National Sleep Foundation, 2009), as well NZ (Agras, et al., 2004; Landhuis, et al., 2008). Birth length and weight as well as current length and weight of the infants was comparable to infants in Australia (Hall, et al., 2007; So, et al., 2007), however this NZ sample was heavier and longer than their German counterparts at 1 year of age (Toschke, Grote, Koletzko, & von Cries, 2004), reflected by a higher ponderal index in the present study.

Past studies have found a correlation between parents' and infants' body status (Locard, et al., 1992; J. J. Reilly, 2005; Williams, 2001). However, these studies tended to include larger samples of infants over 1 year of age, and used weight or BMI rather than ponderal index. In the present study, mothers' BMI was unrelated to infants' ponderal index.

Over one-third of infants were still being breastfed in this study, and two-thirds were reported to be teething at the time of participation. These frequencies are comparable to prevalence rates reported elsewhere for 1-year-olds (DeLeon & Karraker, 2007; Goodlin-Jones, et al., 2001; Tomson, 2000).

4.1.2 Sleep Ecology

Consistent with other western cultures, the infants in this sample were mostly sleeping in a bedroom by themselves, and being left to soothe themselves to sleep at night (Goodlin-Jones, et al., 2001; Morrell & Cortina-Borja, 2002; Sadeh, Mindell, Luedtke, & Wiegand, 2007). However, there was much less variance of place of sleep or soothing methods compared to past studies of similar age groups overseas (Jenni & Molinari, 2006; Morrell & Cortina-Borja, 2002; Sadeh, 2004; Sadeh, et al., 2007; Taveras, et al., 2008; Thünstrom, 1999). Of the present sample, just 8% were sleeping in their parents' bedroom, with one infant actually sharing the parental bed. In a large internet study in the America and Canada, Mindell et al. (2007) found that 12 to 14% of 9 to 17-month-olds were co-sleeping with their parents. Likewise, in a large UK sample of 13 to 19-month-olds, almost 20% of infants were settling in the parent's bed (Morrell & Cortina-Borja, 2002). However in NZ, Wooding et al. (1990) reported similar figures to the present study, with just 10% of infants sleeping in the parents' bedroom by 11 months of age. Likewise, 85% of the present sample were being left to soothe themselves to sleep, whereas of a sample of 122 American infants, Adair et al. (1991) found that 33% of the parents were routinely present when their 8 to 12-month-old infant fell to sleep at night. These findings suggest that, within this sample, and indeed in NZ, autonomy is being encouraged (Morrell & Cortina-Borja, 2002). These practices are in line with NZ parenting guides (Plunket, 2008; Tomson, 2000).

The finding that many infants were sleeping in the prone position was not considered an issue, as the risk of SIDS has reduced by this age (Kahn, et al., 2006; Mitchell, et al., 1992; Tomson, 2000). The sleep position of infants was indicated by parents' reports of what position infants usually slept *most of the time*. To reliably monitor sleep position and evaluate its relationship with actigraphic sleep measures and development, future studies may consider using a digital position sensor alongside actigraphy or PSG.

The lack of variability in the sleep ecology of NZ infants could be due to the disproportionate number of Pākehā being recruited into research. In the study of Wooding et al. (1990), 80% of the infants were Pākehā and in the present sample ethnicity was not considered in the recruitment processes. As mentioned in section 1.6.1, much of the variability of sleep ecology in NZ is likely to be accounted for by ethnicity and culture. Therefore future studies should aim to compare the sleep practices between ethnic groups in NZ.

The lack of variability of the present sample could also be due to the nature of the questionnaire, with fewer options and a limited timeframe compared to alternative infant sleep questionnaires (e.g., the Parental Interactive Behaviour Scale, Morrell & Cortina-Borja, 2002). Due to the limited variability of the place of sleep and soothing techniques, these variables were not compared to actigraphic sleep measures in the present study. Future studies may find it more reliable to keep a daily report of distal extrinsic factors, as well as the mediating relationship between parent and infant. For example, place and position of sleep, and soothing methods used at bedtime as well as times of night waking (Morrell & Cortina-Borja, 2002; Sadeh & Anders, 1993).

4.2 *How are NZ Infants Sleeping?*

4.2.1 Objective versus Subjective Data

Discrepancies have been highlighted in past research between subjective and objective measures of infant sleep (e.g., Sadeh, 1994, 2004; A. Scher, 2001a; Werner, et al., 2008). In the present sample, bedtime was accurately documented by parental questionnaire when compared to actigraphy, with both methods giving an average of 7 p.m. The amount of time spent in bed (as identified actigraphically by rest intervals) was consistent with parental reports as well as national recommendations (Plunket, 2008; Tomson, 2000). In contrast, the duration of actual sleep (as measured actigraphically by sleep intervals) is overestimated by parents (by over 30 minutes) and is less than recommended. Time to settle appears to be underestimated by the parents, with actigraphy recording approximately 12 minutes longer, for infants to settle at night.

These findings are not surprising given that the majority of the parents are leaving their infant to soothe themselves to sleep. Thus their ability to accurately predict settling time as well as sleep duration is limited. These findings are consistent with past research indicating that parental reports overestimate sleep duration (Nixon, et al., 2008; So, et al., 2007; Werner, et al., 2008).

4.2.2 Sleeping like a (Normal) Infant?

Actigraphy recordings revealed that this sample of infants was sleeping approximately 10.5 hours at night and 2.5 hours in the day, with sleep onset latencies of 18 and 9 minutes respectively. Infants were being put to bed on average three times per 24-hours, but up to five times in some instances. The sleep efficiency of this group was high, with an average of 96.3% sleep during a night time sleep interval, and 86.9% sleep during a night time rest interval. These findings are comparable to the norms reported from past studies (e.g., Goodlin-Jones, et al., 2008; Hyde, et al., 2007; Sadeh, 1994; Sadeh, et al., 1991; A. Scher & Asher, 2004).

From the parental questionnaire, around 20% of the infants were reported to take a long time to settle (20 minutes or more) and over two-thirds were waking at least once per night. Although none of the infants were waking more than three times per night, almost 40% were reportedly awake for 20 minutes or more between 10 p.m. and 6 a.m. These results are comparable to past research (Goodlin-Jones, et al., 2008; Sadeh, 1994, 2004; A. Scher, 2001a; A. Scher & Asher, 2004; Thünstrom, 1999; Wooding, et al., 1990). Variance of bedtime, settling time, and time spent awake in the night are indicative of the individual differences in sleep in this age group and should not necessarily be considered problematic (Richman, 1981).

Development changes of the sleep/wake cycle are evident in this sample of infants. Actigraphy recordings revealed that an average of 86% of total sleep time was occurring at night. None of the infants were sleeping entirely at night, with an average of two daytime naps, a finding similar to past studies (So, et al., 2007;

Wooding, et al., 1990). This finding is indicative of the fast cycle of the homeostatic drive for sleep within this age group. With no clear differences between the sleep latency of daytime sleeps compared to night time sleeps, the homeostatic process S is considered to be still in development (Fagioli, et al., 2002; Jenni & LeBourgeois, 2006).

Compared to past studies, the proportion of total sleep occurring at night is higher in the present sample (approximately 12% higher, So, et al., 2007; Spruyt, et al., 2008). In these past studies daytime was defined from 8 a.m. rather than 7 a.m. which may explain some of the variance. However, infants in the present study were not waking up any later than 7:45 a.m. (and any sleep durations for which more than 50% of the interval occurred after 7 a.m. would have been defined as daytime, see section 2.4.5). Definition of night and day varies between studies. In the present study, 7 a.m. to 7 p.m. was used because this time frame was used in the BISQ (Sadeh, 2004), which was incorporated into the study's questionnaire.

The sleep propensity curve produced in the present study shows a clear preference to sleep at night as well as periods of wake in the early morning and late afternoon. Daytime sleep was most likely to occur between 12 p.m. and 4 p.m. This is a clear indicator of the maturation of the circadian and homeostatic cycles (Jenni, et al., 2006; Jenni, Molinari, et al., 2005; Sadeh & Anders, 1993; Sheldon, 2006). The sleep propensity curve developed in the present study closely resembles past studies from the first year of life (Ma, et al., 1993; Pollak, 1994; Sadeh, 2001).

Actigraphy data concerning sleep timing and durations did not differ between boys and girls, which is consistent with previous research of infants and children (Sitnick, et al., 2008; So, et al., 2007; Tikotzky & Sadeh, 2001; Werner, et al., 2008).

The proportion of sleep stages have been found to differ by gender (Sadeh, et al., 1991), but the stages of sleep were not measured in the present study as the reliability of actigraphy for defining sleep states is questionable (Gnidovec, et al., 2002; Pollak, et al., 2001; Sadeh, Acebo, et al., 1995; Sazonova, et al., 2006). Future studies may benefit from including a sub-sample of infants whose sleep is measured using PSG, in order to assess the maturation of sleep stages and cycles at this age.

4.3 *Problem Sleep*

4.3.1 Defining Problem Sleep

Sadeh's (2004) definition of problem sleep identified only five infants in the sample (10%). This definition was derived in order to identify infants with clinically-relevant sleep problems. From the Sadeh-defined group, only three were also identified as problem sleepers by the parents and two were reported to be snoring one or more times per week. Descriptive statistics from the actigraphy recordings also indicated that sleep efficiencies for the sample were within the 'normal' range (Sadeh, 1996; Tikotzky & Sadeh, 2001), with just four infants having a sleep efficiency during the night time sleep interval below 90% (average 96.4%).

Too few problem sleepers were identified by the Sadeh or snoring definitions to permit comparisons with the remaining infants in the sample. Furthermore, defining problem sleep through reports of snoring is not reliable due to the high proportion of infants sleeping alone. Indeed, the prevalence of snoring in the present sample was less than of larger NZ studies in the past (Mitchell & Thompson, 2003). Furthermore, the severity of snoring was not captured in this sample. Oximetry or PSG would be required to diagnose specific sleep disordered breathing (Halbower &

Marcus, 2003; M. S. Scher, 2006). It is recommended that future studies recruit a specific clinical group to make reliable assessments of risk factors for particular sleep problems.

Defining problematic sleep through night waking behaviours was not possible in this sample because no infants were reported to wake excessively (over three times) at night. Moreover, although one-third of infants' were reported to wake for feeding, alternative reasons for waking were not recorded (e.g., unable to self-soothe, comfort or unwell). Therefore comparisons of the reasons for waking and effects of parental interactions could not be made. It is recommended that future studies use more reliable measures of night waking and compare signalling versus self-soothing behaviours (maybe incorporated into the sleep diary or using video observations in a subsample). Such factors have been found to be significantly related to current and persistent sleep problems in infancy (Goodlin-Jones, et al., 2001; Jenni, Fuhrer, et al., 2005; Morrell & Steele, 2003).

Regardless of the 'normality' of the sample's sleep, one-third of the parents considered their infant's sleep to be somewhat problematic (although none reported a severe problem). That parents reported problem sleep in the absence of clinically-defined problems verifies the importance of considering both subjective and objective measures of infants sleep. The level of parentally-reported sleeping problems in this study is similar to past findings which indicate that 10 to 30% of infants during the first years of life are likely to suffer from a sleep-related problem (Goodlin-Jones, et al., 2008; Ottaviano, et al., 1996; Sadeh, et al., 2009; A. Scher & Asher, 2004; Thünstrom, 1999; Zuckerman, et al., 1987).

The percentage of problem sleepers in this sample may have been skewed by the recruitment techniques used. Sadeh (2004) comments on the issue of the disproportionate number of infants with sleeping problems being recruited into research samples. This is due to parents of problem sleepers being more interested in the sleep of infants and seeking solutions for problem sleep, thus making these families more likely to volunteer for such research. Future studies may benefit from recruiting three separate samples based on the question *do you consider your child sleep: no problem at all, a small problem* or *a severe problem?* However, such studies should bear in mind that actigraphy is less reliable in sleep-disturbed groups (Hyde, et al., 2007; Paquet, et al., 2007; Sadeh, Hauri, et al., 1995; So, et al., 2005), and so the use of PSG might be considered.

4.3.2 Factors Associated with Parentally-Defined Problem Sleepers

As in past research, the likelihood of parents identifying their infants as problem sleepers did not differ between genders (Adair, et al., 1991; Jenni, Molinari, et al., 2005; Touchette, et al., 2005), nor between first born and subsequent children (Adair, et al., 1991; A. Scher, et al., 1995; Wooding, et al., 1990). However, infants who were parentally-defined as having a sleep problem were significantly more likely to be still breastfeeding, which has been highlighted in past research in this age group (DeLeon & Karraker, 2007; Hall, et al., 2007; J. Mindell, Sadeh, Luedtke, & Wiegand, 2007; Zuckerman, et al., 1987). The relationship between breastfeeding and problematic sleep has been associated with more time spent awake at night, faster digestion of breast milk, as well as the development of poor habits with regards to sleep rhythmicity and self-soothing behaviours (Mindell, 1997, as cited in DeLeon & Karraker, 2007; Hall, et al., 2007; Touchette, et al., 2005). Breastfeeding at the age of 1 year has also been identified as a risk factor for the persistence of sleep problems into childhood (Hall, et al., 2007). This could be due to the significant relationship between breastfeeding and parental presence at bedtime, increasing the chances of sleep onset association problems (Adair, et al., 1991).

It should be noted that, of the 35% of infants waking to feed during the night, 71% were still breastfeeding at the time of participation. Indeed, Mindell et al. (2007) reported that breastfeeding only accounted for 10% of the variance in the number of night awakenings. It appears that the frequency of feeding (whether by breast or bottle) may be a contributing factor to night awakenings (Nikolopoulou & James-Roberts, 2003). Due to the small sample size in the present study, 'waking for feeds' could not be analysed in relation to problem sleep. Future studies need to investigate the precise differences between the sleep of breastfeeding infants and non-breastfeeding infants.

Parental report of time spent awake at night was also significantly associated with the likelihood of reporting that their infant had problem sleep. Infants spending 20 minutes or more awake at night were more likely to be considered problem sleepers than those spending less than 20 minutes awake. This is consistent with past studies indicating that parentally-defined problem sleepers also wake more often and for longer periods (Sadeh, 2004; Sadeh, et al., 1991; Sadeh, et al., 2009).

