Curriculum Vitae

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Professional Experience

Clinical Positions:

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Certifications/Licensure

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Publications

Hoffman, S., **Terrell, N.**, Driscoll, C. H., & Davis, N. (2016). Impact of High-Flow Nasal Cannula Use on Neonatal Respiratory Support Patterns and Length of Stay. *Respiratory Care*, *61*(10), 1299–1304. http://doi.org/10.4187/respcare.04668

Grants

2018	Huggies No Baby Unhugged Grant Used to support the efforts in developing and maintaining the NICU Cuddler Program at the University of Maryland Medical Center

Professional Organizations

National Association of Neonatal Nurses, NANN – Current Member
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Abstract

Title of Dissertation: The feasibility of actigraphy and care journals to examine sleep-wake patterns of preterm infants in the NICU

Natalie N. Hunt, Doctor of Philosophy, 2022

Dissertation Directed by: Mary Johantgen, PhD, RN

Problem: Sleep disruption in preterm infants can have negative short- and long-term effects, such as behavioral changes, poor emotional regulation, and poor verbal skills.

Purpose: Assess the feasibility of using actigraphy and infant care journals to examine sleep-wake patterns and care activities of premature infants in the NICU.

Methods: An observational study was done in a level IV NICU with clinically stable infants 28-32 weeks gestation at DOL 2-7. Sleep-wake patterns were examined using the Actiwatch 2 and care activities were assessed using an infant care journal over 84 hours continuously. Scoring rules for actigraph data were developed to determine rest intervals. Sleep variables collected included total sleep time, percent of sleep, and number of wake bouts during sleep period. Care activities were documented in journals, including length of activities and whether infants were asleep or awake prior to and after the activity. Actigraphy data was assess using the Actiware software and, along with care activity data, were analyzed using SPSS. Feasibility is assessed through acceptability, implementation, practicality, and limited efficacy.

Results: Data were analyzed on 10 infants. Rest intervals were 155 minutes ±5.3 minutes on average with infants spending an average of 67.1% ± 11.1% asleep. Average daily total sleep time was 902.5 minutes ±158.6 minutes, or 64.3% (± 10.85%) and care clustered with routine care made up 75.5% of the documented care activities.

Conclusions: The feasibility of using actigraphy to examine sleep-wake patterns was supported, despite subjectivity. Sleep data were similar to previous literature, though the this sample is of younger gestation. While the amount of activities were less than previous studies, with modifications to methodology, data collection could be improved.

The feasibility of actigraphy and care journals to examine sleep-wake patterns of preterm infants in the NICU

by
Natalie Hunt

Dissertation submitted to the Faculty of the Graduate School of the
University of Maryland, Baltimore in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
2022

Dedication

To Andrae, Charlotte, and Mack.

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I could not have completed this PhD program without the love and support of my family and friends. Thank you for keeping me on track and forcing me to take a break to keep my sanity. To my husband, thank you for pulling double duty and forcing me to go to the library to work in peace and quiet, and making sure I had everything I needed to be successful.

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List of Abbreviations

AS	Active Sleep
A/B/D	Apnea/Bradycardia/Desaturation
AUC	Area Under the Curve
BiPAP	Biphasic Positive Airway Pressure
EMR	Electronic Medical Record
HELLP	Hemolysis, Elevated Liver enzymes and Low Platelets
IRB	Institutional Review Board
IUGR	Intrauterine Growth Restriction
IV	Intravenous
LD	Lab Draw
MP	Medical Procedure
NCPAP	Nasal continuous positive airway pressure
NICU	Neonatal Intensive Care Unit
NIPPV	Noninvasive Positive Pressure Ventilation
NREM	Non-rapid Eye Movement
PA	Provider Assessment
P/F	Parent/Family Interaction
PSG	Polysomnography
QS	Quiet Sleep
Rad	Imaging
REM	Rapid Eye Movement
RC	Routine Care

R/O	Rule Out
ROC	Receiver Operating Characteristic
SD	Standard Deviation
SGA	Small for Gestational Age
SLP	Sound Pressure Level
UMMC	University of Maryland Medical Center

CHAPTER 1: INTRODUCTION

1.1 Introduction and Significance

Approximately 15 million infants are born prematurely (before 37 weeks gestation) around the globe each year, with rates of preterm birth being about 10% in the United States (Center for Disease Control and Prevention, 2018; World Health Organization, 2018). Infants born prematurely are at increased risk for detrimental medical complications, including neurodevelopmental and cognitive delays, breathing and feeding difficulties, and vision and hearing impairments (Center for Disease Control and Prevention, 2018). Many of these infants require state of the art medical care in a neonatal intensive care unit (NICU). Despite much effort to make the NICU as developmentally appropriate as possible, infants are continuously exposed to noxious stimuli, such as bright lights and loud noises. This makes the NICU quite intrusive for an infant that is not neurodevelopmentally ready to interact with the environment outside of the womb.

An important factor contributing to the well-being of the preterm infant in the NICU is adequate sleep. Sleep is a vital process necessary for normal growth and development, especially during infancy. In the fetus and newborn, sleep serves to develop the sensory system, preserve brain plasticity and create long-term memory and cognitive functioning (Barbeau & Weiss, 2017; Graven & Browne, 2008). Disruption in sleep can negatively impact normal growth and development of the preterm infant by interrupting brain growth, hormone production, and healing of the body, gravely impacting short and long term outcomes (Crawford, 2017). Preterm infants with disorganized sleep (i.e. having quick cycling between short time frames of active sleep and quiet sleep) have been shown to have poorer emotional regulation, verbal skills, symbolic competence, and executive functions at 5 years of age compared to preterm infants whose sleep state organization shifted between mostly quiet sleep (QS) and wakefulness (Weisman et al., 2011). Behavioral changes in the preterm infant, such as fatigue, restlessness, and irritability, can be caused by sleep deprivation, which in turn can lead to an increase in energy expenditure impacting appropriate weight gain and attentiveness (Orsi et al., 2017). Animal models suggest long term negative effects of sleep deprivation in preterm infants, such as increased anxiety, reduced sexual activity and sleep disturbance as adults (Bonan et al., 2015; Graven, 2006; Heraghty et al., 2008).

As health care providers in the NICU continue to explore how to best care for such a vulnerable population, it is imperative to assess how to best protect and promote sleep for preterm infants. To do this, it is necessary to assess how well preterm infants are sleeping in the NICU and what aspects of NICU care may be most disruptive. Many studies have examined sleep disruption in preterm infants in the NICU, yet there is a scarcity of studies examining what specific types of care activities may be most disruptive. Multiple studies have utilized actigraphy to examine sleep-wake patterns in newborns, but few have used it with preterm infants. To this end, the purpose of this study is to assess the feasibility of using actigraphy and infant care journals to examine sleep-wake patterns and care activities of premature infants in the NICU.

Determining the feasibility of using actigraphy and infant care journals in exploring sleep-wake patterns in preterm infants can further research in validating these tools and utilizing these tools to assess interventions aimed at protecting sleep in this population.

Results of these future studies can assist with developing evidenced-based interventions geared toward protecting and promoting sleep in preterm infant in the NICU.

1.2 Specific Aims

The aims of this study are:

AIM 1 – To assess the feasibility of using actigraphy to examine sleep-wake patterns of preterm infants in the NICU. Sleep-wake patterns were explored using actigraphs, worn on the infants' lower extremity beginning between 48-168 hours of age continuously over 84 hours. The 24-hour averages were calculated, and patterns were described. While actigraphy measures activity and is used to estimate sleep-wake patterns, the sleep estimates have been shown to correlate well with infant sleep states.

AIM 2 – To assess the feasibility of using infant care journals to describe NICU care activities that may disrupt preterm infant sleep. Activities were documented by bedside nurses in the infant care journal kept at the infants' bedside throughout the 84-hour study period. Movement associated with care activities were collected simultaneously with actigraph data. Along with care activities, the beginning and end times of each activity were documented, as well as whether the infant was asleep or awake prior to and at the end of each activity.

1.3 Conceptual Model

The transactional model of sleep-wake regulation by Goodlin-Jones et al., (2000) supports the significance of this study. As seen in Figure 1, this model asserts that infant sleep-wake patterns are developed from parent and infant interactions, which themselves are influenced by larger contexts of cultural, familial, and environmental influences over time and are bidirectional (Goodlin-Jones et al., 2000). Sleep-wake regulation then influences the development of sleep-wake outcomes and problems. For this study, the importance of the interaction between the infant and the NICU environment and staff are stressed as factors that may contribute to sleep-wake regulation.

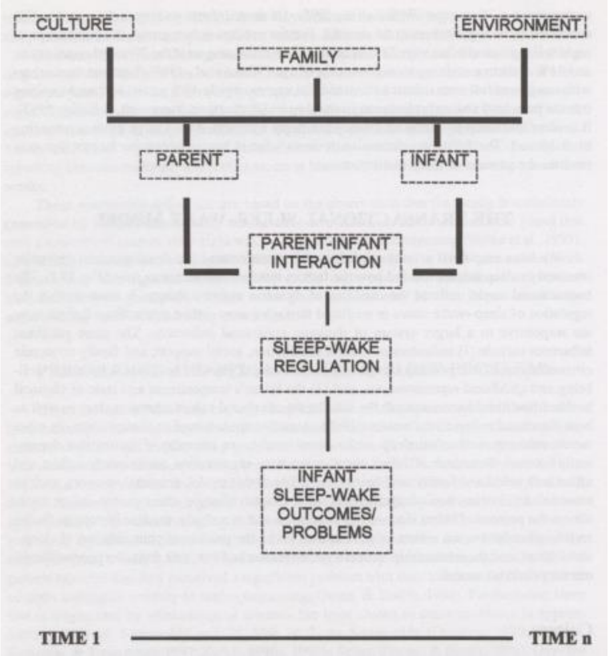


Figure 1. Transactional model of sleep-wake regulation (Goodlin-Jones et al., 2000).

1.4 Assessing Feasibility

Several aspects of feasibility were examined in this study. Bowen and colleages (2009) describe diverse types of feasibility studies related to cancer prevention interventions. While this is not related to an intervention, the authors outline eight areas of focus in feasibility studies, which provide a framework for examining feasibility of actigraph and care journals in this study. The four areas of focused examined for this study include acceptability, implementation, practicality, and limited efficacy testing. As reported by Bowen and colleagues (2009), acceptability focuses on how study participants and those involved in implementing an intervention, react to the intervention. Implementation how well the intervention can be implemented as proposed. Practicality examines how well the intervention can be delivered with constrained resources. Limited efficacy testing is assessed by examining how successful a new idea or intervention can be accomplished and by providing benchmark data. Table 1 lists four of the eight areas of focus and identifies how they were addressed in this study.

Table 1. Areas of focus for feasibility studies defined for this study

	Definition	Outcomes
Acceptability	Extent to which actigraphy and care journals are acceptable to parents, infants and care providers	-Device staying in place throughout study period -Device being replaced if falls off -Parents accepting device utilization by consenting to study -Staff filling out journals
Implementation	Extent to which actigraphy and care journals can be successfully implemented	-Missing data -Data quality -Need for reinforcement -Need for re-education -Adverse effects
Practicality	Extent to which actigraphy and care journals can be carried out within existing resources and circumstances	-Time burden -Interference with care -Cost of device and journals
Limited efficacy	Extent to which data provide evidence of benchmarks/effect size.	-Benchmark data checked for reasonableness and variation

Source: (Bowen et al., 2009)

1.5 Overview of Dissertation

Chapter 2 includes an overview of the relevant literature related to sleep development in the newborn, along with issues with sleep deprivation. Chapter 3 details the study methods, including the scoring rules needed for analysis and to support valid conclusions from data generated by the actigraph software. Chapter 4 presents the study findings, including actigraphy images generated by the software. Chapter 5 discusses the study findings, highlighting the contributions to neonatal sleep knowledge and identifying implications for practice and research.

CHAPTER 2: BACKGROUND AND LITERATURE REVIEW

Chapter 2 provides a review of sleep development in the newborn, as well as discusses the negative effects of sleep disruption in the preterm infants. Despite the many interventions that have been shown to promote and protect the sleep of infants in the NICU, sleep disruption continues to be an issue, so these issues are reviewed. The chapter concludes with a discussion regarding the use of actigraphy in preterm infants in the NICU, including the measurement validity concerns.

2.1 Sleep in the Newborn

Sleep state organization can be seen in the fetus and preterm infant as early as 25-27 weeks gestation (Barbeau & Weiss, 2017). Infant sleep is composed of active sleep (AS) and quiet sleep (QS), as well as indeterminate/transitional sleep, which can include characteristics of both AS and QS (Barbeau & Weiss, 2017). AS is comparable to rapid eye movement (REM) sleep in adults, and is characterized by REM, high physiologic activity, irregular breathing patterns, low voltage on electroencephalograph (EEG) and increased heart rate to increase oxygen supply to the brain (Barbeau & Weiss, 2017; Bonan et al., 2015). QS in infants is comparable to non-rapid eye movement (NREM) sleep in adults and is characterized by visually recognizable cues including the infant making faces, smiling and having sucking movements, blinking and trembling, as well as physiological signs such as slow waves on EEG, and regular heart and respiratory rates with little variability (Barbeau & Weiss, 2017; Bonan et al., 2015; Graven & Browne, 2008).

REM and NREM sleep, which cycle throughout the sleep period, are developed in the preterm infant by 28-30 weeks gestation and are detectable by EEG by 30 weeks gestation (Graven & Browne, 2008). NREM sleep is necessary for brain restoration, energy recovery, cellular repair, increases protein synthesis and production of growth hormone, while REM sleep is necessary for normal central nervous and neurosensory systems development and maturation (Correia & Lourenço, 2020; Crawford, 2017; Graven & Browne, 2008). Thus, disruption of sleep interrupts the normal cycling of sleep stages and has been shown to affect neurological outcomes, particularly during periods of critical brain development.

Full term infants spend about 70% of a 24-hour period asleep, with an average sleep cycle duration of 50-70 minutes in infants 35-41 weeks gestation, while preterm infants can sleep about 90% of the day with those 27-34 weeks gestation having sleep cycles lasting about 40-45 minutes in length (Barbeau & Weiss, 2017; Bertelle et al., 2007; Liaw et al., 2012; Sung et al., 2009). AS is the predominant sleep state in preterm infants, with 90% of the sleep cycle being AS in infants born at 30 weeks gestation, with time in AS decreasing to 50% of the sleep cycle in term infants (Bonan et al., 2015; Graven & Browne, 2008). Infants experiencing AS, or REM, sleep deprivation between 30 weeks gestation and 4-5 months post-term have been noted to have disordered or delayed development of neurosensory systems, such as the somesthetic (touch), kinesthetic (motion), auditory, visual, and hippocampus (memory) systems (Graven & Browne, 2008).

2.2 Sleep Protection and Promotion in the NICU Environment

Various techniques have been examined across multiple research studies to find ways to best protect and promote sleep in preterm infants in the NICU. In a recent review of sleep promotion in infants born prematurely, Park (2020) discussed several interventions that have shown positive impacts on sleep in preterm infants in the NICU. Within this review, the author identified multiple randomized control trials examining effects of skin-to-skin contact (or kangaroo care) on sleep and wake status of infants 24-37 weeks gestation and found that infants had better sleep and wake states organization with less time in active and indeterminate sleep and a higher percentage of quiet sleep. Across three randomized controlled trial assessing the effect of massage therapy on sleep in preterm infants, researchers found that infants receiving massage showed significant improvement in sleep and wake states organization over the study period (five days) and that more infants fell asleep by the end of their therapy session as compared to when they did not have a therapy session. A Cochrane Review by Morag & Ohlsson, (2016) examined the benefit of cycled lighting (12 hours of lights on and 12 hours of lights off per day) across nine randomized controlled trials and found that infants exposed to cycled lighting spent less time in waking and crying states compared to being in an environment with almost continuous light or darkness.

A recent scoping review by Correia & Lourenço, (2020) also examined the literature to assess what sleep promotion strategies have been shown to be beneficial to infants in the NICU. The authors reviewed nine articles published between 2014-2018. A randomized controlled clinical trial that was reviewed looked at the effects of nesting (placing soft boundaries around the infant) on sleep patterns of preterm infants in the NICU compared to routine care and found that infants in the nesting group had a statistically significant increase in total sleep duration, duration of quiet sleep and indeterminate sleep compared to the infants receiving routine care (Mony et al., 2018). A prospective clinical trial also assessing nesting and swaddling compared to no interventions found that infants that were nested and swaddled had a significant increase in total sleep time and quiet sleep compared to infants in the control group (Abdeyazdan et al., 2016). In their review, they also found beneficial effects of cycled lighting, kangaroo care and music therapy. In regard to changes in the environment, a randomized controlled clinical trial examined sleep over three days where day 1 was baseline environmental conditions, day 2 had reduced noise with the infants wearing ear covers and the third day with reduction of light levels with cover placed over the infant's incubator (Lan et al., 2018). The authors found that infants had statistically significant increase in total sleep time compared to those receiving routine care.

There is consensus that sleep is imperative to appropriate growth and development of the preterm infant and the lack thereof can have detrimental short- and long-term consequences. Despite this, preterm infants in the NICU are still subject to an extremely high amount of handling causing disruption in sleep while in the NICU.

2.3 Sleep Disruption in Preterm Infants in the Neonatal Intensive Care Unit

Care in a NICU is a necessity for majority of infants born prematurely. Unfortunately, preterm infants in the NICU are at elevated risk for sleep disruption due to the need for medical care and environmental exposures. Factors that have been found to be most disruptive to sleep in the NICU include environmental noise and brightness of the lights, as well as excessive handling from care provided by the multidisciplinary team (Correia & Lourenço, 2020). Numerous studies have aimed to examine the amount of handling that infants in the NICU receive leading to disruption in sleep.

Pereira et al., (2013) completed an exploratory, observational study where 20 preterm infants were video recorded to examine the frequency, duration, and type of manipulations they incur over a 24-hour period in a NICU in Brazil. Manipulations were defined as any physical procedure meant to provide monitoring, care, or therapy to the infant. The authors found that the infants were subjected to 14-71 manipulations over the single 24-hour study period. The average total time of manipulations was 2 hours and 26 minutes, with 91.7% of the manipulations being ≤10 minutes. Of the manipulations, 65.6% of them were performed as an individual manipulation in contrast to being grouped with other manipulations. While the goal of care within the NICU focuses on being developmentally appropriate and individualized it is clear preterm infants continue to be at high risk for disruption in sleep.

In addition to examining the amount of handling that preterm infant incurs while in the NICU, some studies have examined how hands on care impacts sleep in preterm infants. In a secondary analysis examining the relationship between nursing care and sleep-wake pattern development in 71 preterm infants 28wks ± 2.4 weeks gestation, researchers observed sleep-wake states and related infant behaviors once a week from about 7pm-11pm with observations being recorded every 10 seconds over the 4 hour observation (Brandon et al., 1999). Using hierarchical linear regression, they found that nursing care resulted in a decrease in AS and an increase in drowsiness and sleep-wake transitions. Routine care, such as feeding, bathing and diaper changing, resulted in the most alertness and drowsiness. Procedural care, such as painful procedures and taking of vital signs, resulted in awake behaviors and negative facial expressions. During nursing care that was interactive between the caregiver and the infant (talking, positive touch), infants remained asleep and in AS, and when left alone, infants were able to remain asleep long enough to reach QS (and thereby complete the sleep cycle). A limitation of this study was that observations were solely dependent on the subjective observations of two researchers and did not include the use of instruments that can objectively measure sleep and wake.

In a prospective, descriptive, repeated-measures study, investigators in Taiwan examined caregiving and infant positioning effects on sleep-wake states and state changes of preterm infants between 27-35 weeks gestation who were 3-28 days old (Liaw et al., 2012). Sleep-wake states were observed continuously for three consecutive 24-hour periods while concurrently measuring caregiving patterns, infant position, and the use of non-nutritive sucking. Investigators found that in the absence of care giving, an increase in social interaction, being in the lateral (side-lying) position, and the use of non-nutritive sucking all increased the occurrence of QS. The authors also found that as the frequency of intrusive caregiving increased, there was an increase in infant wake and fussy or crying states. While this study was limited by focusing on the influence of social contexts (e.g. interaction and positioning), and did not analyze the impact of frequency of infant disruption by caregivers other than the bedside nurse, or factor in the infant's environment (e.g. light, noise, temperature), it supports the need to further examine the potential negative impacts of caregiving within the NICU environment on sleep of preterm infants and factors that improve infant sleep.

In a secondary analysis of term and near-term infants at risk for cerebral dysfunction, polysomnography (PSG) was used to determine the frequency and duration of hands-on care in the NICU and how it impacted sleep-wake states in 4-hour periods (Levy et al., 2017). On average, the total duration of handing (direct contact with infant or their immediate environment), during the 4-hour period lasted 65.3 minutes ± 33.0

minutes. Importantly, only 12 of the 25 infants had enough time to complete a full 60-minute sleep-wake cycle between clinical care episodes. The authors also found that hands-on care resulted in arousals or awakenings in 57% of all contact episodes with a sleeping infant and that handling was usually followed by respiratory events such as apneas or hyponeas (complete or partial airway obstructive events), and oxygen desaturations. One limitation of the study was that that 13% of handling episodes were due to the need for technical adjustments related to the PSG, a drawback to the use of PSG. Authors also note that their study did not include critically ill and extreme preterm infants who would not have tolerated use of PSG and are at higher risk for sleep disturbance due to needing more medical interventions and hands-on care.

Investigators from a 16-bed intermediate NICU in Brazil performed a descriptive, correlational study to identify handling procedures (monitoring, therapeutic/diagnostic, and hygiene/comfort) and assess their influence on total sleep, AS, QS and wake times using images obtained by PSG over 24 hours (Maki et al., 2017). Data was collected on 12 late preterm infants, with 73% being direct handlings (direct contact to the infant or a device directly on the infant). There was a total of 2117 handling procedures across the study sample with a mean of 176.4 ±37.9 handlings per infant during the 24-hour study period. Using Freidman test to examine the handling procedures at different times of day, they found a significant difference in the frequency of therapeutic/diagnostic handling procedures during the morning period ($p<0.01$). The mean total amount of time asleep was 824.3 minutes ±237minutes, equating to about 57% of the 24-hour period. Correlation analysis between type, duration, and frequency of the handling procedures and the sleep variables showed no statistical significance, suggesting that these variables did not influence sleep in this study. In reference to wake time, the investigators did find a statistically significant strong positive correlation with single-performed handling procedures (r=0.616, p=0.033). Small sample size was a limitation of this study, as well as the use of PSG, as approximately 35% of the handling procedures were attributed to the need for adjustment to the PSG electrodes.

An observational, correlation study of 12 preterm infants (mean gestation 32.9 ±2.6 weeks) in a neonatal intermediate unit in Brazil aimed to describe total sleep time, different stages of sleep and wakefulness, and how these variables correlated to sound pressure levels (SPL), light levels, temperature, relative air humidity, and handling inside of infant incubators over a 24 hour period with the use of recordings from PSG and a camcorder (Orsi et al., 2017). Investigators found that the infants were handled a mean of 143 times, with 62% of the time being from the health care team and/or family and the remainder of the time by researchers to readjust PSG electrodes (38%). While the number of handling was noted to be significantly higher during the day in comparison to the night, it was not statistically significant (p=0.22), with there being 79.0 ±11.6 manipulations during the day and 65.0 ±23.4 manipulations during the night. The authors did find a statistically significant difference in handling time between the day and nighttime (p<0.001), with a total of 2.5 hours of handling time during the day and 1.4 hours during the night. There was no statistical significance found with correlation between the means of SPL, light, temperature, or humidity and total sleep time, QS, AS, indeterminate sleep, or wakefulness. Investigators did find that wakefulness time had statically significant positive correlation with the minimum (r=0.67, p=0.034) and maximum (r=0.65, p=0.041) values of SPL. Again, small sample size and the use of PSG are limitations of this study.

Investigators in a 15 bed Iranian NICU performed an observational, cross-sectional study examining handling procedures (handling and care procedures, therapeutic measures, and supportive measures) over 24 hours and their effects on sleep-wake time over a 12 hour period (8am-8pm) in preterm infants by infant observation (Godarzi et al., 2018). They analyzed data from 15 preterm infants and found that the mean frequency of handling over the 24-hour period was 59.93 ± 15.86 with mean duration of time for each type of handling being 52.13 ± 12.64 minutes for handling and care procedures, 13.6 ± 13.28 minutes for therapeutic measures, and 76.21 ± 93.08 minutes for supportive measures.

These studies show that NICU staff must not only take care in decreasing the amount of handling that preterm infants are receiving, but also the amount of time that handling take to occur. Providing multiple occurrences of hands-on care contributes to sleep disruptions, but also the lengthy amount of time the handling takes decrease the amount of opportunity that these infants are able to sleep.

2.4 The Use of Actigraphy to Assess Sleep-Wake Patterns in Infants

The gold standard in assessing sleep-wake patterns is PSG, which is used to assess multiple disorders of sleep and includes many components, including electroencephalography, oronasal airflow, abdominal and chest wall movements, pulse oximetry and video-recording (Joosten et al., 2017; Sadeh, 2015). It usually requires patients to come into a sleep lab or into a hospital to be performed. Issues with using

PSG with preterm infants include concerns with injury to the skin from the electrodes and need for frequent electrode adjustment.

Multiple studies that used PSG in this population saw around 13-38% of the handlings infants required were due to adjustments needed for the PSG (Levy et al., 2017; Maki et al., 2017; Orsi et al., 2017). Using PSG in preterm infants can also be complicated, as infant movement and care activities can cause artifacts in the PSG measurements of brain waves and other biological parameters (Lan et al., 2019).

Another method utilized in assessing sleep in preterm infants is behavioral observation. Multiple scoring systems have been utilized to examine sleep and wake states in infants, including the Neonatal Behavioral Assessment Scale, Assessment of Preterm Infants' Behavior, Anderson Behavioral State Scale and Thoman Scoring System (Park, 2020). Scoring occurs at 10 sec to 2 minutes intervals, depending on the scoring system being used. Similar to PSG, behavioral observation can be time consuming, and quite cumbersome for the observers and, to a degree, subjective.