Although soothing technique and place of sleep have been associated with problematic sleep in past studies (Adair, et al., 1991; Goodlin-Jones, et al., 2001; Morrell & Cortina-Borja, 2002; Morrell & Steele, 2003), these factors could not be investigated in the present study due to the small sample size. Teething has also been correlated with sleep problems and night waking during the first years (Sadeh, et al., 2007; Wooding, et al., 1990; Zuckerman, et al., 1987), however, this relationship was not significant in the present study. Past studies of the symptoms of teething found that although 70% of parents reported that disturbed sleep was a symptom of teething, when assessing sleep and tooth development on a day-by-day basis, sleep was not significantly related (Wake, Hesketh, & Lucas, 2000). Therefore it is possible that teething is used as a scapegoat for co-existing problems and events around this age.

Actigraphic recordings confirmed the questionnaire findings in that parentally-defined problem sleepers were having approximately 42 minutes less sleep at night compared to other infants. Sleep duration per 24-hours was also significantly reduced, suggesting that these infants do not make up for lost sleep during the day. The time spent in bed did not differ between groups and, unlike Sadeh's (1991) study, sleep efficiency was not significantly lower among problem sleepers in the present study (discrepancies between studies could be due to the recruitment of a specific clinical sample in the study of Sadeh et al.). Problem sleepers had significantly more rest intervals compared to other infants. Therefore, it appears it is the number of attempts to put the infant down to sleep that is contributing to parents' perception of problem sleep. Parents are putting these infants to bed more often, but the infants are not achieving as much sleep as those considered good sleepers. Previous studies have reported that sleep duration, number of awakenings, and the time spent awake whilst in bed account for 70% of the variance when identifying problem sleepers (Sadeh, 2004). De Leon and Karraker (2007) also found that infants spending more time awake at night are more likely to be put down for more naps in the day, however sleep is not necessarily achieved.

No infants were considered to have a severe sleep problem, indicating that results pertaining to the 'problem' sleepers should be interpreted with caution. Another limitation to using parental perceptions to define problem sleep is that such perceptions will be based on parental knowledge and expectations surrounding infant sleep, as well as levels of attachment (Jenni & O'Connor, 2005; Morrell & Steele, 2003; Zuckerman, et al., 1987). Therefore, what one family may consider problematic (e.g., waking for feeds) may well be considered normal or acceptable by others. Such reports are also likely to vary dependent on the amount of conflict between the infant's sleep routine and that of the parents. Nevertheless, the detection of problematic sleeping behaviours is important because problem sleep at a younger age is one of the leading predictors of persistent sleep problems into childhood (Morrell & Steele, 2003; Stein, et al., 2001).

The present study addressed some of the factors outlined in Sadeh and Anders (1993) transactional model (section 1.6). However, the distal extrinsic factors and the mediating relationship between parent and infant were either not recorded, or not analysed in the present study due to the small sample size. It is clear that factors concerning the living environment, levels of attachment, and the parent-to-child relationship are key mediators in predicting concurrent as well as persistent sleep problems (Goodlin-Jones, et al., 2001; Morrell & Steele, 2003; Sadeh & Anders, 1993). Therefore, future studies should aim to control for such factors.

4.4 *Relationships between Sleep, Mood and Temperament, and Day of the Week*

4.4.1 Sleep, Mood and Temperament

Past research of infants and pre-schoolers has identified relationships between sleep problems with mood and behaviour (Bos, et al., 2009; Lam, et al., 2003; A. Scher & Asher, 2004; Touchette, et al., 2005; Zuckerman, et al., 1987). In the present study, longer sleep latency at night (as recorded actigraphically) was related to being less alert in the mornings, with less alert infants taking approximately 10 minutes longer to settle compared to very alert infants. Mood was also related to sleep, with moderate or bad mood in the morning being significantly related to shorter nocturnal sleep (approximately 1 hour less, as measured by actigraphy). This finding is in part explained by an earlier wake up time, and spending almost 15 minutes longer awake prior to being taken out of bed in the morning, compared to infants reported as being in a good mood in the mornings.

Waking up earlier in the mornings was significantly associated with being rated as more tired at evening bedtimes. However, bedtime or duration of night sleep did not significantly differ between very tired and moderately to not-at-all tired infants. Although infants' mood at bedtime was not related to objective sleep data, parents who most often rated their infants' mood as moderate to bad at evening bedtimes were also significantly more likely to define their infant's sleep as problematic.

Frequent problems putting infants to bed were not significantly related to parental perception of problem sleep. This could be due to the small number of infants being typically rated as problematic at bedtime. Indeed, no parent reported many problems on a regular basis, and only 21% of infants usually had some kind of problem being put to bed. This could in part be due to this daily question being non-specific, future studies might consider asking more direct questions concerning settling behaviours around bedtime.

These findings support hypothesis 3, poorer mood is associated with shorter sleep duration and parents' perception of problem sleep. These findings are similar to past studies, with children's short sleep duration and sleep problems being related to reduced approachability and emotional regulation (Spruyt, et al., 2008; Zuckerman, et al., 1987), as well as poorer mood and alertness (DeLeon & Karraker, 2007; Morrell & Steele, 2003). In a study using similar daily diary questions, Sadeh (1996) also found a significant relationship between morning mood and longer night sleep duration. Furthermore, evening sleepiness was related to sleep efficiency, this finding was not replicated in the present study, possibly due to the sample in Sadeh's study being a clinically referred sleep problem group.

Reporting bias may be an issue when comparing parents' ratings of mood and temperament with their reports of their infant's sleep. However, the actigraphy data supports a link between sleep with mood and alertness. Reasons for these relationships could be related to the parent-to-child interactions, with 'fussy' infants being more likely to elicit parents' presence at times of night waking (A. Scher, 2001a; Seymour, et al., 1984), thereby creating overstimulation and more problems falling back to sleep (France & Hudson, 1993). Future studies may consider incorporating a standardised temperament questionnaire such as the Carey Temperament Scales (1996, as cited in DeLeon & Karraker, 2007), or the Infant Characteristics Questionnaire (Bates, Freeland, & Lounsbury, 1979, as cited in A. Scher, 2001a), in order to gain more reliable and comparable data. It would also be of interest to control for parents psychological well-being; ratings of infant's mood, temperament and sleep may vary in association with parents own mood or presence of depression (Morrell & Steele, 2003; Richman, 1981).

4.4.2 Sleep and Mood Changes across the Week

Sleep duration has been found to vary between school days and weekends in both pre-schoolers and adolescents (Borlase, 2001; Dorofaeff & Denny, 2006; Goodlin-Jones, et al., 2008; Nixon, et al., 2008). In the present group of infants, bedtimes, rise times and sleep durations did not differ between weekdays and weekends. However, sleep latency on Saturday and Sunday nights was longer, with lower sleep efficiencies in the night time rest interval. Daily ratings of mood and temperament add to the objective findings, infants were more often rated in a poorer mood on Saturday or Sunday mornings compared to weekdays. They were also considered more active on weekends, as well as more problematic at evening bedtimes.

Although these findings do not support hypothesis 5 (the timings of sleep does not vary between weekends and weekdays), infants' mood in the morning and problems at bedtime appear likely to have negative effects on sleep latency and quality of sleep at the weekends. More detailed investigation of activities and routines on weekends for parents as well as infants may help to explain the observed changes in sleep quality and parentally-rated mood. In the present study, only 1 week of data was collected, with on average just 1 or 2 valid days of weekend data. To obtain more valid weekend data, monitoring over longer periods of time would be desirable.

4.4.3 Sleep and Mood Changes with Childcare

The routine on childcare days did not significantly differ from non-childcare days so hypothesis 6 was not supported. Some (17.6%) infants were considered less alert by parents on childcare days, but no other daily diary ratings changed between care and non-care days. With regards to actigraphy data, infants had significantly higher sleep efficiency during the night time rest interval after childcare days. These findings could be related to higher levels of stimulation on care days leading to a better quality of sleep at night. This is supported by past studies in adults and children, the effects of extreme exercise creating a higher quality and deeper sleep at night (Dworak, et al., 2008; Shapiro, et al., 1981).

Although parents noted daily in the diary whether their infant was cared for by someone else, a specific type of care was not recorded. There are likely to be differences between levels of activity and stressful events when being cared for by a friend or family member compared to spending time in a childcare establishment. In the questionnaires 40% of infants were reported to spend time in *childcare*, whereas from the sleep diaries, 65% of infants were *cared for by someone else*. Variance between types of childcare may have concealed any effects on routine, sleep quantity and quality, as well as on ratings of mood and temperament. Future studies would benefit from additional diary questions concerning the type of childcare as well as a rating on how the parent feels that time in care affects their infant's mood, behaviour and sleep.

4.5 *Sleep, Age and Developmental progress*

4.5.1 Stage of Development and the Maturation of Sleep

Yu et al. (2007) gathered ASQ data from over 2000 1 to 5-year-olds in the UK. Consistent with the findings from Yu et al., communication was the developmental domain that infants in the present sample were most likely to score below the 'doing well' threshold. However, unlike in the UK sample, the domain of fine motor skills was above threshold for all infants in the present study, and gross motor development was the second most likely domain in which infants scored below the threshold. These differences may be due to the broader range of ages assessed in the study of Yu et al. Over one-quarter of the present sample scored below one or more of the developmental thresholds of the ASQ, twice as many as among the 185 1-year-olds in the UK study of Yu et al. (2007). It would be of interest to collect data from a larger sample of NZ infants to validate these findings.

Although Goodlin-Jones et al. (2008) found a significant link between developmental stage and reports of problematic sleep, in the present study, scoring below one or more threshold(s) was not related to parental perceptions of problematic sleep. This discrepancy could be due to the subjects being much younger in the present study, and that those studied by Goodlin-Jones et al. had severe developmental delays which could indirectly contribute to problem sleep (Sadeh & Anders, 1993). Although the stage of development was not related to parental perception of problem sleep, actigraphy revealed that sleep efficiency during the night time sleep interval was significantly lower for infants scoring below one or more developmental threshold(s). After controlling for age and gender, the sleep efficiency during the night time sleep interval was positively related to the development of problem solving skills and to scoring above the ASQ thresholds. Similar findings have been reported by A. Scher (2005b), who (through using the Bayley's Scale of Infant Development) reported that waking and activity at night were related to poorer cognitive development in 10-month-olds.

In the present study, sleep efficiency was negatively related to the development of fine motor skills. This finding could be affected by the confounding relationships between fine motor skills, age and gender. However, a negative trend with motor development is not unusual. Past research comparing the sleep of crawlers with non-crawlers also reported significantly more disturbed sleep in infants at higher stages of development (as reported by parents and recorded by actigraphy, A. Scher, 2005a; A. Scher & Cohen, 2005). When controlling for age and gender, Scher and Cohen found that motor development accounted for 17% of the variance for the number of night awakenings. The present findings contribute to this field, in that delay in the acquisition of fine motor skills also appears to be associated with fragmented sleep.

When infants are acquiring motor skills, an increase of REM and movements during sleep have been observed, alongside practising new movements during sleep and wake (Kavanau, 1997, as cited in A. Scher, 2005a; A. Scher & Cohen, 2005).It is such movements during sleep that may contribute to the amount of 'sleep fragmentation' recorded by actigraphy. Sleeping position has also been related to the stages of early motor development (Majnemer & Barr, 2006). In the present study sleep position was recorded as *usual* position in the questionnaire. In order to reliably analyse these variables in future studies, specific questions concerning the infants' ability to crawl or walk could be added to the questionnaires. A position sensor and PSG would be required to gather objective data on position throughout the 24 hour day as well as data concerning the NREM/REM cycle to confirm relationships with stages of motor development.

The maturation of the sleep/wake cycle was significantly related to ASQ stages of development. After controlling for age and gender, infants with a higher percentage of total sleep time occurring at night had significantly higher development scores in the domains of communication and problem solving. At the end of the first year of life, the consolidation of the cycle of sleep/wake coincides with the maturation of sleep stages. At this time, stage two sleep becomes more pronounced while the proportion of REM sleep is still relatively high (Goodlin-Jones, et al., 2001). These stages of sleep have been associated with processes of brain plasticity (Clemens, et al., 2006; Graven & Browne, 2008; Plihal, 1996; C Smith, 1995; C Smith & MacNeill, 1994; Stickgold, 2005; Walker, 2008). The findings in the present study support an association between the maturation of the sleep/wake cycle and cognitive development.

The ASQ is considered valid to use 1 month either side of the target age (Bricker & Squires, 1999). Although all of the infants who participated in the present study were 11, 12 or 13 months old, the maximum age in the sample was 13.9 months. There was almost 12 weeks difference between the minimum and maximum ages, a timeframe which in infancy is important for development. In the present study, age was significantly related to the development of gross motor, problem solving and personal-social skills. Future studies could consider recruiting a more restricted age group to reduce this variability.

4.5.2 Maturation of Sleep and Age

The mixed model analyses indicated that age was a more consistent predictor of sleep maturation than stages of development measured by the ASQ. After controlling for ASQ scores and gender, age (in 2 week intervals) was significantly related to the duration of night time sleep and the proportion of total sleep time occurring at night. Older infants were having significantly longer night time sleep as well as a higher proportion of total sleep occurring at night compared to younger infants.

Similar findings regarding age and maturation of sleep have been previously reported. Sadeh et al. (1991) found that between 1 and 3 years of age, time of sleep onset and sleep duration varied significantly with age. Goodlin-Jones et al. (2008) found that younger and more developmentally delayed 2 to 5-year-olds were more likely to sleep in the daytime and spend more time awake in bed.

As discussed above, age was also correlated with stage of development. Together these findings support hypotheses 4, the variation of sleep maturation and efficiency is significantly related to stages of development as well as the age of the infant. It appears that the maturation of sleep as well as cognitive and motor development progresses quickly from 11 to 13 months of age. Further research is required using PSG to confirm whether the links between development and sleep are simply a marker of maturation, or if sleep per se plays a significant role in the development of cognitive and motor functioning in infancy.