To address these short comings, actigraphy can serve as a very useful tool in examining sleep and wake patterns. Actigraphs are small, lightweight accelerometer devices that can be worn continuously over long periods of time. Sleep and wake are determined by activity counts being greater than/equal to or less than the wake threshold, low = 20 activity counts, medium = 40 activity counts, high = 80 activity counts. There is also an automatic threshold that is calculated by the software and is based on the sum of activity counts for the entire data set. Actigraphs have been used in the adult and pediatric population for many years and have been found to be a reliable and valid way to estimate sleep and wake patterns, with its use continuing to grow in the pediatric population over the past decade or so (Meltzer et al., 2012; Sadeh et al., 1991, 2000; Schoch et al., 2021).

Validity of actigraphy use in infants have been examined testing actigraphy against sleep diaries, observation, and PSG. A study examining sleep and wake states in thirteen infants between 3 and 5 months of age for one hour in their home with actigraphy and simultaneous video recording, found a 93.5% agreement rate (Ikeda & Fukai, 2015).

A study by Sung et al. (2009) compared actigraphy and behavioral observational data from 10 preterm infants 29-34 weeks gestation over 24 hours every week while in the nursery, totaling 38 sets of observations for analysis. The sample was separated into groups, 30-33 weeks, 34-36 weeks, and 37-40 weeks. Agreement rates for the study population were 61.9% – 89.1%. For the 30-33 week gestation group, investigators found agreement rates to be about 66.0% – 85.1% across all thresholds (low, medium, high and auto threshold), with the low and auto activity thresholds having the highest agreement rates (81.4% - 85.1%). Predictive values for sleep were about 91-96% across all age groups and noted to be in the higher range for the 30-33 week gestation group (95.6% - 96.5%). As with other studies, predictive value for wake was low, being between 13.2%-57.2%, with lower values for the 30-33 week gestation group (13.2% - 31.1%).

Actigraphy and PSG data were compared in a study of 22 healthy infants (13 term infants 38-42 weeks gestation and 9 preterm infants 30-34 weeks gestation) where data was collected at three time points, 2-4 weeks, 2-3 months, and 5-6 months (So et al., 2005). Study times were mostly between 10am-3pm, with some overnight from 8pm-6am. Agreement rates between actigraphy and PSG across all observations were between

70.4% - 93.7%. For the observations done at the 2-4 week time mark (n=8), researchers found agreement rates between 80.4% – 93.7% across all thresholds (low, medium, high and auto threshold). For this group, predictive value for sleep was between 96.8% - 98.5% with sensitivity being 80.6 – 96.2. Predictive value for wake between 17.0% - 33.5% with specificity being 54.6% - 82.6%.

A study comparing actigraphy against PSG in 40 infants between 24-40 weeks gestation overnight from approximately 5pm-7am (Unno et al., 2022). The researchers found that 90.2% of the 30 second epochs scored as sleep by PSG could be identified as sleep by actigraphy in relatively stable infants in the NICU. The average agreement rate, predictive value, and sensitivity between actigraphy and PSG were 88.1%, 88.8%, and 97.5%, respectfully. A receiver operating characteristic (ROC) curve was made and showed the area under the curve (AUC) to be 0.87, indicating good discriminatory capability of actigraphy.

A study by Rioualen et al., (2015) examined data from 48 infants (24 infants 34-36 weeks and 24 full term infants) over an approximate 3 hour period and compared PSG with an actigraph placed on the leg and another on the arm. Overall mean agreement rate between PSG and leg actigraphy was 62.6% (±17.1%). For the late preterm group, agreement rate between PSG and leg actigraphy was 66.7% (±16.6%).

A study by Derbin et al. (2022) compared actigraphy against PSG in 10 infants 24-37 weeks gestation at ≥30 weeks post-menstrual age (gestational age plus chronological age). Data was collected over three “inter-feed” intervals (time in-between feeding and nursing cares which lasted about 2.5-3.5 hours) between 6am to 6pm. Overall sensitivity and predictive value for sleep ranged between 85.2%-97.2% across three thresholds (low, medium and high) with specificity and predictive value for wake being low at 12%-46%. In contrast to the findings from Unno, et. al,. (2022), this study also constructed a ROC and showed the area under the curve (AUC) to be 0.636 and Youdens' Index to be *J*=0.217). This suggest that actigraphy has low effectiveness to determine sleep.

While these studies aim to determine validity in the use of actigraphy in preterm infants, there is a wide range of infant ages across these studies, being as low as 24 weeks to full term. Sleep patterns are quite different across this age range. There is also a wide range of time periods that these studies occurred, some being as short as a few hours to over a full day. Some studies also assess at different post-menstrual age. The settings were different as well, with some being in sleep labs and others in the NICU or nursery. These factors can impact the results of this study and how they can be applied to this study, as the sample consist of younger infants being cared for in a level IV NICU. The characteristics of this study sample are much different from those studied in the discussed validity studies, supporting the need for further research for this population.

2.5 Use of Sleep Diaries in Infant Sleep Research

Sleep diaries are subjective measures of sleep that can be used in addition to objective measures, such as actigraphy. Data from sleep diaries can be used to reduce artifact in actigraphy data, as it can be used to adjust sleep and wake times captured by actigraphy (Kahn et al., 2018; Sadeh, 2015). As a subjective measure, the use of sleep diaries has notable limitations.

Sleep diaries are mostly utilized in research studies that are done in the home environment and are filled out by parents. One study examining sleep in infants in the

NICU used sleep diaries to document times of feeding and handling by NICU staff, which they excluded from their data analysis (Schmidt et al., 2021). Researchers have utilized sleep diaries to document methods and times of feedings, as well as sleep-wake patterns during naps and overnight. Different sleep diaries have been developed for individual research studies, and have been developed to document infant and/or parental sleep over a wide range of interval times, between 5-30 minute (Guyer et al., 2015; Rudzik & Ball, 2021; Simard et al., 2013). Sleep measurements that have been determined by sleep diaries include total sleep time, length of sleep periods, and times of overnight awakenings (Guyer et al., 2015; Konrad et al., 2016; Simard et al., 2013).

Limitations of sleep diaries have also been documented, such as concern of parental opinion regarding infant quality of sleep. This could be effects by individual parental characteristics, as well as sleep patterns of the parents. Issues with parental compliance are of concern, especially in longitudinal studies. Accuracy in sleep diary data can be a limitation, as parents are completing them overnight while they are also sleeping.

2.6 Summary and gaps in literature

Poor sleep in preterm infants has been associated with disordered or developmentally delayed neurosensory development. This has led to varied approaches to protect and optimize sleep for infants in the NICU, with notable improvements in infant sleep. However, reliable, valid, and feasible measures for infant sleep remain challenging. While PSG is considered the gold standard, actigraphy devices have improved and are likely more feasible in terms of cost and implementation. While there is support for the use of sleep diaries to supplement actigraphy data, there is very little documentation of the use of sleep diaries for this reason in studies examining sleep in the preterm infant population. Feasibility studies with updated devices and concurrent validity measures are needed.

CHAPTER 3: RESEARCH DESIGN AND METHODOLOGY

This chapter begins with a description of the study design, setting and inclusion and exclusion criteria for study participants. This is followed by a discussion of the methodology used to examine sleep-wake patterns in neonates with the use of actigraphy and the use of infant care journals for examining different type of care that infants receive while in the NICU. Lastly, a review of the data analysis plan is described.

3.1 Study Design

This observational study was conducted to test the feasibility of examining sleep wake patterns of premature infants in the NICU with the use of actigraphy and NICU care activities with the use of infant care journals. Four areas of feasibility were assessed including acceptability, implementation, practicality, and limited efficacy.

3.2 IRB/Ethics

This study was approved by the University of Maryland, Baltimore Institutional Review Board (IRB) in December 2020 with an expedited review. A waiver of HIPPA authorization for release of protected health information was approved. The NICU staff members were made aware of the study goals and procedures, including the inclusion and exclusion criteria. Staff members were requested to alert the study team of infants that may be eligible for the study. A member of the study team discussed the study requirements with the infants' clinical team to confirm that the infant was clinically stable enough to participate in the study. For infants that were cleared to participate in the study, their parents were approached, either in person or over the phone, to discuss the study and obtain consent. It was explained to the parents that participation in the study was completely voluntary, and the decision to not participate in the study would not change the care that their infant received while in the NICU. Written or verbal informed consent was received by the parent(s) of the infant prior to enrollment into the study, following waiver of consent documentation procedures implemented during the COVID pandemic.

3.3 Study Setting

The study was conducted in the NICU at the University of Maryland Medical Center's (UMMC) downtown campus in Baltimore, Maryland. The UMMC NICU is a regional, level IV NICU that admits infants from the in-house labor and delivery service, as well as transfers infants that need a higher level of care from all over the state of Maryland and its surrounding areas. The NICU admits approximately 800 infants per year.

The NICU is located on the 4th floor of the main hospital and is a 52 single family room unit. Each room has a similar design allowing for each infant to have comparable environmental conditions. Each room in the NICU is equip with lighting systems that provide cycled lighting, as well as sound machines that monitor and display noise levels. Most infants receive routine care on a 3- or 4-hour schedule, depending on how often the infant is scheduled to be fed. As part of the routine care provided in the NICU, clustering of care routinely occurs at feeding times to minimize disruption to the infant and usually includes taking of vital signs, nursing/physical assessments, diaper changes and feedings. Infants in the study age range of 28 – 32 weeks completed gestation are normally maintained in a double-wall incubator to help with thermoregulation. Being in the incubator also helps protect the infant from obtrusive noises from the NICU environment. In addition, infants of this age typically have a cover

over their incubator to keep the inside of the incubator dark, decreasing exposure to obtrusive environmental light.

3.4 Study Participants

Study participants were recruited by convenience sampling. Only infants of parents that spoke English were eligible for the study. Infants were included in the study if they were born between 28 weeks 0 days through 32 weeks 6 days gestational age and clinically stable per the medical team. Data collection started when the infant was 2-7 days old. Infants were enrolled into the study after 48 hours of chronological age (time since birth). This allowed the infant time to stabilize after delivery and acclimate to the extrauterine environment in the NICU. A focus on this early gestation and time period of the first week of life was the interest of this study, as sleep state organization begins with REM sleep starting at 28-30 weeks gestation (Graven & Browne, 2008). Exclusion criteria were developed from conditions that are known to alter the neurological status of neonates. The exclusion criteria for this study included:

1. complex heart disease or other congenital anomalies
2. grade 3-4 intraventricular hemorrhage or periventricular leukomalacia
3. hypoxic-ischemic encephalopathy
4. genetic syndrome
5. neonatal abstinence syndrome
6. inborn errors of metabolism
7. receiving sedation or pain medication
8. infant of a mother positive for COVID-19
9. infant suspected and being tested for COIVD-19

Infants were screened between March 2021 - December 2021. During that time, 430 infants were admitted to the NICU. Of these infants, seventy-one infants met study criteria based on gestational age, but only 27 of them were clinically stable per the medical team. Of these 27 infants that were screened for the study, 22 infants were eligible. Ten parents declined enrollment in the study due to concerns of infants' clinical status. The final number of infants that were consented and enrolled into the study was twelve.

3.5 Study Measures

3.5.1 Maternal and Infant Characteristics

Maternal and infant demographics were extracted from their respective electronic medical records (EMR). Maternal characteristics that were obtained included age, race, gravida, parity, and significant perinatal medical complications and medications. Infant characteristics that were obtained included gender, race, gestational age, mode of delivery, medical diagnoses, medications, method of nutrition and respiratory support. Infant birth growth parameters were also obtained, including weight in grams and height in centimeters.

3.5.2 Sleep-Wake Patterns

Infant sleep-wake patterns were examined using the Actiwatch 2 (Phillips Respironics, Inc, Murrysville, Pa). The Actiwatch 2 is a lightweight, compact (16 gram) device similar to a wristwatch (Figure 2). It has an integrated light sensor, giving it the capability to record photopic light. It also employs a marker button that can be pushed by the wearer to date- and timestamp activities, such as getting in bed and getting up in the morning. The actigraph uses an accelerometer to continuously record movements and totals the number of these movements in a set epoch (period of time). For this study, actigraph parameters were set up as follows: 30 sec epoch length, medium threshold (40), immobile minutes of 10 to determine sleep onset and offset times. These parameters are commonly used in the pediatric research using actigraphy and in validation studies with preterm infants (Adams et al., 2020; Meltzer et al., 2012; Schoch et al., 2021).

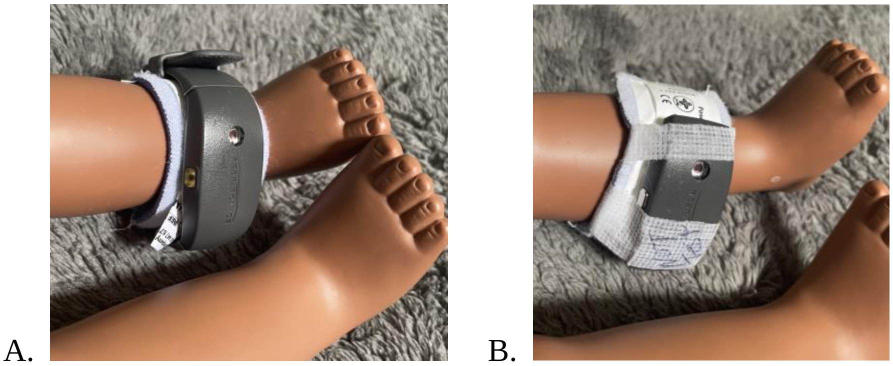


Figure 2. Picture of actigraph used for study. A. Actigraph with straps on placed over top of soft band. B. Actigraph taped to soft band.

Eighty-four hours of data were collected to ensure 72 hours of valid data for each infant. This is in line with the suggestion of collecting data for greater than three days (Sadeh et al., 1995). This time period also ensures comfort for the infants and decreases the potential staff burden. At the end of the 84 hours data collection period, the actigraph data was downloaded into the Philips Respironics Actiware Software version 6.1.2.1. Seventy-two hours of data were analyzed to obtain 24-hour averages for the sleep-wake variables.

Sleep-wake variables that were examined include average of total sleep time during rest intervals and per day, average percent of sleep per day, and number of wake bouts during sleep periods, (see Table 2 for definitions). Clustering of care in the NICU is meant to maximize the amount of time that infants can sleep. Infants in the NICU spend the majority of the 24-hour period in bed with intentions of sleeping. The only time that an infant is expected to be awake is during their routine care times every 3 hours. All other time is meant for infants to sleep so that they can grow and heal. Total sleep time is defined as the total amount of time that is scored as sleep in the actigraph data (Kushida et al., 2001).

Table 2. Sleep and wake variable definitions

Term	Definition
Rest Interval	Time interval in-between routine cares
Total Rest Time (minutes)	Sum of minutes in-between routine care
Total Sleep Time (minutes)	Sum of minutes infant sleeping (sleep interval)
Total Number of Wake Bouts	Number of times infant noted to wake during sleep intervals

The Actiware software utilizes the Oakley algorithm to score sleep and wake for each epoch. The algorithm uses the 2 minutes before and after the epoch being scored to determine the final activity count for that epoch (Kushida et al., 2001). As depicted in Figure 3, the black block represents the 30-second epoch to be scored (E). The recorded activity count for that epoch is multiplied by 2. The epochs in the first minute before (E_{-1}) and after (E_{+1}) the epoch being scored are multiplied by 0.2. The epochs of the second minute before (E_{-2}) and after (E_{+2}) are multiplied by 0.04. These numbers are then added together to determine the final activity count for the epoch being scored. For example, if scoring for data programmed for 30 second epochs, the algorithm would score the epochs' final activity count (FAC) using the formula:

$$FAC=(E_{-2a*}0.04)+(E_{-2b}*0.04)+(E_{-1a}0.2)+(E_{-1b}*0.2)+E+(E_{+1a*}0.2)+(E_{+1b}*0.2)+(E_{+2a}0.04)+(E_{+2b}*0.04)$$

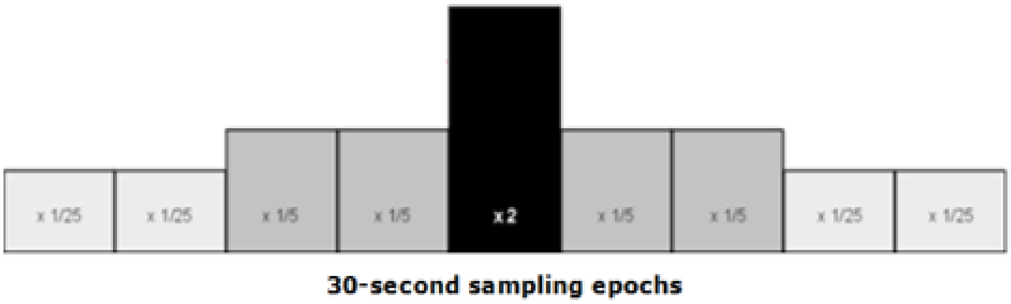


Figure 3. Depiction of epoch scoring formula. Black block is epoch being scored. Surrounding epochs are used in equation to calculate final activity count for epoch being scored using the Oakley algorithm. Source: Actiware Software Manual ver 6.1.2.1

3.5.3 Infant Care Activities

When assessing sleep-wake patterns with the use of actigraphy, it is recommended to utilize a sleep journal to validate and decrease artifact in the actigraph data (Meltzer et al., 2021). For this study, an infant care journal was created to collect sleep and activity data for each infant (Appendix 1). In addition to the type of activity that the infant received, the date and time of the beginning and end of each activity was documented. Whether the infant was asleep or awake at the beginning and end of each activity was also documented. The infant care journal utilized a checklist format to allow the nurse to easily document the care activities. The activities included in the journal were:

1) routine care
2) provider assessment
3) lab draw
4) radiology

5) medical procedure
6) parent/family interaction
7) apnea/brady/desaturation event requiring stimulation
8) “other”

The “other” box was listed as an option if in the event that there was an activity that was outside of the options provided, in an attempt to encompass all care activities. Definitions of each activity, as well as for observing sleep and wake, were included in the infant care journal as a reference for the nurse.

3.6 Study Procedures

Upon IRB approval, education was provided to the NICU staff about the study prior to subject enrollment. Working with the NICU Nurse Educator, nursing education was developed, and education sessions were provided. The education was also assigned to the entire NICU nursing staff on UMMS U, the education portal utilized by UMMS. The nurses were educated on study procedures including how to place the actigraph, how to assess the skin with every routine care time, and how to fill out the infant care journals.

3.6.1 Actigraphy

The actigraph was placed on either of the infant’s lower extremities during a routine care time by the bedside nurse between 2-7 days of life. The location of the actigraph (left or right leg) was documented in the infant care journal. This way, if the actigraph were to fall off, the nurse would be able to replace it on the same extremity for consistent data collection. To ensure skin protection and optimal fit, the actigraph was taped to a soft band, which is routinely used in the NICU as patient label bands, prior to being placed around the infants’ extremity (Figure 2).

At the beginning of each routine care time, the bedside nurse was instructed to push the marker button on the side of the actigraph. The actigraph was only taken off during routine care times every 3 hours by the nurse to assess the infants' skin underneath and then be replaced. If there were no skin issues from the actigraph, it was replaced. If there was skin breakdown noted, the actigraph would have been removed and the data collection would have ended for that infant. This did not happen for any of the infants in this study. At the end of the routine care time, the nurse would again push the marker button. At the end of the 84-hour study period, the actigraph was taken off, cleaned, and collected for data download.

3.6.2 Infant Care Journals

Infant care journals were filled out by the bedside nurse for every activity that was done to the infant, and the infant's immediate environment, during the 84-hour study period. In filling out the infant care journal, the nurse was instructed to document the date and time that each activity started and ended. The nurse also documented whether the infant was asleep or awake at the beginning and end of each activity. If the infant was noted to be visibly asleep with eyes closed and little to no body movements, the nurse would score the infant as asleep. If the infant was noted to be visibly awake with body movements and with eyes open, then the nurse scored the infant as awake. At the end of the care activity, the nurse checked off all activities that were done during that period.

3.7 Cleaning and Scoring Actigraph Data

Scoring rules for actigraphy were developed iteratively between this author (NH) and an actigraphy expert (VR). NH's initial scoring rules were based on current actigraphy research in adults, children and infants, which were then trialed on pilot actigraphy data, and finally refined to fit the unique nuances of the NICU (e.g. restraints of unnatural lighting and scheduled and unscheduled disturbances of sleep opportunities to provide care) and of the characteristically poorly organized sleep cycles of premature infants (e.g. lack of the well-developed 90-minute sleep cycles typical of older infants, children and adults; and unconsolidated, short sleep periods throughout the day and night). The final scoring of each infant's actogram (Figure 4), the graphic representation of the activity counts recorded in the actigraphy data, was carried out using the finalized scoring rules by this author and reviewed jointly with the actigraphy expert (VR) to determine consensus.

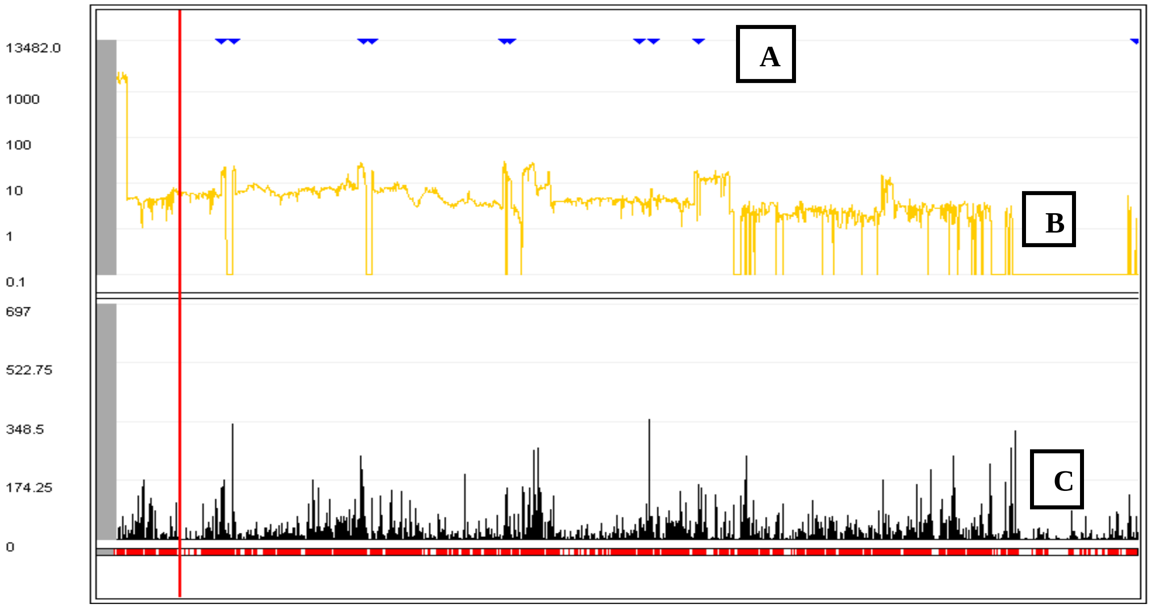


Figure 4. Picture of the actogram in graph view. (A) time stamps (blue triangles), (B) drops and rises in light levels (yellow line), and (C) changes in activity levels (black vertical lines).

A picture of the actogram prior to cleaning and editing is depicted in Figure 5. Prior to analyzing actigraph data, it is advised to first inspect the data and manually adjust the automatically inputted rest intervals and add rest intervals that may have been missed by the software's algorithm (Chow et al., 2016).

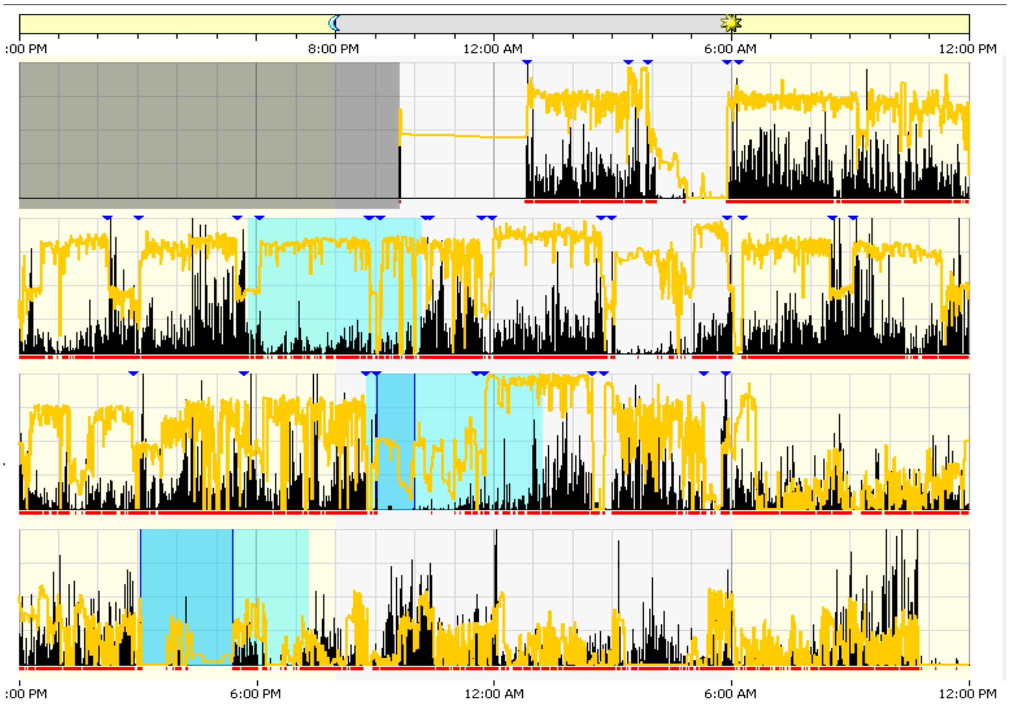


Figure 5. Picture of actogram in raw form prior to cleaning. Blue triangles indicate time stamps. Yellow line indicates tracing of light level. Black lines indicate tracing of activity levels. Light blue shaded area indications rest intervals. Dark blue shaded area indicates sleep interval.