4.6 *Sleep and Body Habitus*

Past studies have identified short sleep duration as a risk factor for being overweight (e.g., Agras, et al., 2004; Locard, et al., 1992; J. J. Reilly, 2005; Sekine, et al., 2002). However, in the present study there no significant relationships were found between ponderal index and sleep duration at night, per 24-hours, or the percentage of total sleep occurring at night. There was no significant relationship between sleep duration and ponderal index after controlling for age, gender and maternal BMI. These findings do not support hypothesis 2.

One reason for these non-significant relationships in the present sample is the small number of overweight or short sleeping infants, which limits the power of the study to detect relationships. Of the infants in the present sample, only 7 were over the 90^{th} percentile for weight. Only two infants were sleeping less than 9 hours per night. One infant was sleeping less than 12 hours per 24-hours. So, the numbers of infants representing the short sleepers, as defined in past studies (Nixon, et al., 2008; Taveras, et al., 2008), were few.

Another possible reason for the non-significant relationship between sleep duration and ponderal index could be that, at this age, the relationship between sleep and body status is not yet established. Infants' sleep duration has not been related to their current weight (Jenni, Molinari, Caflisch, & Largo, 2007; Nixon, et al., 2008). Past studies recording weight and body mass throughout childhood have found that it is not until 2 to 4 years of age that sleep duration or sleeping problems become a significant predictor of being overweight (Al Mamun, et al., 2007; J. J. Reilly, et al., 2005). This could be due to the large variability of sleep as well as height and weight fluctuations during infancy (Jenni, et al., 2007).

During infancy and early childhood (i.e. 1-2.5 years of age) sleep duration has been found to be a significant predictor of future obesity (J. J. Reilly, 2005; Taveras, et al., 2008). Past literature highlights that Māori and Pacific Island children having higher prevalence of being overweight (Gordon, et al., 2003; Rush, Plank, Davies, Watson, & Wall, 2003; Tyrrell, et al., 2001), as well as differing sleep practices compared to their Pākehā counterparts (Abel, et al., 2001; Scragg, et al., 1996; Tuohy, et al., 1998). A longitudinal study using objective monitoring is recommended. Through following a representative sample of NZ infants, a time when short sleep duration becomes a risk factor for current and future weight would be ascertained.

Previous research into the relationship of sleep duration and being overweight has not used ponderal index as a measure of body habitus. This measure was used in the present study as the infants were under the age of recommended use of BMI. (Cole, et al., 2006). Although reference curves are available for the ponderal index of newborns (Lehingue, et al., 1998), normative data for ponderal index into infancy and childhood were not available. Therefore the ability to compare the present sample characteristics to past study samples is difficult, furthermore definitions of 'high' and 'low' ponderal index are unreliable. Past studies reveal that differing measures of body status (e.g., percentage of body fat) do not correlate with sleep duration (Duncan, et al., 2008). The use of ponderal index may also be inappropriate for detecting this relationship. Future studies may consider assessing the weight gain from birth, current weight, BMI, as well as ponderal index to evaluate relationships with sleep duration.

A further limitation to the measures in the present study is that the weights, heights and lengths were taken by reading off analogue scales. Furthermore the weight of the infant was taken by weighing the mother with and without her infant. Future studies would benefit from using digital devices as well as specific scales for weighing the infants alone.

4.7 *Piloting a Method: Strengths and Limitations*

As the first study using actigraphy to gather objective data on the sleep of NZ infants, the present study was designed as a pilot. With the long-term goal of studying sleep longitudinally, it is important to pilot the methodology prior to recruiting a larger cohort. Parents' opinions on the study methodology and procedures were gathered using a feedback questionnaire.

4.7.1 Using Actigraphy to Measure the Sleep of One-Year-Olds

Protocol.

Of the three methods used (actigraphy, diaries and questionnaires), actigraphy was the only one that any parents rated as difficult. This method was less familiar to parents, and forgetting, or not being able to access the event marker were the main issues with using the actigraph. From a researcher's point of view, using actigraphy with infants held some concerns. It was suspected that actigraphs would be removed and/or lost. Except for one case, all actigraphs were returned in one piece, and the case of the lost actigraph was due to the family dogs rather than the participating infant (see Appendix Figure C8)!

Although little harm came to the actigraphs, from reviewing the feedback forms it became clear that parents had concerns about the monitor slipping out of the band. In the initial study weeks, adaptations were made to widen the pocket of the band, as several families noted that they had temporarily lost the actigraph. Parents also noted that the actigraph sometimes slipped and/or was moved out of place by their infant. Such events were not requested to be noted in the diary or through using the event marker. In future studies it would be useful to be made aware of such times in order to exclude data where necessary. Despite these minor set-backs, actigraphy proved to be a robust and appropriate method to use for measuring the sleep of 1-year-olds.

Analysis.

One-third of the data recorded were rejected as invalid. Days of actigraphy recording were defined as invalid if over 1 hour of data was excluded within that day. It was deemed appropriate to completely exclude these days from statistical analyses because of the higher incidence of daytime sleep in infancy, and because some variables were totalled across the 24 hour time frame.

Although this protocol ensured that the data being used was of reliable quality, many days of potentially usable data may have been lost due to the use of the 1 hour threshold. To avoid having to eliminate as much data in future studies, the start and end times of the study for each infant could be matched. For example all studies start at 10 a.m. Such protocols have been used in past studies (e.g., So, et al., 2007; Spruyt, et al., 2008) and would make data more complete as well as avoiding the exclusion of data at the beginning and end of the study when variable amounts of the day were recorded between participants.

Even with the strict exclusion criteria, infants in the present study had an average of 5 full days of valid data. This amount of data is comparable to past studies using actigraphy in this age group (e.g., Acebo, et al., 2005) and also meets the recommended guidelines for reliable data (Acebo, et al., 1999; Sadeh & Acebo, 2002; Trost, et al., 2005). More days of data provide greater reliability when making estimates regarding infants' relatively unstable sleep patterns (Sadeh, Hauri, et al., 1995). There was high inter-scorer agreement for the scoring of actigraphy data (86.8 %), indicating that the actigraphy scoring rules used are reliable (Appendix C2).

Sadeh, Hauri et al. (1995) note that, although actigraphy has been validated against PSG in the laboratory setting, in the field the reliability of actigraphy may be reduced. As actigraphy is based on movement, future studies should record times in the diary when sleep could have been masked (e.g., if sleeping in the car or buggy or parental handling whilst asleep). Controlling for artifact increases the reliability of actigraphy for use with infants and children in their home environments (Sadeh & Acebo, 2002; Sadeh, Hauri, et al., 1995; Sadeh, et al., 1994; So, et al., 2005).

The nature of infants' bedtime routines sometimes made it difficult to identify the beginning of a rest interval. On many occasions, an excluded interval closely preceded the recorded bedtime in the diary. This was due to a high incidence of parents bathing their infant prior to bed and replacing the actigraph once the infant was in bed. This common routine made accurately identifying bedtime and sleep onset more difficult.

Past research has found that actigraphy's ability to detect the number of awakenings, time spent awake at night, and sleep efficiency is limited compared to PSG, observations or sleep diaries (Gnidovec, et al., 2002; Goodlin-Jones, et al., 2008; Hyde, et al., 2007; Sitnick, et al., 2008; So, et al., 2005; Werner, et al., 2008). In the present study, the actigraphy variables concerning the number of awakenings and time spent awake were not used in analyses. However, estimates of sleep efficiency were used. These estimates describe the percentage of the rest and sleep intervals that the actigraphy algorithm identifies as sleep. If infants woke in the night and parents defined the end of a rest interval, the active time between night time rest intervals was not taken into consideration when estimating sleep efficiency. This means that sleep efficiency is not a reliable estimate of sleep disruption.

In the present study, many of the significant findings relate to the sleep efficiencies. For example the sleep efficiency during the night time rest intervals differed from childcare to non-childcare days, as well as from weekdays to weekends. And the sleep efficiency during the night time sleep interval was related to stage of development. These findings need to be interpreted with caution. Future studies may consider using smoothing algorithms for defining awakenings using actigraphy (e.g., Acebo, et al., 2005; Goodlin-Jones, et al., 2008; Sadeh, 1994; A. Scher, 2001a, 2005b; Sitnick, et al., 2008). However a standardised algorithm is yet to be agreed on and Sitnick et al. note that even when smoothing algorithms are used, detecting arousals in children with actigraphy is still unreliable. Alternatively, PSG or video observations could be used in order to more accurately record the number of awakenings, time awake and sleep efficiencies. However these measures are also more costly and invasive than actigraphy.

4.7.2 Using Sleep Diaries to Measure the Sleep of One-Year-Olds

Protocol.

As a rule, the diaries were well maintained by parents. However, there were cases when the diary did not match the actigraphy data. This could have been due to parents' completing the diary after the day in question. Past studies raise the concern of relying on sleep diaries over long periods of time due to a reduction in accuracy

(Sadeh, 1996). In the present study, parents commented that they sometimes forgot to complete the diary.

In some instances the exact time was not noted below diary entries and, although marks on a timeline can be measured, a note of clock time makes it easier to determine where on the actigraph output to define the beginning and end of a rest interval. A protocol was developed to resolve discrepancies between diaries and actigraphy (Appendix C2). Future studies may incorporate a reminder on each day of the diary for precise timing to be noted when possible. Alternatively, diaries may be requested daily via the internet or telephone to maximise compliance (as used in Sitnick, et al., 2008).

Analysis.

Although parents were asked to note *intended* and *unintended sleeps*, the data were not analysed with respect to these categories. This was because the study hypotheses did not distinguish between these types of sleeps, and some parents noted confusion surrounding the definition of unintended sleeps. Future studies may address whether there are differences between sleeps occurring at times intended by the parent and those of a spontaneous nature. The quantity of unintended sleep may act as a marker of the homeostatic drive, daytime sleepiness, or as a measure of poor sleep quality at night.

Although parents were asked to make notes of interest, these notes were not incorporated into analyses due to the variability of number and detail of notes between subjects. This may have been partly due to there not being much space in the diary for notes (a factor identified through the feedback questionnaire). Future may provide more space, as well as specific questions concerning whether or not the infant was unwell or whether there had been a stressful event that day. Such information could be used for categorical analyses or for excluding such days if necessary.

In the present study, parents indicated whether their infant was unwell when answering the snoring question (which was deemed inappropriate for unwell infants). This question revealed that almost one-third of the sample were unwell around the time of data collection. However to what extent they were unwell, and for how long was not recorded or rated in the questionnaire. For future studies it is recommended that sick-days are recorded in the daily diary. Such data have been used in past research, with sick-days being excluded from analyses (e.g., Acebo, et al., 1999; A. Scher, 2005a).

Stressful event days have been compared against non-stressful days to assess the effects of stress on sleep with inconclusive results (Anders, et al., 1985; Goodlin-Jones, et al., 2001). As with defining 'sleep problems', defining 'stressful events' may vary among families. Although cry diaries kept alongside sleep diaries have been found to offer useful information with regards to daily stressors in infancy (e.g., DeLeon & Karraker, 2007), the addition of such a diary in the present study may have overwhelmed the families.

Ratings of mood and temperament came from the daily diary. From the feedback questionnaire, it was clear that there was some confusion surrounding the options given for rating mood and temperament. Parents also commented on the fact that they were not comfortable rating their infant's mood as *bad*. Due to connotations surrounding particular ratings, future studies may find using a likert-type scale more reliable for parents to define the mood and temperament of their infant (e.g., the

Sleep and Settle Questionniare, Matthey, 2001; or the Infant Characteristics Questionnaire, Bates, Freeland & Lounsbury, 1979, as cited in A. Scher, 2001a). The ratings of mood and temperament also suffer from issues of reliability, as these ratings were being made by the parents, whose own mood may have affected the ratings.

4.7.3 Limitations of the Questionnaires

The sleep questionnaire.

Although there were clear differences between the questionnaire data and actigraphy data concerning sleep timing and quality, this does not reduce the importance of combining the two methods. Incorporating parental reports adds to the picture of an infant's sleep, as this data pertains to beliefs and perceptions surrounding sleep, as well as providing data on sleep ecology in a less invasive and more cost effective manner compared to using observational techniques.

The majority of the sleep questions were adapted from the BISQ, a questionnaire validated for gathering data from large samples and classifying problem sleep (Sadeh, 2004; Sadeh, et al., 2009). The range of responses on the sleep ecology was limited by the way in which the questions were asked, only allowing one answer per question. Some parents commented that the answer could change from day to day. Future studies may find that the ecology of sleep and soothing techniques used are better captured on a daily basis in the diary or through asking more detailed questions (such as in DeLeon & Karraker, 2007; Morrell & Cortina-Borja, 2002). Future studies may incorporate questionnaires specifically focused on problems of initiating and maintaining sleep (e.g., the Tayside Children's

Sleep Questionnaire McGreavey, Donnan, Pagliari, & Sullivan, 2005), as these appear to be key issues in infancy (Sadeh, 2001; Sadeh & Anders, 1993).

The ages and stages questionnaire.

Parentally-completed questionnaires concerning development are not as reliable as using ambulatory screening (Rydz, Shevell, Majnemer, & Oskoui, 2005). However, as the stage of development was not the main focus of the present study, using a questionnaire was considered appropriate. The ASQ is a standardised questionnaire assessing development (Bricker & Squires, 1999; Squires, Bricker, & Potter, 1997). Some parents commented that the ASQ took a long time to complete as they had to perform certain actions with their infant to be able to complete particular questions. However, using such a questionnaire is more convenient and quicker than ambulatory screening.

Although one-quarter of the present sample scored below one or more developmental threshold(s), none of the infants were considered in need of clinical follow up. Through comparing clinical and control groups, Yu et al. (2007) found that the ASQ had a sensitivity of 87.4% and specificity of 82.3%. Although the ASQ was reliable for identifying control subjects in the study of Yu et al., the clinical group were considered to have major neurosensory disabilities thereby making it easier to distinguish between groups. The ability for the ASQ to identify less severe degrees of developmental delay is lower, varying from 51% to 90% with an average sensitivity of 75%, and specificity of 86% (Bricker & Squires, 1999). Although the ASQ may not be as reliable in identifying developmentally delayed infants in a 'normal' sample, the degrees of development from the ASQ scales were related to sleep maturation, thereby making this a useful tool when assessing the changes sleep with regards to development.