Before doing this, it is imperative to first examine the actogram to find any prolonged periods that would be considered missing data. Sherar et al. (pg.5, 2011) suggest "a period of 60 minutes of consecutive zeros, allowing for 2 minutes of non-zero interruptions" be considered off-wrist time, which would be considered missing data. With this criterion, all the actigraph data was examined, and for time periods that met this criterion, an excluded interval was manually edited in the actigraph software. This allows the software to recognize that interval as missing data and exclude it from the data analysis. If there were 24 hour periods of actigraphy data that had >4 hours of missing data, those days were excluded based off of criteria used by Patel et al. (2015). If infants had <2 qualifying 24-hour periods of actigraphy data, the data for that infant was determined to be invalid and that data was not included in the final analysis. After going through the data and marking the excluded intervals, two of the infants were noted to have <2 qualifying 24-hour periods of actigraphy data. The data for those infants were excluded from the final analysis leaving 10 infants with data to be analyzed.

Because there would be a need to input all the rest intervals so that they would correlate with the routine care times, all intervals that were automatically inputted by the software were cleared. Next, data trimming was done. This involves "trimming" off data at the beginning and end of the data file that were not used in the analysis to only include the timeframe that will be analyzed (Fekedulegn et al., 2020). Data was collected over 84 continuous hours to ensure 72 hours of complete data for each infant. The actigraph data was compared to the infant care journals to find a 72-hour period that had data available for both sources. With this, as well as taking into account any missing data within 24 hours periods, a 72-hour period was determined and the data before and after that 72-hour period were made excluded intervals (see Figure 6 for actigraph after trimming). Once all the necessary exclusion intervals were set, the actigraph data and infant care journals were examined to determine the rest intervals.

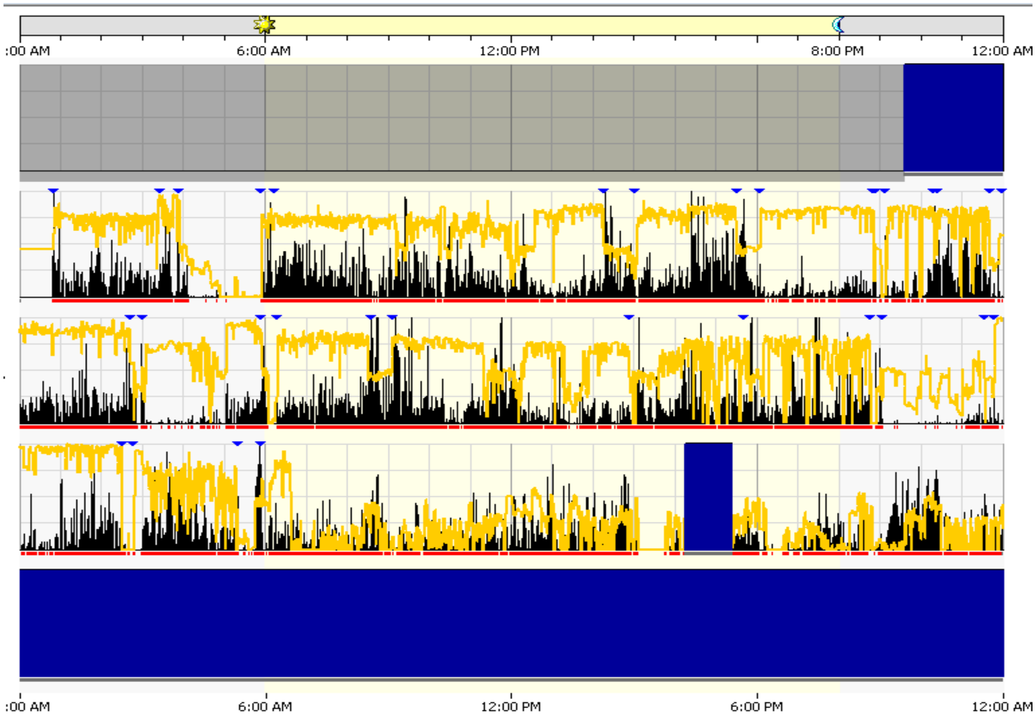


Figure 6. Picture of actogram after trimming and adding exclude interval (dark blue areas) for missing data.

For this study, rest intervals were defined as the amount of time in-between routine care times, as this time is assumed to be dedicated to infant sleep. For this study, rest intervals were inputted to begin at the end of routine care times and to end at the beginning of the next routine care time. While there is no standardized method in setting rest intervals, some research has recently been done to address this gap in the literature. For this study, a combination of the methods was utilized as a means of validating the use of care times as the start and end of rest intervals, specifically the use of a hierarchy of reliable markers. Markers in descending order of their importance in the hierarchy include (a) time stamp, (b) sleep journal data, (c) light sensor, and (d) activity counts (Fekedulegn et al. 2020; Patel et al. 2015). As described, at the beginning and end of each routine care time, the bedside nurse was instructed to press the marker button, recording a timestamp in the actigraphy data, and to also document this in the infant care journal. To determine the beginning and end of routine care times using light level and activity count data, the actogram was examined for sudden drop and/or rise in each level.

Based on the work of Patel et al. (2015), the likely rest interval times extrapolated from each marker was examined and organized in a table (Appendix 2). Once the times were organized in the table, scoring rules (Appendix 3) were applied to determine if the beginning and end times for the rest interval times needed to be altered. If ≥ 2 markers were in agreement within 15 minutes of each other, the highest ranked marker defined the start and/or end time of the rest interval. If two pairs of markers are each in agreement for different times (e.g. time stamp and journal suggest a 10am start time and light and activity markers suggest 10:20am start time), the highest ranked marker, the time stamp, defined the start and end of the rest interval (Patel et al., 2015). If there were no markers in agreement within 15 mins of each other, the mean time of routine care for that infant was calculated based on the other routine care beginning and end times based on hierarchy markers. The amount of time was either (a) added to a marker determined start time, or (b) subtracted from a marker determined end time. Also, if no markers can be used to determine start/end times for the rest intervals, the start time was inputted at the standard start times for routine care (12, 3, 6, 9 am/pm) and the mean time for routine care was added or subtracted to that time.

Routine care times happened every three hours at 12, 3, 6 and 9 am and pm for the infants in this study. For each infant, the routine care times were extrapolated from the infant care journals at the times that the nurse checked the “routine care” box. The length of routine care times in minutes was then divided by the number of routine care times to determine the average length of time for routine care for each infant. For instances that there is either a missing time for the beginning, end, or both in the actigraph data, the average time was inputted. For example, if there were no markers in agreement within 15 minutes of each other to determine a beginning time or end time for the routine care that was to start at 12pm, then 12 pm was recorded as the beginning of the routine care time and the average routine care time calculated for that infant. As an example, if the calculated average routine care time is 24 minutes, then 24 minutes would be added to the 12 pm beginning time (e.g. 12:24pm) and manually inputted into the actigraph data. This results in a routine care time of 12:00pm-12:24pm. If there is a time stamp that can be used as the beginning of the routine care time that starts within 15 minutes of 12pm (e.g. 12:08 pm), but there are no markers in agreement within 15 minutes to define an end time, the time stamp was used as the beginning of the routine care time and the average routine care time (again for example 24 minutes) was added to the time stamp time to determine the end time to be manually inputted. The routine care time for this instance would be 12:08pm-12:32pm. Lastly, if the missing data point is at the at the beginning of the routine care time, but there is a marker to define an end time for the routine care, then that marker was used as the end time (e.g. 12:32pm) and the average routine care time was subtracted to determine the calculated routine care beginning time (e.g. 12:08pm). This makes the calculated routine care time to be inputted as 12:08pm-12:32pm.

3.8 Assessing Feasibility

The assessment of feasibility for this study was guided by four of eight areas of focus presented by Bowen et al. (2009) and include acceptability, implementation, practicality, and limited efficacy (see Table 1 for summary of definitions and measures). Acceptability was examined by how well the infant, parents, and staff accepted the use of the actigraph and infant care journals. Acceptability by the infant and parents was assessed by how well the actigraph stayed in place and if the parents felt comfortable having the infant wear the device by consenting to the study. Acceptability by NICU staff was assessed by examining if the bedside nurse maintained the actigraph by ensuring that it stayed in place throughout the study period or replacing it when it fell off and completing the infant care journal. Implementation was assessed by examining missing data in the actigraphy and infant care journal data, evidence of adverse effects, and the need for reinforcement and reeducation of study protocols. Comparability of actigraphy data across the study sample and to current literature will be assessed as well. The area of practicality was examined by whether the actigraphy and infant care journals can be used with existing resources and under current circumstance in the NICU. This was done by considering how these tools interfered with standard care delivered in this level IV NICU. Lastly, the area of limited efficacy was assessed by comparing study results to existing research as a benchmark.

3.9 Data Analysis

To assess sleep-wake patterns, actigraphy data were downloaded and reviewed for each infant after their study period ended. Once actigraphy data were reviewed and cleaned, the data was exported into a Microsoft Excel sheet to examine rest, sleep, active and daily summary statistics. Data for the variables of interest were then imported into SPSS for final analysis. Data for the infant care journals were inputted by hand into an Excel file and then imported into an SPSS file along with the actigraph data.

Data for ten infants were included in the final analysis. Infant and maternal demographics were extracted from the EMR, actigraph data was extracted from the Actiware software (Phillips Respironics, Murrysville, Pa), and care activities were extracted from the infant care journals. Data were analyzed using SPSS v27 (IBM Corp, Armonk, NY). Descriptive statistics were employed to describe sample characteristics, and sleep and wake patterns from actigraphy data over time from a “wide” file. Infant care activities from care journals were formatted to a “long” file to describe the types, frequency, and duration of care activities. Statistics included frequencies (n), minimums (min), maximums (max), means, standard deviations (SD), and percentages (%).

CHAPTER 4: RESULTS

In this chapter, the results of the data analysis are presented. After describing maternal and infant characteristics of the study sample, analysis of sleep and wake patterns and care activities are presented. Feasibility concepts of accountability, implementation, practicality, and limited efficacy are then discussed.

4.1 Study Sample

Of the 12 infants enrolled into the study, 2 of them were excluded from data analysis due to high amount of missing data. The final study sample size that data were analyzed on was10. Maternal and infant demographics of the ten study participants are presented in Table 3 and Table 4, respectively. Maternal age ranged from 18-40 years old (mean age 30.2 ±8.2 years). Half of the mothers were Caucasian (50%). Gravida ranged from 1-7 pregnancies, and all infants in the sample were either the mothers' first or second surviving baby. The most frequently diagnosed prenatal conditions among the mothers were preeclampsia (40%), preeclampsia with severe features/HELLP (Hemolysis, Elevated Liver enzymes and Low Platelets) syndrome (30%) and preterm labor (20%). All mothers in the study were treated with antenatal steroids and magnesium sulfate, which is a standard of care for mothers threatening an early delivery. Sixty percent of mothers required additional treatment with an antihypertensive. The most frequent mode of delivery was cesarean section (70%).

Half of the infants were female, and 40% were Caucasian. Gestational ages ranged from 28.0 weeks to 32.0 weeks (mean 30.0 weeks ±1.2 weeks). At birth, infants' average weight was 1243 grams ±246.1 grams and average head circumference was

26.3cm ±1.6cm. All infants were diagnosed with respiratory distress shortly after birth and half received surfactant via an endotracheal tube.

Table 3. Maternal Characteristics, (n=10)

	N (%)	Range	Mean	Std. Deviation
Maternal Age (years)		18-40	30.2	8.2
Maternal Race				
Caucasian	5(50)			
African American	3 (30)			
Hispanic	1(10)			
Other	1 (10)			
Gravida		1-7	2.5	1.8
Parity		0-2	0.9	0.7
Significant Maternal Prenatal Diagnosis				
Preeclampsia	4 (40)			
Preeclampsia with Severe Features/HELLP	3 (30)			
Preterm Labor	2 (20)			
Premature Rupture of Membranes	1 (10)			
Placenta Previa	1 (10)			
Epilepsy	1 (10)			
Maternal Antepartum Medications Use				
Antenatal Steroids	10 (100)			
Magnesium Sulfate	10 (100)			
Antihypertensive	6 (60)			
Nifedipine	5 (50)			
Labetalol	4 (40)			
Hydralazine	3 (30)			
Antibiotics/Antifungals	3 (30)			
Gabapentin	3 (30)			
Pitocin	3 (20)			
Indomethacin	1 (10)			
Cesarean Section Delivery	7 (70)			

For 80% of infants, the highest level of respiratory support was nasal continuous positive airway pressure (NCPAP)/ Biphasic Positive Airway Pressure (BiPAP). Eighty percent were diagnosed with apnea of prematurity, with all infants in the study treated with caffeine prophylactically, which is a standard of care for treating apnea in premature infants less than 34 weeks gestation. Most infants required a central line for intravascular access (70%) and eighty percent received parenteral nutrition. Ninety percent of infants were fed with breastmilk only. Ninety percent of infants were diagnosed with hyperbilirubinemia. Forty percent of infants were observed for sepsis, with the same percentage treated with antibiotics for 36-48 hours, if blood cultures remained negative.