4.8 *Conclusions*

With regards to the research gaps outlined in the overview (section 1.1), the present study has contributed the following observations based on objective sleep monitoring:

1. Between the age of 11 to 13 months, maturation of the sleep/wake cycle is related to the stages of cognitive and motor development and to age.
2. Together with the objective recordings, parental reports have provided a clearer picture of sleep and sleep ecology in this age group. Differences in the data recorded using these methods highlights the importance of using multiple measures when assessing sleep.
3. The present findings begin to address the need for normative sleep data of this age group. Representative normative data allow parents as well as clinicians to screen and identify sleep problems. Definitions of problem sleep should be considered from research and clinical findings as well as parental reports in order to clearly identify the factors affecting sleep in infancy.
4. In this sample, parentally-defined problem sleep is as prevalent as reports from other westernised countries. Risk factors outlined in the present sample of 'small problem sleepers' are similar to those

outlined in past research, notably the relationships between parents perception of problem sleep and current breastfeeding, time spent awake at night, shortened sleep duration, and infants' mood.

Throughout this chapter the strengths and limitations of the methods of recruitment, as well as assessment and interpretation of results have been addressed. Most importantly it should be stressed that the present sample is not representative of the NZ infant population. Particular considerations for future research include:

1. Use of varied recruitment methods to gather a more representative sample of NZ infants.
2. Stratifying the sample to allow for comparisons between ethnicities, SES, geographical area, as well as severity of sleep problem or developmental delay.
3. Adapting questionnaire and diaries to gather more reliable data concerning the place of sleep and soothing techniques used, as well as controlling for days when the infant is unwell or experiencing stressful events.
4. Recruiting a subsample of infants to undergo PSG recordings in order to verify findings concerning parents' perceptions of problem sleep, mood and temperament as well as relationships between sleep and age and stage of development.
5. Recruiting a cohort of infants for longitudinal analysis in order to ascertain at what age the relationship between sleep duration and body habitus becomes significant.

6. Further exploring the relationship between body habitus and sleep through comparing different measurements of 'overweight' in infancy.

The sleep of the 1-year-olds in this sample is variable. The maturation of the sleep/wake cycle is clear around this age and relationships between sleep with age and stages of development are identified. These findings highlight the importance of considering the quality and quantity of sleep when evaluating daytime mood and functioning. Problem sleep is a phenomenon that is linked to both intrinsic and extrinsic factors that require identification and if necessary, modification in order to decrease the risk of persistent problems into childhood.

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Appendix A

Tools used in Data Collection

A1 *Sleep Questionnaire*

OBJECTIVE MONITORING OF SLEEP PATTERNS IN INFANTS: A PILOT STUDY

Questionnaire

Office Use Only ☐☐

If you have any questions, please call...0508 328448...............................

Most questions require you to TICK your answer in a box. If you make a mistake put a cross in the box and tick the correct answer. Only tick one option unless otherwise instructed.

Examples of how to mark the questionnaire — Age [26] Years

	Yes	No
To answer "no"	☐	☑
To answer "yes"	☑	☐

TODAY'S DATE: ______ / ______ / ______
Day Month Year

PARENT AND CHILD'S DETAILS:

Name parent: First Name ____________ Surname ____________

Name child: First Name ____________ Surname ____________

Child's date of birth ______ / ______ / 20______
Day Month Year

Is your baby a boy or a girl? Boy ☐ Girl ☐

Address: ____________________
____
____

Phone Numbers: Home ( ) ____________ Work ( ) ____________

Cell Phone ____________

E-mail: ____________________

1. How many weeks of your pregnancy were completed on the birth of your baby
☛ *(Please check "Well child health book" – Plunket book if necessary)*

☐

PARENT'S HEIGHT AND WEIGHT DETAILS
(RESEARCHER TO COMPLETE IF MEETING ARRANGED)

2. (a) What is the mother's current height (Centimetres) and weight (Kilograms)?

Height (cm) ☐ Weight (Kgs) ☐

2. (b) What is the father's current height (Centimetres) and weight (Kilograms)?
(only complete if known/available)

Height (cm) ☐ Weight (Kgs) ☐

CHILD'S WEIGHT, LENGTH AND HEAD CIRCUMFERENCE:
(Please check "Well child health book" – Plunket book if necessary)

3.(a) What was your child's length in centimetres **at birth**? ☐ Centimetres

3.(b) What was your child's weight in kilograms **at birth**? ☐ Kilograms

3.(c) What was your child's head circumference **at birth**? ☐ Centimetres

3.(d) What is your child's weight in kilograms **now?** ☐ Kilograms
(Researcher to complete if meeting arranged)

3.(e) What is your child's length in centimetres **now?** ☐ Centimetres
(Researcher to complete if meeting arranged)

3. (f) What is your child's head circumference **now**? ☐ Centimetres
(Researcher to complete if meeting arranged)

4. Is this your first baby? Yes ☐ No ☐

5. Was this baby a single baby?

Yes ☐ No ☐ → Twin ☐ Multiple ☐

FEEDING PRACTICES:

6. (a) Has your child ever been breastfed?

Yes ☐ No ☐ → *Go to Question **7***

6. (b) When did you start breast feeding your child?

☐ From birth

_______ Weeks after birth

6. (c) When did you stop breast feeding you child?

☞ *(please record approximate age in weeks or months)*

_______ Weeks after birth

_______ Months after birth

☐ I am still breastfeeding.

7. Does your child wake for feeding? Yes ☐ No ☐

If yes, how often? ☐

8. Is your child teething? Yes ☐ No ☐

YOUR CHILD'S SLEEP:

9. In the past week what was your child's sleeping arrangement:

Cot or bed in a separate room ☐

Cot or bed in parent's room ☐

Cot or bed in room with sibling ☐

In parent's bed ☐

Other – *please specify* ______

10. In the past week in what position did your child sleep most of the time:

On his/her belly ☐

On his/her side ☐

On his/her back ☐

11. On average in the past week how much time did your child spend asleep during the **night**?
☛ *(Between 7.00pm in the evening and 7.00am in the morning)*

☐ Hours ☐ Minutes (Per night)

12. On average in the past week how much time did your child spend asleep during the **day**?
☛ *(Between 7.00am in the morning and 7.00pm in the evening)*

☐ Hours ☐ Minutes (per day)

13. In the past week what was the average number of wakings per night? ☐

☛ *(From 10.00pm in the evening to 6.00am in the morning)*

14. On average in the past week how much time did your child spend in wakefulness in the night?

☛ *(From 10.00pm in the evening to 6.00am in the morning)*

☐ Hours ☐ Minutes (per night)

15. On average in the past week how long did it take to put your child to sleep in the evening?

☐ Hours ☐ Minutes (per evening)

16. In the past week how did your child normally fall asleep:

- While feeding ☐
- Being rocked ☐
- Being held ☐
- In bed alone ☐
- In bed near parent ☐

17. In the past week at what time did your child normally fall asleep for the night?

Time _____:____

18. In the past week how many nights has your child snored or have you noticed noisy breathing during sleep?

☛ *(Answer only if your child has been well)*

☐ Nights

☐ Not applicable because my child has not been well

19. In general do you consider your child's sleep a problem:

A very serious problem ☐

A small problem ☐

Not a problem at all ☐

YOUR HOME:

20. How many people are living in your house?
☛ *(including you, your partner and your child(ren))*

	Adults (18 years and older)	Children & teenagers (0 to 17
	☐	☐

21. How many people come and go for work during your child's sleeping hours? ☐

On average, how many nights per week does this occur? (in total/all people) ☐

22. Do you or any member of the household have a health condition which may affect the sleep of your child? (for example a sleep disorder or mental health issue)

Yes ☐ No ☐

If yes please specify ☐

YOUR CHILD'S ROOM:

23. Does your baby share the room he/she sleeps in with:

Other children Yes ☐ → How many other children share this room? ☐
No ☐

Any adults? Yes ☐
No ☐ → How many adults share this room? ☐

24. What sort of bed does your child usually sleep in?

How many share the bed?

Parent(s) bed ☐ → ☐

Cot ☐

Own bed ☐

Other – *please specify* ☐

25. Does your child spend any time in child care?

Yes ☐ No ☐

If yes how often?

(e.g. number of hours per week) ☐

Thank you very much for your help with this questionnaire. We appreciate your participation in this study. Please return your completed questionnaire with the other questionnaires and Actiwatch using the self-addressed freepost envelope provided:

R.Gibson
Sleep/Wake Research Centre
Massey University
Wellington Campus
Private bag 756

A2 *Ages and Stages Questionnaire*

Ages & Stages Questionnaires®: A Parent-Completed, Child-Monitoring System
Second Edition
By Diane Bricker and Jane Squires
with assistance from Linda Mounts, LaWanda Potter, Robert Nickel, Elizabeth Twombly, and Jane Farrell

12 Month • 1 Year Questionnaire

On the following pages are questions about activities children do. Your child may have already done some of the activities described here, and there may be some your child has not begun doing yet. For each item, please check the box that tells whether your child is doing the activity regularly, sometimes, or not yet.

Important Points to Remember:

- ☑ Be sure to try each activity with your child before checking a box.
- ☑ Try to make completing this questionnaire a game that is fun for you and your child.
- ☑ Make sure your child is rested, fed, and ready to play.
- ☑ Please return this questionnaire by ______________
- ☑ If you have any questions or concerns about your child or about this questionnaire, please call: ______________
- ☑ Look forward to filling out another questionnaire in ____ months.

ASQ™

0305 I

Ages & Stages Questionnaires®: A Parent-Completed, Child-Monitoring System
Second Edition
By Diane Bricker and Jane Squires
with assistance from Linda Mounts, LaWanda Potter, Robert Nickel, Elizabeth Twombly, and Jane Farrell

12 Month • 1 Year Questionnaire

Please provide the following information.

Child's name: ______________________________

Child's date of birth: ______________________________

Child's corrected date of birth (if child is premature, add weeks of prematurity to child's date of birth):

____

Today's date: ______________________________

Person filling out this questionnaire: ______________________________

What is your relationship to the child? ______________________________

Your telephone: ______________________________

Your mailing address: ______________________________

____

City: ______________________________

State: ______________ ZIP code: ______________

List people assisting in questionnaire completion: ______________________________

____

Administering program or provider: ______________________________

ASQ

0305 2

COMMUNICATION *Be sure to try each activity with your child.*

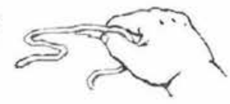
	YES	SOMETIMES	NOT YET	
1. If you ask her to, does your baby play at least one nursery game even if you don't show her the activity yourself (e.g., "bye-bye," "Peekaboo," "clap your hands," "So Big")?	☐	☐	☐	___
2. Does your baby follow one simple command, such as "Come here," "Give it to me," or "Put it back," *without* your using gestures?	☐	☐	☐	___
3. Does your baby say one word in addition to "Mama" and "Dada"? (A "word" is a sound or sounds the baby says consistently to mean someone or something, such as "baba" for bottle.)	☐	☐	☐	___
4. When you ask, "Where is the ball (hat, shoe, etc.)?" does your baby look at the object? Make sure the object is present. Check "yes" if he knows one object.	☐	☐	☐	___
5. When your baby wants something, does she tell you by *pointing* to it?	☐	☐	☐	___
6. Does your baby shake his head when he means "no" or "yes"?	☐	☐	☐	___
		COMMUNICATION TOTAL		___

GROSS MOTOR *Be sure to try each activity with your child.*

	YES	SOMETIMES	NOT YET	
1. While holding onto furniture, does your baby bend down and pick up a toy from the floor and then return to a standing position? 	☐	☐	☐	___
2. While holding onto furniture, does your baby lower herself with control (without falling or flopping down)?	☐	☐	☐	___
3. Does your baby walk along furniture while holding on with only one hand?	☐	☐	☐	___
4. If you hold both hands just to balance him, does your baby take several steps without tripping or falling? (If your baby already walks alone, check "yes" for this item.) 	☐	☐	☐	___
5. When you hold *one hand* just to balance her, does your baby take several steps forward? (If your baby already walks alone, check "yes" for this item.) 	☐	☐	☐	___
6. Does your baby stand up in the middle of the floor by himself and take several steps forward?	☐	☐	☐	___
		GROSS MOTOR TOTAL		___

3

ASQ **12 months/1 year**

	YES	SOMETIMES	NOT YET	
FINE MOTOR *Be sure to try each activity with your child.*				
1. After one or two tries, does your baby pick up a piece of string with her first finger and thumb? (The string may be attached to a toy.) 	☐	☐	☐	___
2. Does your baby pick up a crumb or Cheerio with the tips of his thumb and a finger? He may rest his arm or hand on the table while doing it. 	☐	☐	☐	___
3. Does your baby put a small toy down, without dropping it, and then take her hand off the toy?	☐	☐	☐	___
4. Without resting his arm or hand on the table, does your baby pick up a crumb or Cheerio with the tip of his thumb and a finger? 	☐	☐	☐	___*
5. Does your baby throw a small ball with a forward arm motion? (If he simply drops the ball, check "not yet" for this item.) 	☐	☐	☐	___
6. Does your baby help turn the pages of a book? (You may lift a page for her to grasp.)	☐	☐	☐	___
		FINE MOTOR TOTAL		___

**If fine motor item 4 is marked "yes" or "sometimes," mark fine motor item 2 as "yes."*

	YES	SOMETIMES	NOT YET	
PROBLEM SOLVING *Be sure to try each activity with your child.*				
1. While holding a small toy in each hand, does your baby clap the toys together (like "Pat-a-cake")?	☐	☐	☐	___
2. Does your baby poke at or try to get a crumb or Cheerio that is inside a clear bottle (such as a plastic soda pop bottle or baby bottle)?	☐	☐	☐	___
3. After he watches you hide a small toy under a piece of paper or cloth, does your baby find it? (Be sure the toy is completely hidden.)	☐	☐	☐	___
4. If you put a small toy into a bowl or box, does your baby copy you by putting in a toy, although she may not let go of it? (If she already lets go of the toy into a bowl or box, check "yes" for this item.)	☐	☐	☐	___
5. Does your baby drop two small toys, one after the other, into a container like a bowl or box? (You may show him how to do it.) 	☐	☐	☐	___*

	YES	SOMETIMES	NOT YET	
PROBLEM SOLVING *(continued)*				
6. After you scribble back and forth on paper with a crayon (or a pencil or pen), does your baby copy you by scribbling? (If she already scribbles on her own, check "yes" for this item.)	☐	☐	☐	___
		PROBLEM SOLVING TOTAL		___

**If problem solving item 5 is marked "yes" or "sometimes," mark problem solving item 4 as "yes."*

PERSONAL-SOCIAL *Be sure to try each activity with your child.*	YES	SOMETIMES	NOT YET	
1. When you hold out your hand and ask for his toy, does your baby offer it to you even if he doesn't let go of it? (If he already lets go of the toy into your hand, check "yes" for this item.)	☐	☐	☐	___
2. When you dress her, does your baby push her arm through a sleeve once her arm is started in the hole of the sleeve?	☐	☐	☐	___
3. When you hold out your hand and ask for his toy, does your baby let go of it into your hand?	☐	☐	☐	___
4. When you dress her, does your baby lift her foot for her shoe, sock, or pant leg?	☐	☐	☐	___
5. Does your baby roll or throw a ball back to you so that you can return it to him?	☐	☐	☐	___
6. Does your baby play with a doll or stuffed animal by hugging it?	☐	☐	☐	___
		PERSONAL-SOCIAL TOTAL		___

OVERALL *Parents and providers may use the back of this sheet for additional comments.*

1. Do you think your child hears well? YES ☐ NO ☐
   If no, explain: ______________________
2. Does your baby use both hands equally well? YES ☐ NO ☐
   If no, explain: ______________________
3. When your baby is standing, are her feet flat on the surface most of the time? YES ☐ NO ☐
   If no, explain: ______________________
4. Does either parent have a family history of childhood deafness or hearing impairment? YES ☐ NO ☐
   If yes, explain: ______________________
5. Do you have concerns about your child's vision? YES ☐ NO ☐
   If yes, explain: ______________________
6. Has your child had any medical problems in the last several months? YES ☐ NO ☐
   If yes, explain: ______________________
7. Does anything about your child worry you? YES ☐ NO ☐
   If yes, explain: ______________________

12 Month/1 Year ASQ Information Summary

Child's name: ______________________ Date of birth: ______________________

Person filling out the ASQ: ______________________ Corrected date of birth: ______________________

Mailing address: ______________________ Relationship to child: ______________________

City: __________ State: __________ ZIP: __________

Telephone: ______________________ Assisting in ASQ completion: ______________________

Today's date: ______________________

OVERALL: Please transfer the answers in the Overall section of the questionnaire by circling "yes" or "no" and reporting any comments.

1. Hears well? YES NO
   Comments:
2. Uses both hands equally well? YES NO
   Comments:
3. Baby's feet flat on the surface? YES NO
   Comments:
4. Family history of hearing impairment? YES NO
   Comments:
5. Vision concerns? YES NO
   Comments:
6. Recent medical problems? YES NO
   Comments:
7. Other concerns? YES NO
   Comments:

SCORING THE QUESTIONNAIRE

1. Be sure each item has been answered. If an item cannot be answered, refer to the ratio scoring procedure in *The ASQ User's Guide*.
2. Score each item on the questionnaire by writing the appropriate number on the line by each item answer.
   YES = 10 SOMETIMES = 5 NOT YET = 0
3. Add up the item scores for each area, and record those totals in the space provided for area totals.
4. Indicate the child's total score for each area by filling in the appropriate circle on the chart below. For example, if the total score for the Communication area was 50, fill in the circle below 50 in the first row.

Total	0	5	10	15	20	25	30	35	40	45	50	55	60
Communication	○	○	○	○	○	○	○	○	○	○	○	○	○
Gross motor	○	○	○	○	○	○	○	○	○	○	○	○	○
Fine motor	○	○	○	○	○	○	○	○	○	○	○	○	○
Problem solving	○	○	○	○	○	○	○	○	○	○	○	○	○
Personal-social	○	○	○	○	○	○	○	○	○	○	○	○	○
Total	0	5	10	15	20	25	30	35	40	45	50	55	60

Examine the blackened circles for each area in the chart above.

5. If the child's total score falls within the ☐ area, the child appears to be doing well in this area at this time.
6. If the child's total score falls within the ■ area, talk with a professional. The child may need further evaluation.

OPTIONAL: The specific answers to each item on the questionnaire can be recorded below on the summary chart.

12 months/1 year	Score	Cutoff
Communication		15.8
Gross motor		18.0
Fine motor		28.4
Problem solving		25.2
Personal-social		20.1

Item	Communication (Y S N)	Gross motor (Y S N)	Fine motor (Y S N)	Problem solving (Y S N)	Personal-social (Y S N)
1	○○○	○○○	○○○	○○○	○○○
2	○○○	○○○	○○○	○○○	○○○
3	○○○	○○○	○○○	○○○	○○○
4	○○○	○○○	○○○	○○○	○○○
5	○○○	○○○	○○○	○○○	○○○
6	○○○	○○○	○○○	○○○	○○○

Administering program or provider: ______________________

 6 ASQ **12 months/1 year**

A3 *Sleep Diary*

Diary number ______________________

Infant Sleep Diary Example

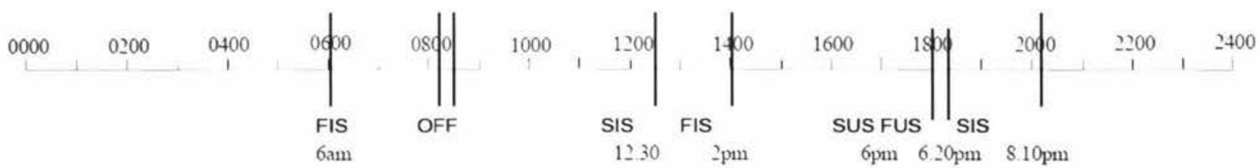
Each line represents one day (24 hours from midnight to midnight).

For each day, please complete one line, and mark the following times:
1. When your child started an intended sleep (**SIS**) and finished the intended sleep (**FIS**), **for any sleep 10 minutes or longer**
2. When he/she fell asleep unexpectedly (**SUS**) and finished the unexpected sleep (**FUS**) **for any sleep 10 minutes or longer**
3. Times when the actiwatch was removed, for example when bathing (**OFF**)
4. Please also note any times when your baby was in the care of another person – for example at day care or being baby sat

NOTE: A sleep at night may start on one line and finish on the next line (the next day).

EXAMPLE: A child finished an intended sleep at 6am (0600) on Day 1 (**FIS**) and started an intended nap at 12.30pm (1230) (**SIS**). He/she finished napping at 2pm (**FIS**). he/she also fell to sleep un-expectantly at approximately 6pm (**SUS**) and woke up again at approximately 6.20pm (**FUS**). The infant was put to bed to start trying to sleep (**SIS**) at 8.10pm (2000). The actiwatch was removed between 8.10 and 8.40 am **(OFF).** The child was in another person's care from 9-12.

DAY 1 (date 30/11/2006) **was your child in another person's care during this day?** Yes No **If yes, from 9am to 12pm**



2

Please turn the page

Diary number ____________________

DAY 1 (date__________) **Was your child in another person's care during this day?** Yes No **If yes, from ______ to______**

Each line represents one day (24 hours from midnight to midnight).

0000 0200 0400 0600 0800 1000 1200 1400 1600 1800 2000 2200 2400

Notes of interest (for example special events)?________________

Please circle as appropriate

How did your child wake up this morning?	By themselves	Parental initiative	Other
To what degree is s/he alert this morning?	Not at all	Somewhat	Very
Mood in the morning?	Bad	Moderate	Good
Compared to other days, what this a:	Low activity day	Typical activity day	High activity day
To what extent where there problems putting your child to sleep?	None	Some	Many
To what extent did your child appear to be tired at bed time?	Not at all	Somewhat	Very
Mood at bed time?	Bad	Moderate	Good

Please mark the following times on the above line:
Started an intended sleep **(SIS)**
Finished the intended sleep **(FIS)**
Fell asleep unexpectedly **(SUS)**
Finished the unexpected sleep **(FUS)**
When the actiwatch was removed **(OFF)**

3

Please turn the page

A4 *Feedback Questionnaire*

Massey University
WELLINGTON

Private Box 756
Wellington 6140
New Zealand
www.massey.ac.nz

Objective Monitoring of Sleep Patterns in Infants: A Pilot Study

Feedback form

Dear Parent,

Thank you very much for taking part in the baby sleep study. I have received your equipment and your baby's sleep is being analysed. In the meantime I would really appreciate your feedback on the study. Below are some questions and space for you to comment on how you felt the study went and what could be done better.

The content of this form will anonymous so please don't hesitate to be critical (your comments will help us to redesign this study in the future).
Once complete could you please post the form back to me in the enclosed pre-paid envelope.

1. How did you hear about this study? (for example through a friend, particular club or notice board)

2. Do you feel that the information provided to you prior to the study gave you a full picture of what the study entailed?

   Yes ☐ No ☐ If you answered no – what information would you recommend including?

3. Were you satisfied with the answers from the researcher to any queries you had concerning the study?

   Yes ☐ No ☐ I didn't have any queries ☐

Please turn over

4. How did you find using the monitor and band?

Easy	OK	Difficult
☐	☐	☐

Do you have any comments on the monitor and band?

5. How did you find completing the sleep diary?

Easy	OK	Difficult
☐	☐	☐

Do you have any comments on the sleep diary?

6. How did you find completing the questionnaires?

Easy	OK	Difficult
☐	☐	☐

Do you have any comments on the questionnaires?

7. Any other comments?

Many thanks and best wishes,

Rosie Gibson

[redacted]

Appendix B

Ethics, Advertisements, and Information Pack

B1 *Letter of Ethical Approval*

Massey University

OFFICE OF THE ASSISTANT
TO THE VICE CHANCELLOR
(Research Ethics)
Private Bag 11 222
Palmerston North 4442
New Zealand
[illegible]
[illegible]
www.massey.ac.nz

20 June 2008

Ms Rosemary Gibson
Sleep/Wake Research Centre
WELLINGTON

Dear Rosemary

Re: HEC: Southern A Application – 08/26
Objective monitoring of sleep patterns in infants: A pilot study

Thank you for your letter dated 19 June 2008.

On behalf of the Massey University Human Ethics Committee: Southern A, I am pleased to advise you that the ethics of your application are now approved. Approval is for three years. If this project has not been completed within three years from the date of this letter, reapproval must be requested.

If the nature, content, location, procedures or personnel of your approved application change, please advise the Secretary of the Committee.

Yours sincerely

Professor John O'Neill, Chair
Massey University Human Ethics Committee: Southern A

cc Professor Philippa Gander
Sleep/Wake Research Centre
WELLINGTON

Massey University Human Ethics Committee
Accredited by the Health Research Council

Te Kunenga ki Pūrehuroa

B2 *Information Pack for Parents*

Massey University
WELLINGTON

Private Box 756
Wellington 6140
New Zealand
T 64 4 801 5799
F 64 4 801 2692
www.massey.ac.nz

RE: Objective Monitoring of Sleep Patterns in Infants: A Pilot Study

Dear Parent,

We are inviting you to take part in a study concerning sleep in infants. This sleep study is being run by the Sleep/Wake Research Centre at Massey University, Wellington.

Research has identified sleep quality as a risk factor for many health issues including obesity, learning ability and breathing difficulties in adults. However there is limited information concerning normal sleep patterns of infants at different ages, or how their sleep may be linked to such issues.

This will be a pilot study for a potentially much larger project studying the sleep of infants across New Zealand. For this particular study we are recruiting 45 families in the Wellington region with children of approximately 12 months of age.

Participation in this study would involve completing a sleep diary for your child for a week, while they wear a small activity monitor (the size of a small wrist watch) in a hypoallergenic band on their lower leg, to monitor their sleep patterns. Use of the actiwatch and completing the sleep diary will require 5-10 minutes of your time per day. You would also be asked to complete a questionnaire about your child's sleep and factors that might affect it, as well as a standard developmental questionnaire. Questionnaires will take approximately 30 minutes in total to complete.

If you wish to take part in this project, please carefully read through the enclosed information sheet and then complete the consent form and return it to us. This should take about 5-10 minutes of your time. All of the information you supply is confidential and we will not publish any information that could identify you or your family. The results of this study will be used for a Masters of Science thesis as well as being published in a scientific journal.

If you decide to participate, you can chose to have an annotated copy of your child's sleep recording, and to discuss it with the research team. We will also send a summary of the study findings to everyone who takes part.

You have the right to:

- Decline to participate;
- Refuse to answer any particular questions;
- Withdraw from the study at any time.

Please contact us at the Sleep/Wake research centre if you have any queries or concerns about the study. Thank you very much for your time.

Yours sincerely,

Rosemary Gibson, Masters of Science (Psychology) student, Commonwealth Scholar, Sleep/Wake Research Centre

R.Gibson@massey.ac.nz
Tel: 04 801 2794 ext 6035
Toll Free: 0508 328448

Supervisor - Professor Philippa Gander
P.H.Gander@massey.ac.nz
Tel: 04 801 2794 ext 6033

Te Kunenga ki Pūrehuroa

Massey University
WELLINGTON

Private Box 756
Wellington 6140
New Zealand
T 64 4 801 5799
F 64 4 801 2692
www.massey.ac.nz

Information sheet

Objective Monitoring of Sleep Patterns in Infants: A Pilot Study

The sleep pilot study is a project being run by the Sleep/Wake Research Centre at Massey University, Wellington. We are asking you to consider taking part in a pilot study that will take an in-depth look at infants' sleep patterns. Findings from the sleep pilot study will be included in the Masters Thesis research of Rosemary Gibson. The research team is as follows.

Principal Investigator – Professor Philippa Gander, Massey University Sleep/Wake Research Centre.
Co Investigator – Dr Dawn Elder, Department of Paediatrics, School of Medicine and Health Sciences, University of Otago, Wellington New Zealand
Researcher – Rosemary Gibson, Masters of Science (Psychology) student, Commonwealth Scholar, Sleep/Wake Research Centre
Supervisor – Professor Philippa Gander, Director of the Sleep/Wake Research Centre

Venue of study: Sleep/Wake Research Centre, Massey University, Wellington campus.