Table 4. Infant Characteristics, (n=10)

	N (%)	Range	Mean	Std. Deviation
Female	5 (50)			
Infant Race				
Caucasian	(40)			
African American	3 (30)			
Hispanic	1 (10)			
Other	2 (20)			
Gestational Age (weeks)		28.0-32.0	30.0	1.2
Birth Weight (grams)		900-1640	1243.0	246.1
Birth Head Circumference (cm)		23.8-29.0	26.3	1.6
Infant Medical Diagnosis				
Respiratory Distress	10 (100)			
Hyperbilirubinemia	9 (90)			
Apnea of Prematurity	8 (80)			
R/O Sepsis	4 (40)			
SGA/IUGR	2 (20)			
Anemia of Prematurity	1 (10)			
Supraventricular Tachycardia	1 (10)			
IV Access				
None	1 (10)			
Peripheral IV	2 (20)			
Central Line	7 (70)			
Infant Diet				
Breastmilk Only	9 (90)			
Mix of Breastmilk and Formula	1 (10)			
Infant Medications				
Caffeine	10 (100)			
Parenteral Nutrition	8 (80)			
Antibiotics	4 (40)			
Surfactant	5 (50)			
Antifungal Prophylaxis	2 (20)			
Highest level of Respiratory Support				
NCPAP/BiPAP	8 (80)			
RAM CPAP/NIPPV	1 (10)			
Conventional Ventilator	1 (10)			

4.2 Aim 1: To assess the feasibility of using actigraphy to examine sleep-wake patterns of preterm infants in the NICU.

4.2.1 Description of Rest and Sleep Times

Rest intervals were defined as the times between routine care when an infant was to be left undisturbed and his/her sleep was to be protected, unless the infant was clinically unstable and required more frequent care. For the study sample, on average, rest intervals were 155 minutes ±5.3 minutes (Table 5). On average, infants spent 67.1% ± 11.1% of rest intervals asleep. Nine of the ten infants ranged from 62.87%-79.93%, with one infant having only slept 38.58%.

Table 5. Summary of infant sleep and wake outcomes across the 72-hour study period, (n=10)

ID	Rest Interval (minutes)	% Sleep during rest interval	% Wake during rest interval	Average % sleep in 24 hours	Average % wake in 24 hours	Number of wake bouts in 24 hours
12004	153.46	62.06	37.94	59.75	40.25	296.00
12005	157.92	68.30	31.70	67.28	32.72	297.67
12006	163.92	62.87	37.13	57.41	42.59	269.33
12007	151.72	38.58	61.42	36.94	63.06	242.33
12008	142.63	71.11	28.89	64.65	35.35	238.33
12009	153.76	68.46	31.54	66.50	33.50	182.67
12010	157.28	78.00	22.00	73.13	26.87	207.33
12011	154.88	75.77	24.23	71.84	28.16	221.00
12012	155.31	65.83	34.17	67.45	32.55	193.00
12013	159.12	79.93	20.07	78.48	21.52	125.00
Statistics across study sample, mean (SD)	155 (±5.27)	67.1 (±11.12)	32.9 (±11.12)	64.3 (±10.85)	35.7 (±10.85)	227.3 (±50.85)

Data for sleep were calculated by the actigraph software based on the study parameters and analyzed for each 24-hour period (Table 6). On average, 902.5 minutes ±158.6 minutes was spent sleep per day, or 64.3% (± 10.85%) of the day. On average, infants had 226.9 ± 53.3 wake bouts per day. Figure 7 depicts the average percentage of time each infant spent asleep and awake during each 24 hours day. It is noted here that while a majority of the infants spent approximately 20-40% of the 24-hour day awake, infant 12007 spent a much higher percent of time awake, a little over 60%.

Table 6. Summary of daily infant sleep times and wake bouts

	Minimum	Maximum	Mean	Std. Deviation
Day 1				
Sleep Time (mins)	490.5	1202.5	908.2	215.9
Sleep Time (%)	38.6	80.6	67.1	11.8
Wake Bouts (n)	103	306	221.4	60.3
Day 2				
Sleep Time (mins)	601.0	1114.5	924.7	165.4
Sleep Time (%)	41.7	77.4	65.4	11.5
Wake Bouts (n)	155.00	296.0	227.5	52.6
Day 3				
Sleep Time (mins)	479.5	1032.5	874.7	160.4
Day 3 Sleep Time (%)	35.0	76.4	63.4	11.9
Day 3 Wake Bouts (n)	89.00	326.0	231.9	65.7
Daily Average				
Sleep Time (mins)	523.67	1102.5	902.5	158.6
Daily Sleep Time (%)	36.9	78.5	64.3	10.85
Daily Wake Bouts (n)	125	297.7	227.3	50.85

Day-to-day variation of total sleep time for each infant over the three-day study period is depicted in Figure 8. Here, it is noted that the average day-to-day total sleep time for infant 12007 was considerably less than the rest of the study sample. Because the data for this infant was an outlier in comparison to the rest of the study sample, data for this infant were double-checked by the investigator (NH) for potential errors. The missing data and excluded intervals on the actogram were rechecked to make sure they were inputted correctly (Figure 9). An example of actogram of another infant with similar demographics is depicted in Figure 10 for comparison. Each rest interval was also reviewed to make sure they were inputted correctly. To ensure the quality of the data, the number of rest intervals were checked and was 25, which was comparable to the other infants. The number of daily intervals and their length were also comparable, having three daily intervals each lasting for 1440 minutes each. The demographics for this infant were additionally similar to the rest of the study sample. This infant also had similar average rest interval times (151.72 minutes) compared to the sample average (155 minutes ±5.27 minutes). Since the quality of the data for infant 12007 was in every other way comparable to the other infants, data for this infant was retained for analysis.

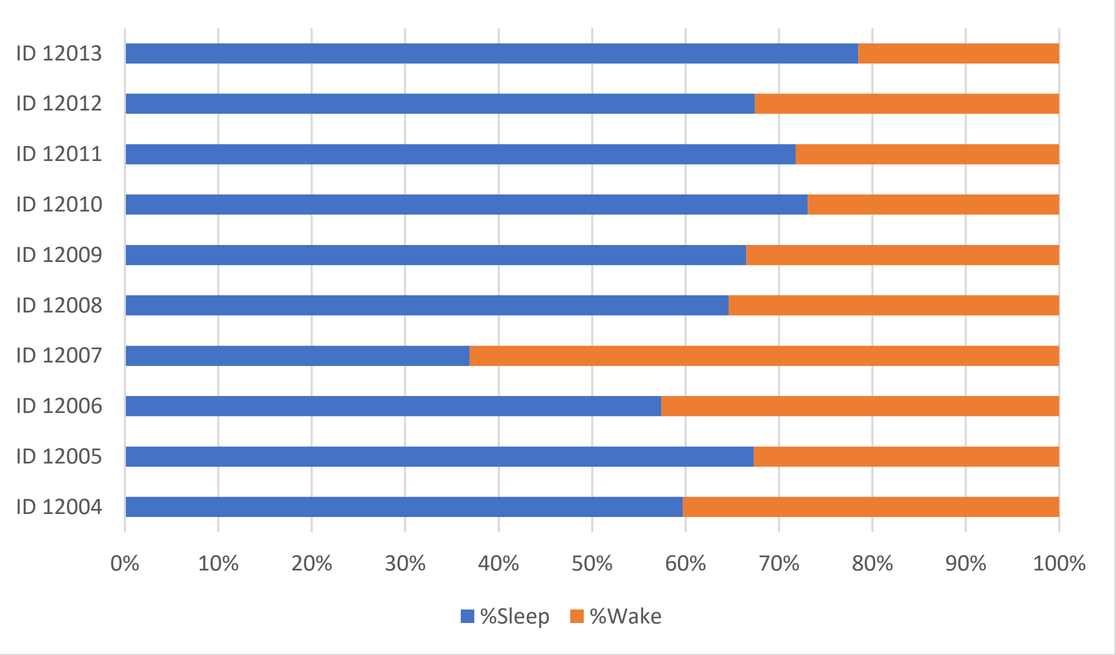


Figure 7. 100% chart showing the average percent of sleep and wake times over the three 24-hour study periods.

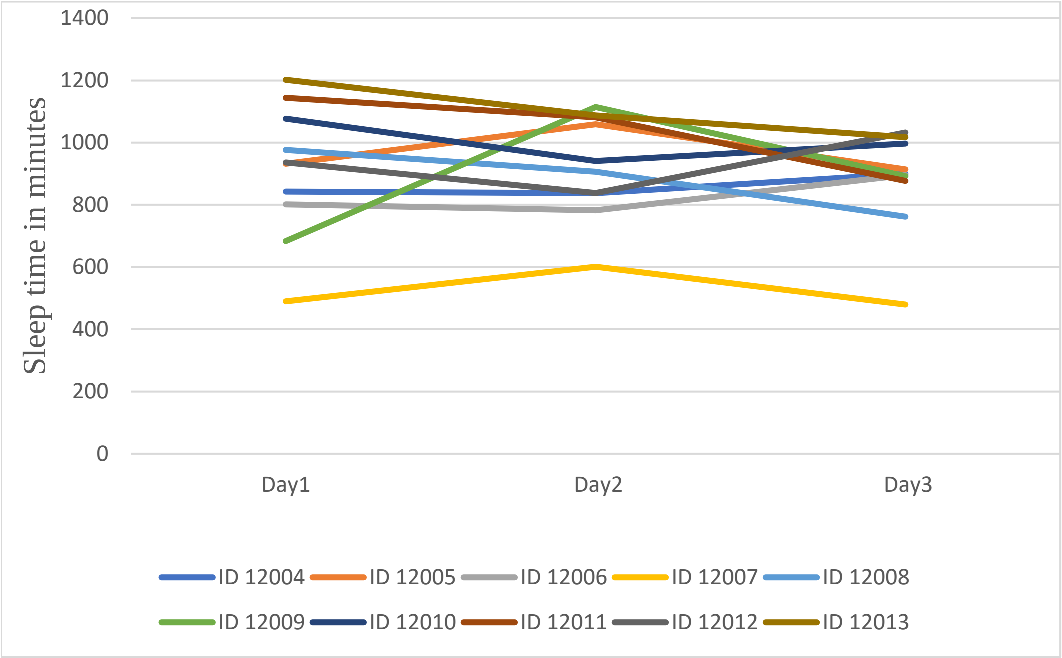


Figure 8. Spaghetti plot of day-to-day variation for total sleep time over the 3-day study period.

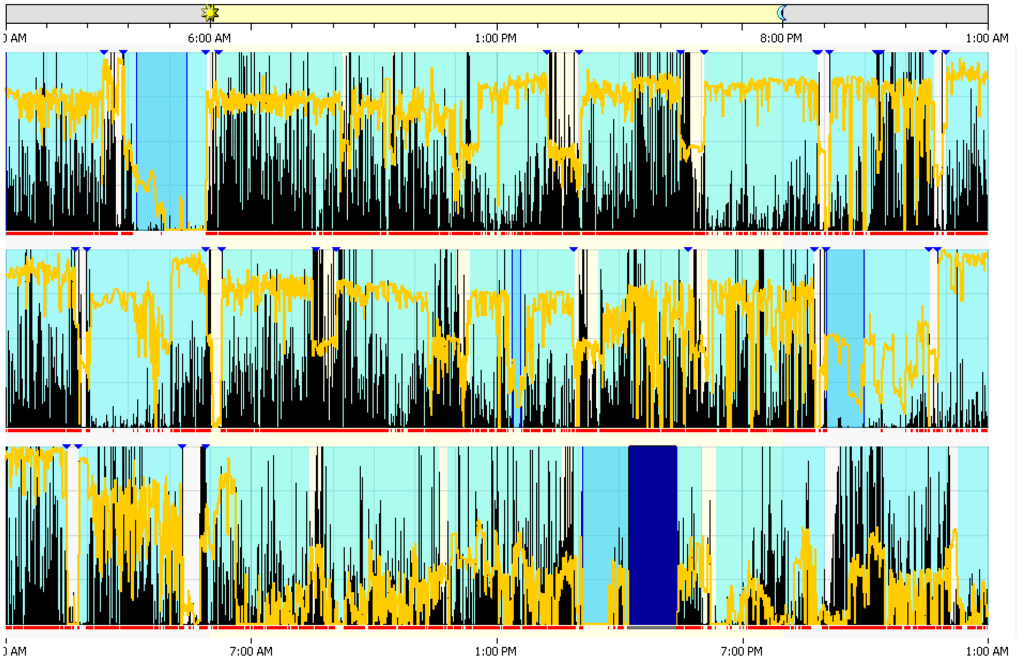


Figure 9. Actogram of study participant 12007 (activity scale at max 250). Black vertical lines=activity measure. Yellow line=light level. Blue triangle=time stamp.