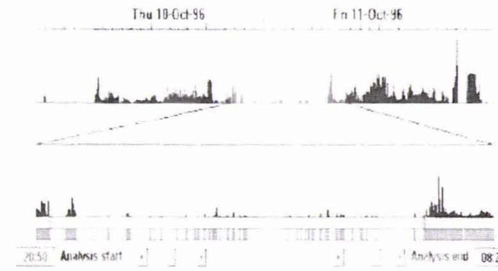
What is this study about?

In adults, inadequate sleep has been linked to increased risk of obesity, diabetes, suppression of the immune system, and poor daytime functioning. However, there is limited scientific information about sleep in infants, or how it may be linked to growth, learning, or health issues. In particular, there is a lack of objective data on the sleep patterns of infants, making it difficult for doctors and parents to know when a child's sleep pattern may be a cause for concern.

We are inviting you and your family to join a pilot study that will monitor the sleep of 45 infants in the Wellington region, for one week. This study will provide a first glimpse of the range of sleep patterns in this age group as well as vital information to help us design a much larger study to document the sleep patterns of a representative group of infants, and some of the key factors affecting them.

What is involved?

The research will take place when your child reaches 11-13 months of age. It will involve keeping a time-line type diary of your infant's sleep for one week (which will take approximately five minutes per day to complete), as well as having your child wear a device called an Actiwatch, which is the size of a small wrist watch. Please be aware that the actiwatch does not monitor your baby's breathing; it is not a tool to provide additional safety or monitoring of your child's sleep and is not fitted with any alarms. It is worn on the leg and continuously monitors movement, from which we can identify periods of sleep and activity. We would ask you to have your child wear the actiwatch at all times in that week except when bathing. The actiwatch is a widely used tool in sleep research and is non-invasive. It will be fitted inside a soft hypoallergenic band, to be comfortable for your child to wear. Each participant will be given 2 single-use bands (bands can be washed if necessary), the actiwatch itself will be sterilised between participants. You will not be held liable if the actiwatch is damaged or lost. Overleaf is a photograph of a young baby wearing the actiwatch and an example of the kind of data it will record.



Further information about the equipment can be found on the manufacturer's website: http://www.minimitter.com/Products/Actiwatch/index.html#Anchor-sleep/wake

You will also be asked to complete a questionnaire that includes questions about your child's sleep, and we would like to record your child's length and weight and parent/s height and weight. Sleep patterns change as your child develops, so the questionnaire also includes an Ages and Stages Questionnaire (ASQ). This is a well validated questionnaire which assesses the developmental stage of your child. It will take approximately 30 minutes to complete both questionnaires. In the highly unlikely event that the ASQ questionnaire raises any concerns about your child, you would be offered the opportunity to discuss this in greater depth with Dr Dawn Elder, a very experienced Paediatrician on the research team, at no cost.

Part of the reason for conducting a pilot study is for us to learn how we can improve the experience of being in the study, from the point of view of the participating families. We would greatly appreciate having your feedback on any aspect of the study.

If you choose to participate, the researcher will arrange a time for you to receive the equipment and questionnaires. Instructions will be provided on how to complete the diary as well as how to use the actiwatch. There will be a free phone number available for you to ask any questions before, during and after the research.
Our preference is to visit you at home and record height and weight measurements the parent/s and baby. This visit allows us to offer you maximum information and support concerning the study as well as to ensure that height and weight measurements are made using standardised equipment. If a visit is inconvenient for you or your family a courier can be arranged to deliver the equipment and you can take these measurements at your convenience and write them in the questionnaire

What will happen to the data?
The data will be analysed and presented as a Masters Thesis, and be published as scientific paper. They will also help us decide whether we need to undertake a larger scale study of the sleep of New Zealand infants.

Participants will only be identified to research team members from the Sleep/Wake Research Centre All study data will be identified only by study I.D numbers, only grouped data will be reported, and no information that could lead to identification of individuals will be provided in the study outputs.

You will have the option to receive an annotated print out of your child's sleep/wake patterns as recorded by the actiwatch and the sleep diary, and have the opportunity to discuss it. In addition, all participating families will receive a short brochure describing the study findings

Your rights

You are under no obligation to accept this invitation. If you decide to participate, you have the right to:

- decline to answer any particular question
- withdraw from the study at any time
- ask any questions about the study at any time during participation
- provide information on the understanding that your name will not be used unless you give permission to the researcher;
- be given access to a summary of the project findings when it is concluded

Project contacts

Please feel free to contact the researcher or supervisor on the contacts below if you have any questions concerning this research.

Telephone 04 801 2794 ext 6066
Toll free 0508 328448
Email Rosemary Gibson R.Gibson@massey.ac.nz
Professor Philippa Gander P.H.Gander@massey.ac.nz

Ethics committee approval

This project has been reviewed and approved by the Massey University Human Ethics Committee: Southern A, Application 08/26. If you have any concerns about the conduct of this research, please contact Professor John O'Neill, Chair, Massey University Human Ethics Committee: Southern A, telephone 06 350 5799 x 8771, email humanethicsoutha@massey.ac.nz

Thank you for your time and consideration of this project.

3

Massey University
WELLINGTON

Private Box 756
Wellington 6140
New Zealand
T 64 4 801 5799
F 64 4 801 2692
www.massey.ac.nz

Consent form

OBJECTIVE MONITORING OF SLEEP PATTERNS IN INFANTS: A PILOT STUDY

This consent form will be held for a period of five (5) years

I have read the Information Sheet and have had the details of the study explained to me. My questions have been answered to my satisfaction, and I understand that I may ask further questions at any time.
I agree to participate in this study under the conditions set out in the Information Sheet.

Signature: .... Date: ....

Full Name - printed ....

Please tick one box for each of the following questions.

I would like the researcher to visit me at home to deliver the research materials and instructions on how to use them. Yes ☐ No ☐

I would like to be provided with an annotated copy of my baby's sleep/wake recording. Yes ☐ No ☐

I am happy to be contacted regarding future studies concerning my child's sleep. I understand that ticking 'yes' does not mean I consent to our family participating in future studies, just that we are prepared to consider this. Yes ☐ No ☐

Te Kunenga ki Pūrehuroa

B3 *Advertisements*

Massey University

SLEEP / WAKE RESEARCH CENTRE
MOE TIKA, MOE PAI

We are seeking families with healthy babies in the age range of 11-13 months, living in the Wellington region, to take part in a sleep study.

This study will provide the first objective data on the sleep patterns of New Zealand infants and some of the factors that affect their rest.

For more information, please contact Rosie Gibson on:

Toll free 0508 328 448
04 801 2794 ext 6035
r.gibson@massey.co.nz

B4 *Actigraph and Sleep Diary Protocol for Parents*

SLEEP / WAKE
RESEARCH
CENTRE

SLEEP LOG AND ACTIWATCH PROTOCOL

The band you are about to put on your baby's leg contains an activity monitor called an actiwatch. The actiwatch is a small accelerometer with a memory chip and it records movement.

The data from the actiwatch is analysed along with the information from the sleep log to determine when and how well your baby has slept.

Information about wearing the actiwatch:

1. The actiwatch should be inserted within the band with the black side next to the bug motif on the strap. This way, you can push on the event marker (round button on the face of the actiwatch) by pushing on the bug motif. When you push this button, a marker is inserted into the data. It does not stop or start the watch, which will keep going the entire time that you have it.

2. Fit the actiwatch around either of your baby's legs, just below the knee. This can be fitted by simply slipping the band up the leg or by using the poppers on the strap.

3. Fit the strap with the face motif on the outside of your baby's leg. It should be attached reasonably firmly so that it does not move about. If it does move about, or you feel the strap is too tight contact the researcher for other band size options.

4. Please push the event marker when you put your baby down to start trying to sleep and again when they wake up (day or night). We would also like you to press the marker at times when your baby has had an unintentional nap of **10 minutes or longer**.

5. The watch is water resistant, not waterproof. This means that it should be removed when bathing your baby or when washing the band. Please remember to put it back on again after contact with water.

6. If you take the watch off for any reason (for example bathing) then please note this in the sleep log.

7. If you forget to put the watch back on at any stage, please put it on as soon as you remember. Do not worry if you accidentally missed some time – we are interested in as much data as possible so simply note in the sleep log the time when you put the watch back on.

8. We cannot tell what your baby is doing from the actiwatch data. We can only tell whether they are moving or not. Please be aware that the actiwatch does not monitor your baby's breathing. It is not a tool to provide additional safety or monitoring of your child's sleep and is not fitted with any alarms.

Sleep log and actiwatch protocol – Objective Monitoring of Sleep in Infants: A pilot Study 1

Information about filling out the sleep log:

For an example of how to complete Sleep Log please see the first page of your log sheets.

1. The sleep log is set out so that each line represents 24 hours, from midnight to midnight on one day.

2. Please write the date for each day in the space provided.

3. We are interested in **any** sleep that is 10 minutes or longer. It does not matter whether this is during the day or during the night.

4. The information that is essential to us are the times that you **put your baby to bed** and **when they woke** up after any sleep that is **10 minutes or longer**.

5. Please also note start and finish times of unintended sleeps of **10 minutes or longer**.

6. Please place a mark on the line at each of these times and then write underneath what the line relates to for example *start of intended sleep* (SIS), with the time in hours and minutes. There are abbreviations listed on the sleep log for each of these events.

7. It is these start and finish times of intended and unintended sleeps that we would also like you to push the event marker on the actiwatch (i.e. your corresponding bug motif!)

8. Some babies will lay awake for some time or play alone once put to bed. We do not expect you to change your routine or observe your baby closely for sleep onset. Simply mark the time they were put to bed or when you noticed that they fell asleep. Again, some babies may not signal immediately that they are awake. Just mark the times you are aware that they are awake (for example if they signal to you in the night) and the time that you get them up for the day.

9. If your baby wakes up momentarily during a sleep period, you do not need to write anything in the sleep log. If you are aware that they wake for **more than 10 minutes** then please treat any later sleep as a new sleep period.

10. For each day, please record any time your baby spent in another person's care. If possible appropriate, you can pass the log on to other carers to complete, but this is not essential.

11. There is space for you to write any comments you have for the day. We are particularly interested in events which may effect your baby's sleep, for example being in an unusual, stressful or exciting environment, or events which displaced routine sleep times or places.

12. For each diary day, there are also some questions concerning your baby's levels of alertness, moods at bedtime and on waking, as well as methods problems putting to bed and getting up in the morning. Please circle one answer per question.

B5 *Example of a Feedback Letter and Actigraph Output*

Massey University
WELLINGTON

Private Box 756
Wellington 6140
New Zealand
T 64 4 801 5799
F 64 4 801 2692
www.massey.ac.nz

Dear ...

Thank you for taking part in the Sleep/Wake Research Centre's Baby Sleep Study! Enclosed is the report on your baby's actiwatch recording.

The report runs from midday to midday. The blue markers running along the top of the data are when the event marker was pressed on your baby's actiwatch (I think a lot of babies were pressing the button as well as parents!). The vertical black lines show when your baby was moving, and the height of each line indicates how much movement was recorded in each 1-minute interval.

Underneath each day's data you will see areas marked by a red bar; these times are periods when the software has indicated that your baby was awake. Where there is no red line they are either deemed to have been asleep, or this may be a period when the monitor was removed.

... appears to have a good sleep routine; his bedtime varies between 5 and 7pm. he tends to have both morning and afternoon naps. .... has some wakeups during the night (these appear as little red marks below the line, but remember that these can be as short as one minute and they are based only on movement). As you noted in the sleep diary and questionnaires,... tends to wake around once a night for a feed which may account for the lengthier awakenings.

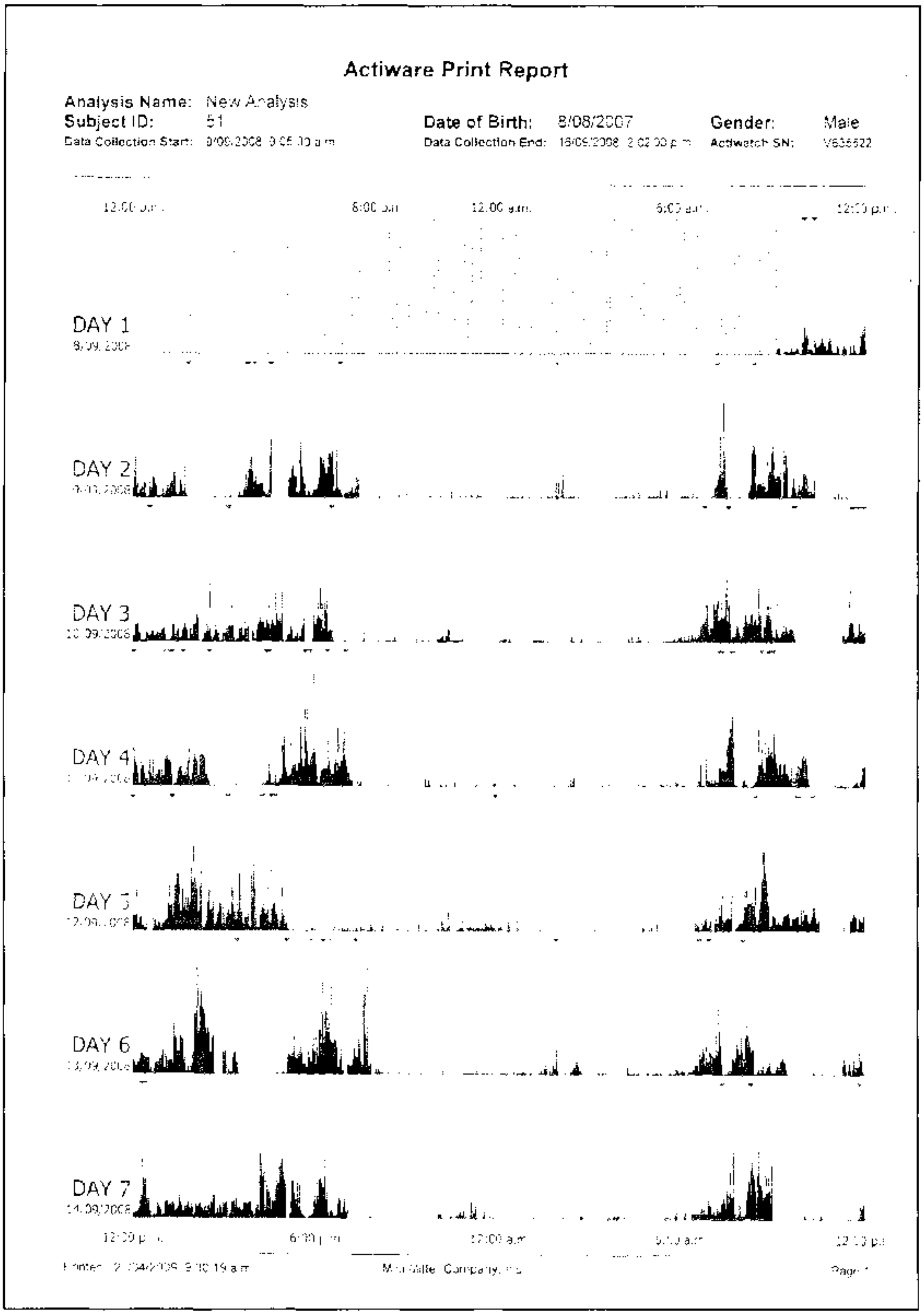
The computer programme that we use to analyse your baby's data produces a lot of statistical summaries which I will be analysing for my thesis, and for our scientific papers. If you would like more detailed information about your baby's record, please feel free to give me call on (04) 801 57999 ext 6035

Thanks again and best regards to your and your family,

Rosie Gibson

Msc Commonwealth Scholar
Sleep/Wake Research Centre
Massey University
Wellington campus
(0064) 04 801 2794 ext 6035
r.gibson@massey.ac.nz

Te Kunenga ki Pūrehuroa


Actiware Print Report
Analysis Name: New Analysis
Subject ID: 51
Date of Birth: 8/08/2007
Gender: Male
Data Collection Start:
Data Collection End:
Actiwatch SN:
6:00 p.m.
12:00 a.m.
DAY 1
DAY 2
DAY 3
DAY 4
DAY 6
DAY 7
14/09/2008
Page 1

Appendix C

Analysis and Additional Results

C1 *Tests of Normality*

Table C1

Kolmogorov-Smirnov Tests of Normality Results for Questionnaire Data.

Variable	*D*	*df*	*p*
Gestation	.216	49	.000
Age	.107	52	.195
Head circumference	.143	52	.010
Weight	.220	52	.000
Length	.099	52	.200
Ponderal index	.120	52	.200
Weight at birth	.110	51	.172
Weight gain	.095	51	.200
Mother's BMI	.186	49	.000
Fathers BMI	.197	42	.000
Minutes to settle to sleep	.232	51	.000
Day sleep duration	.134	52	.021
Bedtime	.248	52	.000
Night sleep duration	.197	52	.000
Time awake	.243	50	.000
Number of awakenings	.205	52	.000
Wake for feed	.395	52	.000
No. nights snoring	.440	35	.000
Hours per week in childcare	.093	21	.200
Percent of study week in childcare	.254	52	.000
Ages and Stages Questionnaire			
ASQ communication	.167	52	.001
ASQ gross motor	.180	52	.000
ASQ fine motor	.201	52	.000
ASQ problem solving	.137	52	.016
ASQ personal-social	.149	52	.006

Table C2

Kolmogorov-Smirnov test of Normality Results for Actigraphy Variables.

Variable	*D*	*df*	*p*
Daytime variables (7 a.m. – 7 p.m.)			
Activity count per min	.187	52	.000
Number rest intervals	.317	52	.000
Rest duration	.072	52	.200
Number sleep intervals	.301	52	.000
Sleep onset latency	.085	52	.200
Sleep duration	.060	52	.200
Sleep efficiency during rest interval	.116	52	.078
Sleep efficiency during sleep interval	.375	52	.000
Wake-rise time	.147	52	.006
Night time variables (7 p.m. – 7 a.m.)			
Activity count per min	.246	31	.000
Number rest intervals	.391	52	.000
Rest duration	.095	52	.200
Bedtime	.146	52	.007
Time of sleep onset	.145	52	.008
Number sleep intervals	.420	52	.000
Sleep onset latency	.104	52	.200
Sleep duration	.081	52	.200
Sleep efficiency during rest interval	.144	52	.009
Sleep efficiency during sleep interval	.241	52	.000
Wake-rise time	.133	52	.022
24-hr variables			
Activity count per min	.317	52	.000
Number rest intervals	.221	52	.000
Rest duration	.084	52	.200
Number sleep intervals	.258	52	.000
Sleep duration	.079	52	.200
Proportion of total sleep occurring at night	.063	52	.200

C2 *Protocol for Manual Scoring of Actigraphy Data*

Scoring Baby Actigraphy Protocol

Marker is not as reliable as in adults as parents forget or cannot access it and it appears that babies are pressing it throughout the day! However there is often a clear marker around bedtimes which can be deemed more reliable.

Although the drop is activity is a useful mark of bed time we are interested in time the baby spent in bed. Therefore the diary is important as sometimes the baby doesn't sleep at all (e.g. during daytime naps) or may be awake for some time before they are taken out of bed in the morning.

Rest intervals

Use the diary, event marker and actigraphy to define beginning and end of rest times.

If there is a clear marker around the times reported in the diary – use the marker

If there is no marker – consider the accuracy of the participants diary –if it is usually consistent with markers and there is a reliable routine then define the rest interval depended on the diary

If there is no marker and no time noted down but a mark on the timeline document a time based on the mark (if there are routine bedtimes this is much easier)

If there is no marker or diary entry – consider the routine of the baby/diary – if they have gone to bed a 7pm every other night then can reliably mark at this time. Otherwise use the drop in activity indicated by the actigraphy.

If the marker and activity match up but diary doesn't (for example may be an hour out by accident) use the marker

If nothing matches – Actigraphy data is primary source, then marker, then diary

If the parent has noted a period of wakefulness longer than 15 minutes during a rest interval, end the rest interval and begin a new one at the time parents have indicated their child was put back to bed.

If the parent has noted a period of wakefulness but it is less that 15 minutes do not end the rest interval.

Exclusion intervals

Exclude initial period between the set up and monitor going on.

If it is reported that the actiwatch came off for any reason – bathing, swimming, forgetfulness etc – exclude this time from analysis.

If there is no activity recorded for 60 minutes or more and no documentation of sleep or the actiwatch being removed.

If it is reported that the actiwatch came off at any point in the night (or any other rest period) then that full night's sleep is excluded as is less reliable.

Exclude the time actiwatch was off – in the post at the end of study.
If there's a consistent bath time the days when this has not been recorded in the diary but there is a loss of activity – deem actiwatch to be off.

C3 *Additional Figures and Tables of Results*

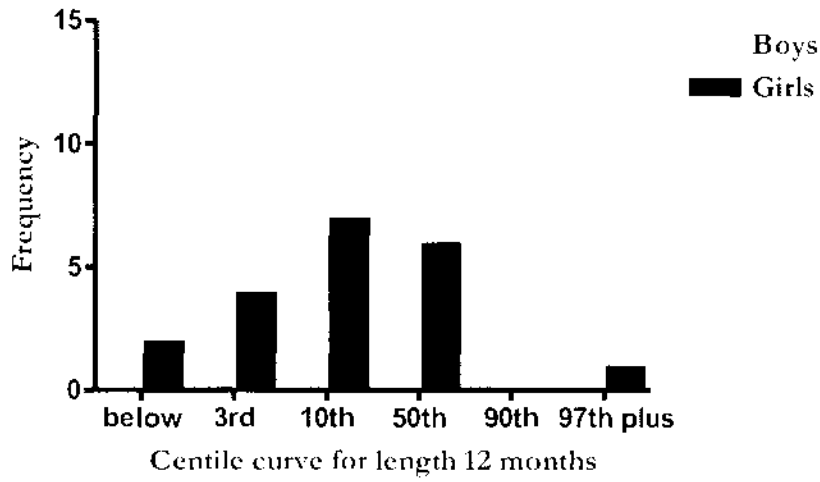


Figure C1. Length of infants represented by the centile curves for 12-month-olds.

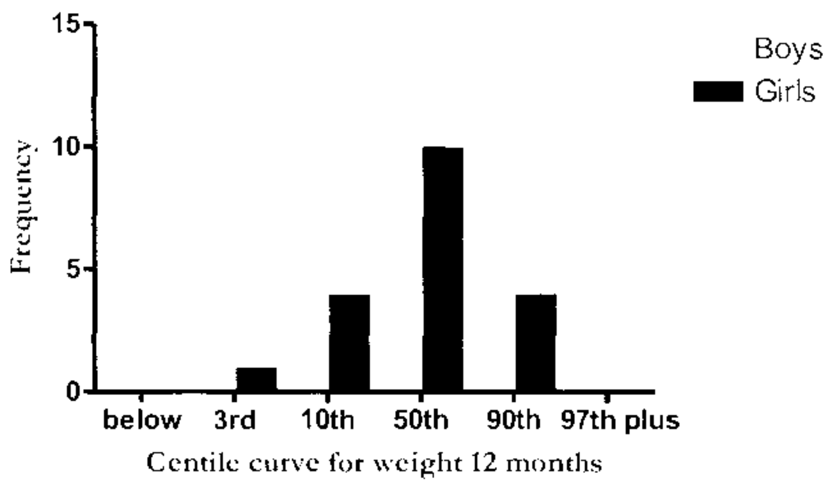


Figure C2. Weight of infants represented by the centile curves for 12-month-olds.

Table C3

A comparison of Ponderal Index Between Girls (n = 18) and Boys (n = 33,Mann-Whitney Test).

Girls Median (range)	Boys Median (range)	*U*	*p* (one-tailed)	*Effect Size*
2.91 (2.7-3.08)	2.83 (2.67 – 3.01)	189.5	.009	-.33

Table C4

Distribution of Parentally-Defined Problem Sleepers by Gender (Chi-Square Analysis).

Gender	No Problem	Small Problem	χ^2 (1)	*p* (two- tailed)
Boys	66.7	33.3	0.66	0.79
Girls	63.2	36.8		

Table C5

Relationship between being Tired at Bedtime and being Problematic at Bedtime (as Rated in the Daily Diaries, Chi-Square Analysis).

Gender	Some problems at bedtime	No problems at bedtime	χ^2 (1)	*p*(one- tailed)
Very tired at bedtime	66.7	33.3	0.27	0.42
Somewhat - not tired at bedtime	63.2	36.8		

Frequency distributions of ASQ results.

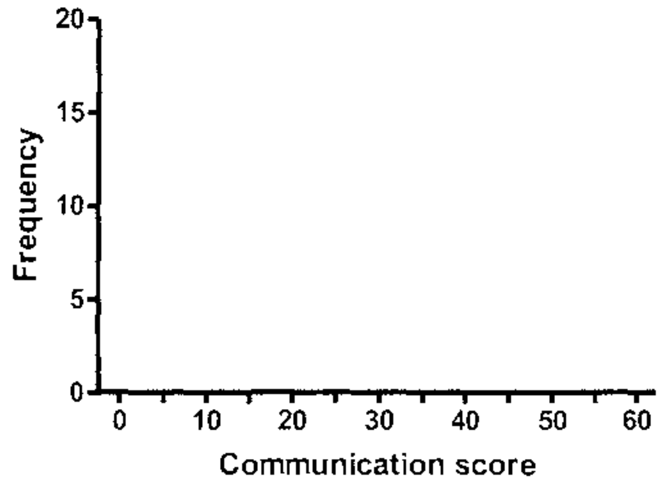


Figure C3. Frequency distribution of ASQ scores for the communication domain.

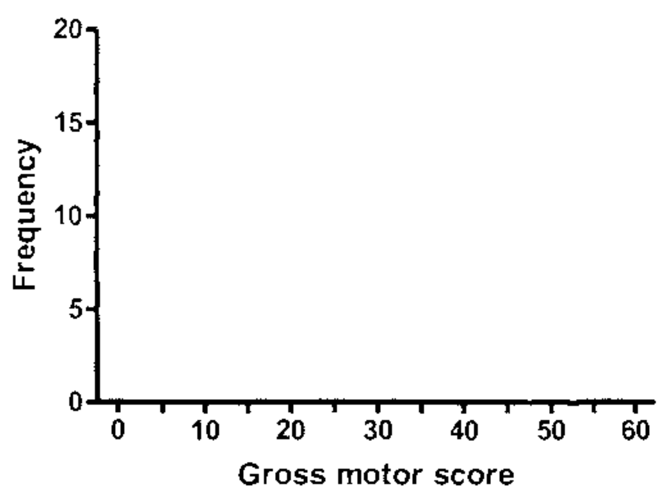


Figure C4. Frequency distribution of ASQ scores for the gross motor domain.

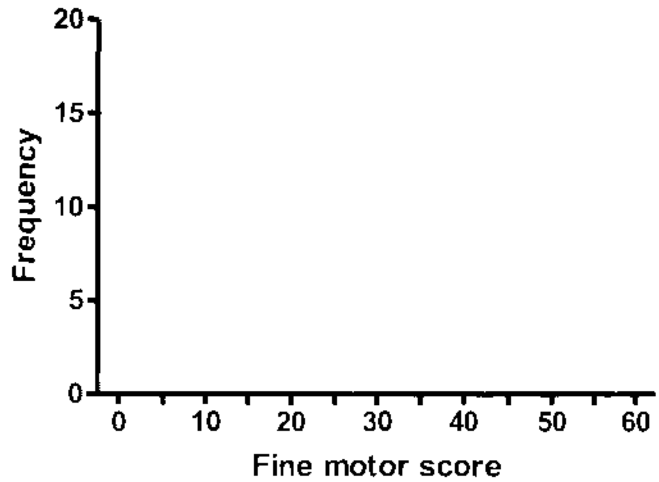


Figure Cc. Frequency distribution of the ASQ scores for the fine motor domain.