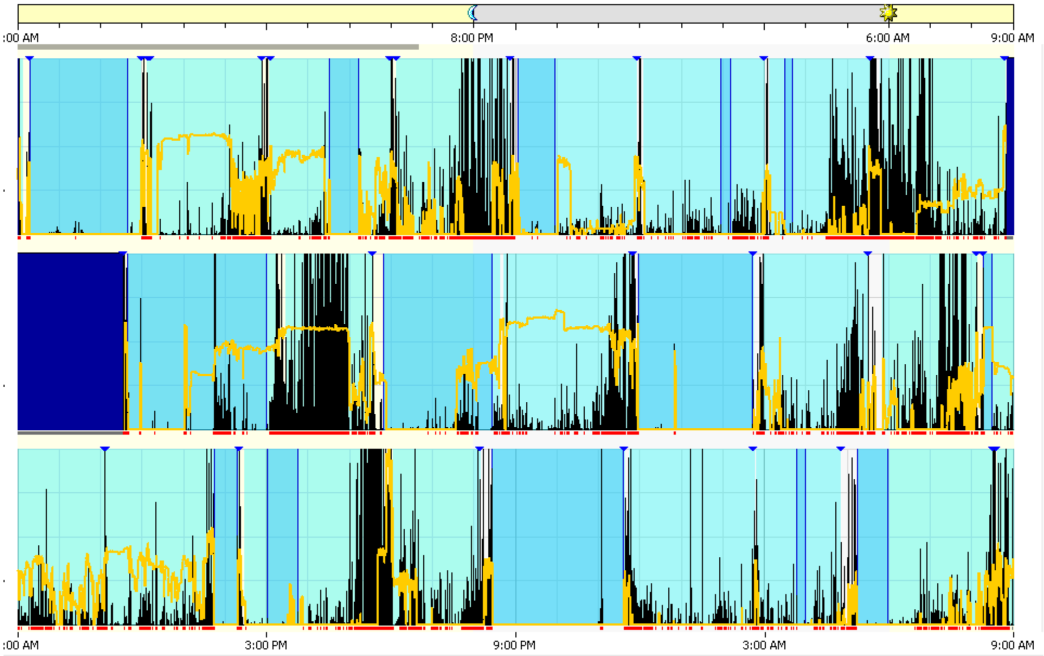


Figure 10. Actogram of study participant with similar demographic to study participant 12007 (activity scale at max 250). Black vertical line=activity measure. Yellow line=light level. Blue triangle=time stamp.

4.2.2. Feasibility of using Actigraphy

Acceptability of the use of actigraphy was somewhat supported by the parents, as 55% of eligible families consented to study participation. NICU staff completed the study education and were able to maintain the actigraph on the infants throughout the study period. For the two infants with a large amount of missing data that required their data to be excluded from the data analysis, the bedside nurses were sure to replace the actigraph when it fell off and made a note in the infant care journal that it was found off the infant. This supports acceptability by the NICU staff. There were no reports of infants being made uncomfortable by wearing the actigraph by NICU staff, supporting acceptability by the infants.

Implementation feasibility of the actigraph was reflected primarily in data quality. As part of examining the data quality of the actigraph data, the amount of rest intervals was examined for each infant. Each infant was noted to have 24-27 rest intervals per day. This was an expected number of intervals as infants in the NICU receive routine care about eight times per day, although this can change depending on the needs of the infant. For the study period of 72 hours, accounting for the rest interval before the first routine care time and after the last routine care time of the study period, it is feasible to have about twenty-five rest intervals. In reviewing the actigraph data, attention was paid to the number of daily intervals to ensure that there were only three 24-hour periods in the data and 1,440 minutes (24 hours) in each 24-hour period. This assured that only 72 hours were included in the data that was to be analyzed.

The amount of missing data was also an important aspect of assessing implementation feasibility. Missing data for actigraph, as well as infant care journals, is described in Table 7. After editing, it was noted that 6 of the 10 infants had time periods qualifying as missing data, with the amount of time of missing data ranging from 68 to 280 hours (mean 101.8 hours ±104.4 minutes) over the 72-hour study period. For each routine care documented, there should be two timestamps in the actigraphy data, one to signal the beginning of the routine care and one to signal when it ended. All infants were noted to have some degree of missing time stamps.

Across the 10 subjects, missing time stamps (a start and a finish marker for each routine care) ranged from 16-58%, with an average of 39.5% (±13.7%). Missing time stamps were noted to occur slightly more often on dayshift (7am-7pm) at 41%, as compared to the night shift (7pm-7am) at 37%. Missing data was examined by each day within the study period. The amount of missing time on days 1 and 2 across the study sample were similar, being 253 and 260 minutes (respectively), each being about 18% of a 24-hour period. Day 3 was noted to be much higher being 505 (35%) minutes although this was largely attributed to two cases (12009 and 12013).

Table 7. Missing values for actigraphy markers and infant care journal documentation of routine care by day/night shifts and study day

ID (n=possible values)	Actigraphy Data Time Stamp n (%)	Infant Care Journal Routine Care Times n (%)	Actigraphy Minutes (possible 1440) n (%)
12004 (n=50)	15 (30)	4 (8)	
Day Shift (n=24)	10 (42)	4 (17)	
Night Shift (n=26)	5 (19)	0 (0)	
Day 1			0 (0)
Day 2			0 (0)
Day 3			0 (0)
12005 (n=50)	8 (16)	48 (96)	
Day Shift (n=24)	7 (29)	22 (92)	
Night Shift (n=26)	1 (4)	26 (100)	
Day 1			0 (0)
Day 2			0 (0)
Day 3			0 (0)
12006 (n=48)	27 (56)	8 (17)	
Day Shift (n=24)	15 (63)	6 (25)	
Night Shift (n=24)	12 (50)	2 (8)	
Day 1			0 (0)
Day 2			0 (0)
Day 3			0 (0)
12007 (n=48)	20 (42)	10 (21)	
Day Shift (n=24)	16 (67)	10 (42)	
Night Shift (n=24)	4 (17)	0 (0)	
Day 1			0 (0)
Day 2			0 (0)
Day 3			68 (5)
12008 (n=52)	24 (46)	0 (0)	
Day Shift (n=24)	3 (13)	0 (0)	
Night Shift (n=28)	21 (75)	0 (0)	
Day 1			137 (10)
Day 2			0 (0)
Day 3			74 (5)
	15 (30)	0 (0)	

Table 7. Missing values for actigraphy markers and infant care journal documentation of routine care by day/night shifts and study day

ID (n=possible values)	Actigraphy Data Time Stamp n (%)	Infant Care Journal Routine Care Times n (%)	Actigraphy Minutes (possible 1440) n (%)
12009 (n=50)			
Day Shift (n=26)	11 (42)	0 (0)	
Night Shift (n=24)	4 (17)	0 (0)	
Day 1			108 (8)
Day 2			0 (0)
Day 3			172 (12)
12010 (n=48)	28 (58)	20 (42)	
Day Shift (n=24)	11 (46)	12 (50)	
Night Shift (n=24)	17 (71)	8 (33)	
Day 1			0 (0)
Day 2			108 (8)
Day 3			86 (6)
12011 (n=48)	13 (27)	9 (19)	
Day Shift (n=24)	6 (25)	3 (13)	
Night Shift (n=24)	7 (29)	6 (25)	
Day 1			0 (0)
Day 2			0 (0)
Day 3			0 (0)
12012 (n=50)	23 (46)	4 (8)	
Day Shift (n=26)	10 (38)	0 (0)	
Night Shift (n=24)	13 (54)	4 (17)	
Day 1			8 (0.6)
Day 2			152 (11)
Day 3			0 (0)
12013 (n=50)	19 (38)	0 (0)	
Day Shift (n=24)	11 (46)	0 (0)	
Night Shift (n=26)	8 (31)	0 (0)	
Day 1			0 (0)
Day 2			0 (0)
Day 3			105 (10)
Study Sample (n=494)	192 (39)	103 (21)	
Day Shift (n=244)	100 (41)	57 (23)	
Night Shift (n=250)	92 (37)	46 (18)	
Day 1			253 (18)
Day 2			260 (18)
Day 3			505 (35)

Note. Possible recording reflects 2 markers/recording (a start and finish) per routine care. Day shift is 7am to 7pm. Night shift is from 7pm to 7am.

Another aspect of feasibility of actigraphy was the practicality, reflected in the time burden of applying the actigraph, assessing how it interfered with care, and the cost of the device. Placing the actigraph did not take much time, as it was attached to a soft band routinely used in the NICU and is very quick to place on the infant. There were no reports that placing the actigraph on the infant interfered with the care the infant received. The cost of the Actiwatch system, which includes the Actiware software, the communication dock station to download the actigraphy data and an Actiwatch 2 cost about $700-$800 each. The Actiwatch alone cost about $600 - $700.

Lastly, the aspect of feasibility of actigraphy use examined was limited efficacy. Preterm infants are known to sleep about 90% of the day. The infants slept less than this benchmark, sleeping approximately 64% of the day on average. Results from this study regarding total sleep time was noted to be similar to previous research, which is discussed further in Chapter 5, along with more subjective aspects of feasibility.

4.3 AIM 2: To assess the feasibility of using infant care journals to describe NICU care activities that may disrupt preterm infant sleep.

4.3.1 Description of Infant Care Journal Data

A summary of each care activity that was documented in the infant care journals is presented in Table 8. Instances of only routine care as a single activity comprised 59% of all documented activities and lasted a mean length of 17.2 minutes. There were 44 additional routine care activities that were bundled with additional activities (clustered care). Altogether, 200 (75.5%) of the care activities that were documented were routine care or bundled with routine care. The second most frequent care activity was apnea/bradycardia/desaturation events requiring stimulation, occurring 28 times (10.6% of the documented care activities).

Data describing if the infant was awake prior to and at the end of activities are also displayed in Table 8. Infants were noted to be asleep at the beginning of most of the documented care activities. Care activities that started with the infant being asleep and resulting in all the infants being awake at the end of the routine care activity only occurred 5 times over the 265 documented activities. These activities included:

1. clustered care of routine care, provider assessment, and parent/family interaction (n=1)
2. clustered care of lab draw, imaging, and “other” (n=1)
3. clustered care of imaging and A/B/D event requiring stimulation (n=1)
4. imaging occurred as a single activity (n=2)

The only activity that resulted in an infant starting the activity awake and ending it asleep 100% of the time was a clustered care activity including parent/family interaction and “other” (n=1). Twenty-nine of the documented activities resulted in no change in infant sleep/wake status, which were:

1. clustered care activities of routine care and provider assessment (n=6)
2. clustered care activities of routine care, parent/family interaction, and A/B/D event requiring stimulation (n=1)
3. clustered care activities of routine care and A/B/D event requiring stimulation (n=2)
4. clustered care activities of routine care, A/B/D event requiring stimulation, and “other” (n=1)

5. clustered care activities of routine care and “other” (n=4)
6. provider assessment as a single activity (n=5)
7. clustered care activities of provider assessment and “other” (n=1)
8. “other” as a single activity (n=9).

Table 8. Characteristics of Infant Care Activities (n=265)

	N (%)	Mean minutes	Mean % Awake Pre-activity	Mean % Awake Post-activity
RC only	156 (58.9)	17.2	22%	47%
RC + PA	6	21.0	33%	33%
RC + PA + P/F	1	126.0	0%	100%
RC + LD	19	20.9	33%	47%
RC + Rad + MP	1	34.0	100%	0%
RC + P/F	9	56.6	44%	56%
RC + P/F + A/B/D	1	28.0	0%	0%
RC + A/B/D	2	15.0	50%	50%
RC + A/B/D + “other”	1	11.0	0%	0%
RC + “other”	4	19.8	50%	50%
All RC	200 (75.5)			
PA only	5 (1.9)	2.8	0%	0%
PA + “other”	1	-	0%	0%
LD alone	4 (1.5)	7.5	50%	25%
LD + Rad + “other”	1	15.0	0%	100%
Rad only	2 (0.8)	9.5	0%	100%
Rad + A/B/D	1	6.0	0%	100%
P/F only	8 (3)	52.1	25%	0%
P/F + “other”	1	112.0	100%	0%
A/B/D only	28 (10.6)	1.5	4%	33%
A/B/D + “other”	3	2.0	33%	100%
“other” only	9 (3.4)	4.3	33%	33%
Missing	2 (0.7)	17.5	0%	50%

Note. A/B/D-Apnea/Bradycardia/Desaturation Event requiring Stimulation, LD-Lab Draw, MP-Medical Procedure, P/F-Parent/Family Interaction, PA-Provider Assessment, Rad-Imaging, RC-Routine Care

Activities that occurred over the longest amount of time included parent/family interactions, clustered care including routine care, provider assessment, and parent/family interaction (mean 126 minutes) and parent/family interaction and “other” (mean 112 minutes). On average, care activities that took less than 10 minutes to complete included provider assessment only (2.8 minutes), lab draw only (7.5 minutes), imaging only (9.5 minutes), imaging and A/B/D event requiring stimulation (6 minutes), A/B/D event requiring stimulation only (1.5 minutes), A/B/D event requiring stimulation and “other” (2.0 minutes), and “other” only (4.3 minutes).

4.3.2 Feasibility of using Infant Care Journal

Aspects of implementation feasibility of the journals related to missing data. At the end of each infant’s study period, infant care journals were assessed for completeness and were used as a benchmark for confirming routine care times. Seven of the 10 infants in the study sample had missing data for routine care in the infant care journals (Table 7). Of those infants with missing data, 103 (21%) of the routine care activity time stamps were not documented. There were more missing data noted during the day shift having 57 (23%) missing time stamps, compared to the 46 (18%) missing time stamps on night shift. The amount of missing data also speaks to the acceptability by the NICU staff of using the care journals. While one infant had almost all of the time stamps for routine care missing, the other infants had relevantly good completion of the journals. This supports the acceptability of NICU staff in the use of the journals, although the missing data was not optimal.