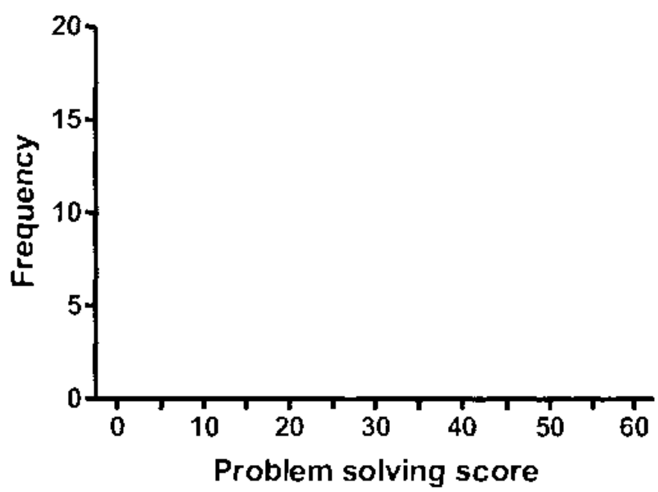


Figure Cd. Frequency distribution of the ASQ scores for the problem solving domain.

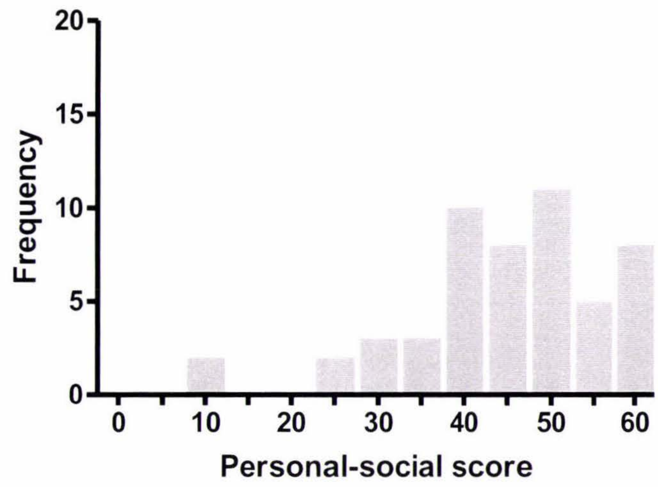


Figure C7. Frequency distribution for the personal-social domain.

Table C6

Developmental Scores on the Five Domains of the Ages and Stages Questionnaire Comparing Babies Parentally Defined as Problem Sleepers (n = 18) and Non-Problem Sleepers (n = 38, Mann-Whitney Test).

	No Problem	Small Problem			
ASQ Domain	Median (range)	Median (range)	*U*	*p* (two tailed)	*Effect size*
Communication	45.0 (0-60)	37.5 (5-60)	268.5	.474	-.10
Gross motor	40.0 (0-60)	50.0 (10-60)	285.5	.697	-.06
Fine motor	52.5 (30-60)	57.5 (40-60)	245.0	.220	-.17
Problem solving	47.5 (15-60)	50.0 (30-60)	296.0	.851	-.03
Personal-social	47.5 (10-60)	42.5 (25-60)	266.0	.442	- .11

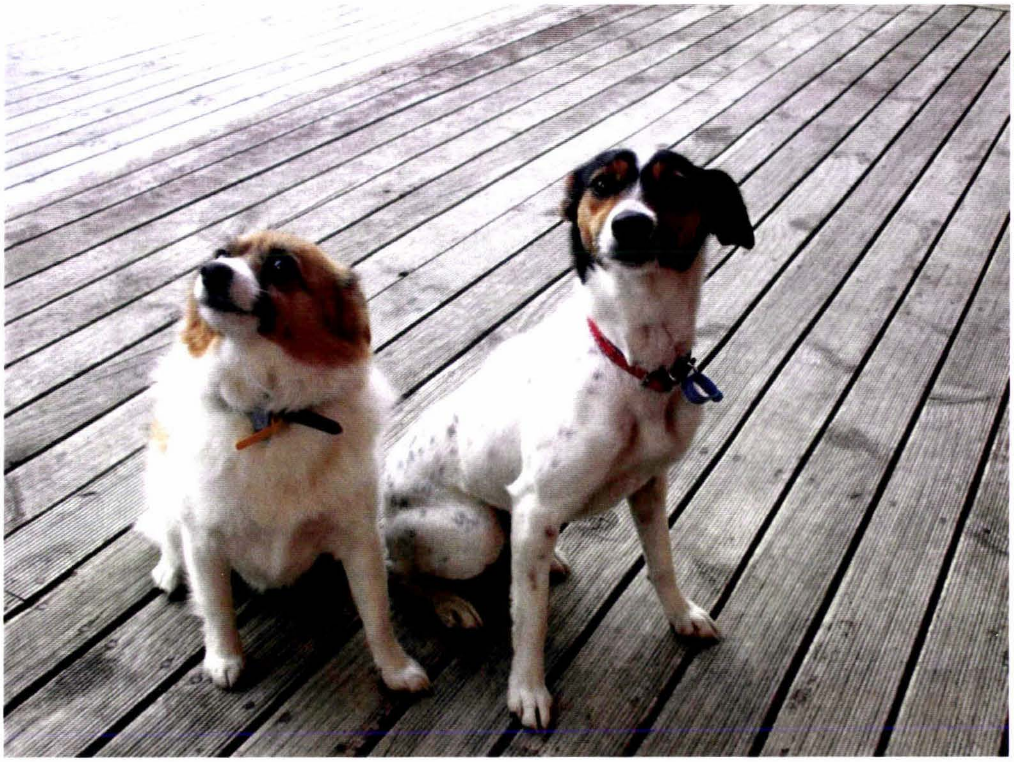


Figure C8. The naughty dogs that ate our actigraph!

Table C7

Comparisons of Boys (n = 33) and Girls (n = 18) Actigraphic Sleep Results (Mann-Whitney Test).

	Boys		Girls				
Variable	Median	Range	Median	Range	*U*	*p*(two-tailed)	*Effect size*
Number of rest intervals per 24- hrs	3	2 - 5	3	1.5 - 5	286	.599	-.07
Number of sleep intervals per 24- hrs	3	2 - 4.5	3	2 - 4	270	.379	-.12
Sleep onset latency at night (mins)	15.5	2.5 - 62.5	22.5	6.5 - 40	250	.232	-.17
Rest duration per 24-hrs	13.9	12.3 - 15.9	13.9	12.3 - 16.9	288	.638	-.07
Night sleep duration (hrs)	10.4	9.1 - 12.3	10.6	8.5 - 12.2	304	.862	-.03
Wake-rise time in morning (mins)	24.5	2.0 - 111.5	8.3	0.9 - 36	297	.760	-.04
Sleep efficiency during night sleep intervals	96.5 %	89.5 - 99.5 %	96 %	75.2 - 99 %	254	.263	-.16
Sleep efficiency during night rest intervals	87.0 %	74.2 - 94.9 %	86.8 %	60.0 - 93.9 %	286	.608	-.07
Activity count per min daytime active intervals	407.3	235.1 - 884.8	367.8	219 - 781.6	243	.187	-.19
Sleep duration per 24 hrs	12.2	9.8 - 13.5	11.6	10.3 - 14.4	270	.379	-.16
Percentage of total sleep occurring at night	85.6%	75.9 - 95.8%	87.5%	76.4 - 94.8	256	.282	-.15

Table C8

Relationship between Age (Months) and Sleep Timing and Efficiency (Actigraphy data, Linear Regression Analysis).

variable	R^2	B	SEB	β
Night sleep duration night [a] (hrs)	.003	11.66	1.325	.053
Sleep duration per 24-hrs (hrs)	.11	13.19	1.403	-.104
Percentage of sleep occurring at night	.041	9.58	1.772	.202
Sleep efficiency during night sleep interval	.82	13.64	2.535	-.082

Note: * = $p < .05$

[a] Night intervals = 7 p.m. 7 a.m.

Table C9

Relationship between Ponderal Index of Babies and Actigraphic Sleep Variables (Linear Regression Analysis).

Variable	R^2	B	SEB	β
Night sleep duration [a] (hrs)	.005	2.77	0.173	.074
Sleep duration per 24-hours (hrs)	.01	2.98	0.18	-.091
Percentage of sleep at night	.05	2.48	0.230	.224

[a] Night intervals = 7 p.m. 7 a.m.

Table C10

Comparisons of Actigraphic Sleep Variables for Infants Rated as High vs. Typical-Low levels of Activity (as Rated Daily by Parents, Mann-Whitney Test).

	High activity day	Typical – low activity day			
Variable	Median (range)	Median (range)	*U*	*p* (two-tailed)	*Effect size*
Activity count per min-daytime active intervals	519.6 (481.7 – 567.3)	393.4 (235.1 – 884.8)	29.0	.086	-.24
Bedtime (average start of first night rest)	19:13 (18:55- 19:28)	19:10(18:15-20:55)	57.0	.543	-.09
Sleep onset latency at night (mins)	17.5 (10 – 18)	20 (2.5 – 62.5)	56.0	.519	-.09
Night sleep duration (hrs)	9.9 (9.8 – 11.1)	10.5 (8.5 – 12.3)	72.0	.965	-.00
Sleep efficiency during night rest interval	90.2 % (81.5 - 90.6%)	86.9% (59.9 – 94.9%)	60.0	.627	-.07
Sleep efficiency during night sleep interval	96.4% (94.13 – 96.3%)	96.5% (75.2 – 99.5%)	46.0	.301	-.15
Time of final wake up in the morning	05:57 (04:49 – 06:11)	06:25 (05:08 – 07:45)	31.0	.101	-.23
Wake-rise time in morning (mins)	15 (11.5 – 26)	25 (2 – 111.5)	42.0	.233	-.17
Number of rest intervals per 24- hrs	3.5 (3 – 4)	3 (1.5 – 5)	45.5	.271	-.16
Rest duration per 24-hrs (hrs)	14.5 (13.9 – 15.3)	13.9 (12.3 – 16.9)	-.922	.384	-.13
Sleep duration per 24-hrs (hrs)	12.3 (12.2 – 12.6)	12.1 (9.8 – 14.4)	59.0	.596	-.08
Percentage of total sleep occurring at night	81.9% (78.2-89.8%)	86.4 (75.9-95.8%)	49.0	.363	-.13

Table C11

Comparisons of Actigraphic Sleep Variables for Infants Rated as having no Bedtime Problems vs. Some to Many Bedtime Problems (as Rated Daily by Parents, Mann-Whitney Test).

	No bedtime problems	Some-many bedtime problems			
Variable	Median (range)	Median (range)	*U*	*p* (two-tailed)	*Effect size*
Activity count per min-daytime active intervals	417.1 (252.9-884.8)	389.5 (235.1-781.6)	253.0	.394	-.12
Bedtime (average start of first night rest)	19:00 (18:15-20:55)	19:09(18:26-20:17)	260.5	.477	-.10
Sleep onset latency at night (mins)	18.0 (2.5 62.5)	17.5 (6.5 - 40)	295.0	.965	-.00
Night sleep duration (hrs)	10.3 (8.5 12.3)	10.7 (9.1 12.2)	279.0	.724	-.05
Sleep efficiency during night rest interval	86.3% (71.6 - 94.3%)	87.4% (59.9 94.9%)	236.5	.238	-.17
Sleep efficiency during night sleep interval	96.4% (81.8 99.5%)	96.5% (75.2 99.4%)	294.5	.958	-.00
Time of final wake up in the morning	06:26 (05:08 07:32)	06:10 (04:49 07:45)	267.0	.559	-.08
Wake-rise time in morning (mins)	24 (5 70.9)	32 (2 111.5)	295.0	.965	-.00
Number of rest intervals per 24- hrs	3 (2 5)	3.5 (2 4.5)	271.5	.603	-.07
Rest duration per 24-hrs (hrs)	13.9 (12.3 15.9)	13.8 (12.3 16.9)	284.0	.802	-.04
Sleep duration per 24-hrs (hrs)	12.1 (9.8 13.5)	12.2 (10.7 14.4)	281.5	.761	-.04
Percentage of total sleep occurring at night	86.8% (75.9-95.8%)	85.8% (80-94.4%)	267.0	.562	-.08

Table C12

Comparisons of Actigraphic Sleep Variables for Infants Rated as being in a Good Mood at Bedtime vs. a Moderate to Bad Mood at Bedtime (as Rated Daily by Parents, Mann-Whitney Test).

	Good mood bedtime	Moderate-bad mood bedtime			
Variable	Median (range)	Median (range)	*U*	*p* (two-tailed)	*Effect size*
Activity count per min-daytime active intervals	393.4 (252.9 -884.8)	406.4 (235.1-884.1)	281.0	.757	-.04
Bedtime (average start of first night rest)	19:00 (18:15-20:55)	19:00(18:26-20:17)	296.0	.981	-.00
Sleep onset latency at night (mins)	21.0 (6 – 62.5)	12.0 (2.5 – 40)	231.5	.202	-.18
Night sleep duration (hrs)	10.6 (8.5 – 12.3)	10.3 (9.1 – 12.2)	252.0	.381	-.12
Sleep efficiency during night rest interval	86.8 % (71.6 - 94.9%)	87% (60 – 93.3%)	280.5	.746	-.05
Sleep efficiency during night sleep interval	96% (81.2 – 99.5%)	96.5% (75.2 – 99.1%)	283.0	.783	-.04
Time of final wake up in the morning	06:25 (05:08 – 07:32)	06:15 (04:49 – 07:45)	247.5	.335	-.14
Wake-rise time in morning (mins)	25 (2 – 70.9)	23 (10 – 111.5)	296.5	.988	-.00
Number of rest intervals per 24- hrs	3 (2 –5)	3 (1.5– 4.5)	266.0	.527	-.09
Rest duration per 24-hrs (hrs)	14.1 (12.5 – 15.9)	13.6 (12.3 – 16.9)	244.0	.304	-.14
Sleep duration per 24-hrs (hrs)	12.3 (9.8 – 13.5)	11.4 (10.6 – 14.4)	207.5	.080	-.24
Percentage of total sleep occurring at night	85.8% (76 – 95.8%)	87.3% (80 – 94.4%)	267.0	.562	-.08