Other aspects of implementation feasibility were reflected in the need for reinforcement and re-education related to journal documentation. Periodic assessment by the investigator (NH) showed consistent documentation in the journals, except for the infant that had 96% of the routine care time stamps missing. Re-education and reinforcement occurred with the bedside nurse at the time the study began for each infant by the investigator, which also helps with acceptability. No adverse effects were noted during the study period concerning the use of the infant care journals.

The practical aspect of feasibility was assessed by talking with nurses about the time burden interference with care, and costs of making the infant care journals. Nurses did not report documentation in the infant care journal being burdensome or interfering with the care they needed to give to the infant. Cost of making the infant care journals were minimal, as they were developed in a Microsoft Word document by the investigator (NH), printed, and organized in a paper folder for each infant.

CHAPTER 5: DISCUSSION

The purpose of this feasibility study was to address the following aims: 1. to assess the feasibility of using actigraphy to examine sleep-wake patterns of preterm infants in the NICU, and 2. to assess the feasibility of using infant care journals to describe NICU care activities that may disrupt preterm infant sleep. Chapter 1 provided the significance of sleep disruption and the need to examine sleep in preterm infants in the NICU, as well as discussion of the transactional model of sleep-wake regulation and areas of focus for feasibility studies. In addition to reviewing the current literature regarding sleep disruption in preterm infants and its negative impact on neurodevelopment and the use of actigraphy in pediatric sleep research, sleep promotion and protection were discussed in Chapter 2. Chapter 3 extensively detailed the methodology used for the study to assess the feasibility of using actigraphy and infant care journals in the neonatal intensive care unit (NICU). The study results are described in Chapter 4. Here in chapter 5, there will be a discussion of study finding and an assessment of feasibility. Study limitations and implications for future research and clinical practice are also discussed.

5.1 Review of Study Significance

Understanding sleep-wake patterns of preterm infants and how care in the NICU can disrupt those patterns are essential to optimize developmental care. Sleep is a time of healing and growth, which is essential for preterm infants. Research has demonstrated negative consequences of sleep disruption in preterm infants, including behavioral changes and increase energy expenditure, in addition to long term consequences including increased anxiety, reduced sexual activity and sleep disturbances in adulthood

(Bonan et al., 2015; Graven, 2006; Heraghty et al., 2008; Lan et al., 2019; Orsi et al., 2017). Sleep deprivation in preterm infants has also been shown to cause dysfunction in development of neurosensory systems (Graven & Browne, 2008). It is well known that infants in the NICU are at high risk for sleep disruption due to the care they require. While many interventions have been shown to promote and protect sleep in the NICU, many studies have highlighted the continued problem of sleep disruption associated with the care that preterm infants receive in the NICU (Levy et al., 2017; Maki et al., 2017; Pereira et al., 2013).

Challenges in measuring infant sleep are acknowledged. Polysomnography (PSG) is considered the gold standard in sleep assessment, but it can be too invasive and costly to use in such small and fragile patients over multiple days. Actigraphy has been successfully used in adult, pediatric and infant populations as a cost effective, noninvasive and convenient method in assessing activity to estimate sleep-wake patterns. Some authors have used actigraphy to assess sleep wake patterns in preterm infants, but have yielded mixed results due to differences in sample characteristics, time periods studies, measurement methods used, and other characteristics that influence actigraphy results (Derbin et al., 2022; Rioualen et al., 2015; So et al., 2005; Unno et al., 2022). There are also issues with the consistency of methodology and actigraph parameters used across studies to allow for generalizability and reproducibility, as discussed in Chapter 2 (Meltzer et al., 2012; Schoch et al., 2021). To add to the literature, this feasibility study was done to assess the feasibility of using actigraphy to examine sleep-wake patterns of preterm infants in the NICU, including the development of scoring rules using available hierarchical markers to establish rest intervals that are appropriate to the NICU setting.

Furthermore, this study reinforced the usefulness of an infant care journal developed for this study to assess care activities that can be disruptive to the sleep of preterm infants in the NICU.

5.2 Summary of Study Findings

Data were collected and analyzed from 10 medically stable preterm infants in a level IV NICU. Twenty-four-hour average total sleep time for the sample was 902.5 minutes ±158.6 minutes, similar to other studies. Though studies by Orsi et al., (2017) and Lan et al., (2018) had study samples with mean gestational ages slightly higher than the sample of this study, 32.2 weeks ±4.2 weeks and 32.53 weeks ± 1.98 weeks, respectively, total sleep times were comparable to the present study. Orsi et al. (2017) found total sleep time of 899 minutes ± 71.8 minutes by PSG over the 24-hour study period and Lan et al., (2018) found total sleep time of 885.18 minutes ± 134.75 minutes in their control group by actigraphy over the 10 days study period. A study by Maki et al. 2017 also had a study sample with older gestational ages than the current study (described as late preterm, which is 34-36 weeks gestation) and found a mean total sleep time of 824.3 ±237.0 in a 24 hour period using PSG.

Full term infants spend about 70% of the 24 hour day sleeping, compared to preterm infants who can spend about 90% of the 24 hour day sleeping (Barbeau & Weiss, 2017; Sung et al., 2009). Data from this study showed that on average infants slept about 64.4% ± 11.4% of the day. It is expected that an infant requiring care in a NICU will have some sleep disruption, so it is not surprising that the infant's average percent of sleep per day fell short of the 70% mark as compared to a full-term infant and even more so when compared to preterm infants at 90%. It is important to note that the population in this study are very low birthweight infants, that the medical needs of this population likely attributes to the lower time spent sleeping per day. This population usually requires some level of respiratory support and need for IV nutrition and medications, such as daily caffeine. These confounders could affect the sleep outcomes and should be considered in future research. This supports the ongoing need to provide continual education on implementation of methods to promote and protect sleep in the NICU. It may also highlight the need to establish reliable scoring rules for infants so that sleep parameters can be more accurately compared between studies.

Information from the care journals also allowed for insight on activities that infants incur most frequently. Several studies have shown a high amount of handling in infants in the NICU (Maki et al., 2017; Orsi et al., 2017; Pereira et al., 2013). The information from the present study showed that the majority of the handling was due to routine care. About three-quarters of all care activities that infants received for this study were either routine care alone (58.9%) or other care activities that were clustered with routine care (16.6%). On one hand, this is encouraging, as it shows that there is a good effort by staff to protect infant sleep by combining as many of the required care activities as possible with the routine care time. On the other hand, the amount of handing was much lower in this study compared to other studies assessing infant handling and sleep disruption of the preterm infant. It is difficult to decipher whether this is because nursing did not document all the activities the occurred or whether the staff did a great job in clustering care.

This study also examined whether infants were sleeping or awake before and after each activity. While there are multiple studies examining the high level of handling of preterm infants in the NICU, there is currently a lack of research looking at sleep and wake status before and after handling and care activities. The data from this study showed that most of the activities were started when the infant was asleep. This emphasizes the importance to re-education of NICU staff to provide care when infants are awake to better align with their sleep-wake cycles as much as possible. Of course, this is dependent upon the level of intense care each infant's needs. It is also helpful to understand which activities are more likely to leave an infant awake at its end so that staff can attempt to focus those activities more closely aligned with infants' sleep-wake cycles as much as possible.

Activities that were noted to occur over the longest amount of time included parent/family interactions, clustered care including routine care, provider assessment, and parent/family interaction (mean 126 minutes) and parent/family interaction and "other" (mean 112 minutes). This is encouraging, as parent/family interaction is encouraged to strengthen attachment and bonding between the infant and their parents and family members.

One infant in this study had sleep time was much lower than that of the rest of the study sample regarding average total sleep times, as well as sleep and wake percentages over 24 hours period. In reviewing clinical characteristics of this infant, there was not much difference between the infant's demographic and that of the rest of the study sample, so it is unclear why this infant's sleep was such an outlier. Sleep patterns can vary greatly among infants, particularly premature infants whose neurological development lags that of full-term infants, and therefore likely affects their sleep organization. To illustrate this, actograms of an infant at of 28 weeks gestation is shown in Appendix 1a and an infant of 32 weeks gestation is shown in Appendix 1b for comparison. The younger infant had more activity than the older infant, which could be due to the care needs of the younger infant. Given the importance of sleep on brain development, in future studies, it might be helpful to assess additional clinical and environmental factors that may be related to sleep disruption in this population such as light and sound levels. It may also be helpful to collect data over longer periods of time to assess changes in sleep as neurodevelopment progresses.

5.3 Assessing Feasibility

5.3.1. Acceptability

Parental acceptability of the use of actigraphy was determined by parents consenting to the study. The parents were shown the actigraph during the consent process. Of the 22 infants that were eligible for the study, 55% of the infants' parents approached about the study consented. Some parents stated concern for their infant's clinical status as the reason to not participate in the study during the consent process. This concern may have been heightened due to the COVID-19 pandemic, in addition to the overall stress of having an infant in the NICU. Infants' acceptability was measured by how well they were able to tolerate wearing the actigraph. There were no reports from nursing concerning intolerance of the infant wearing the actigraph. Having the actigraph secured to the soft band that is normally used in the NICU as an ID band more than likely contributed to the comfort for the infant.

Maintenance of the actigraph by NICU staff demonstrated acceptability. This is shown by having complete data on each of the infants. While there was a high amount of missing data for the first two infants that disqualified them from the final analysis, throughout the study period, nurses documented in the infant care journal when the actigraph fell off and was found in the bed. When this happen, the actigraph was replaced by the nurse. The remainder of the infants in the study had complete data, supporting the NICU staff's acceptance of maintaining the actigraph. Staff acceptance of utilizing the infant care journals were demonstrated by the low amount of missing data for routine care times, which will be discussed further in the following section.

5.3.2. Implementation

Implementation was assessed by examining missing data and data quality of the actigraph and infant care journal data. Only 2 of the 12 infants enrolled in the study had to be excluded due to the large amount of missing data. This likely related to the loose fit of the actigraph. Once the configuration of the actigraph was altered (taking wrist bands off of the actigraph device and taping the device to a soft band), implementation was much improved, with all of the remaining infants having complete data for analysis. Missing data for routine care documented in the infant care journals was 21%, though approximately 10% of this was from one infant.

NICU staff was educated about the study prior to implementation. Since the study occurred over 2 months, once an infant was enrolled into the study, the bedside nurse was re-educated on the study and what was expected of the nurse to do to maintain the actigraph and complete the infant care journal. It may have been helpful to touch base with the oncoming nurse at the beginning of each shift to increase documentation in the infant care journal and compliance with pushing the marker button on the actigraph. However, this was not feasible since the study did not have resources for these activities. No adverse effects were reported for the use of the actigraph.

5.3.3. Practicality

The area of practicality was examined by whether the actigraph and infant care journals can be used with existing resources and under current circumstance in the NICU. The infant care journal was developed by the researcher (NH) as a Microsoft Word document and cost were minimal. The cost of the Actiwatch system, which includes the Actiware software, the communication dock station to download the actigraphy data and an Actiwatch 2 cost about $700-$800 each. The Actiwatch alone cost about $600 - $700. While these costs may seem high, it is still much less than the cost of performing PSG, including equipment, time, and personnel. This cost could be covered by a small grant or other support as was possible in this study. And the ability to reuse these actigraphs and software on future studies makes their purchase more practical.

In regard to how the actigraph and infant care journals interfered with standard care in this level IV NICU, there was no direct feedback from the NICU staff that either tool was burdensome. Despite the lack of feedback, it could be assumed that there was some inference due to the potential of missed activity documentation. Future studies should consider a more formal assessment of time burden and interference with care.

5.3.4. Limited Efficacy

Limited efficacy was assessed by comparing study results to existing research as a benchmark. Results from this actigraph data analysis was similar to previous research in regard to total sleep time, but not in regard to infant handling. While the percent of sleep per day in this study, approximately 64%, is less than what is expected of a preterm infant (90%), it may still be appropriate for an infant in the NICU. This is supported by the fact that the total sleep time for this study was very similar to previous research. This also endorses the concept that the actigraph can measure activity to estimate sleep as intended.

Despite the high amount of missing data for the actigraph time stamps, overall feasibility was supported by this study. With some changes to methodology, improvements in data collection can be achieved. Assessment of feasibility for this study was partly subjective. Future studies would benefit from utilizing more objective ways to examine feasibility.

5.4 Study Lessons Learned

Several lessons were learned in the process of conducting this study that can be useful for other researchers. The actigraph used for this study was the Philips Actiwatch 2, a common device used in pediatric sleep research for infants and young children (Schoch et al., 2021). It is designed like a wristwatch with the actigraph connected to straps. For this study, the actigraph was initially placed on the infant using the provided wristband under which a soft band was placed to act as a barrier between the actigraph and the infants' skin. However, it was difficult to get consistent data due to the actigraph not staying snugly in place throughout the study period. Missing data may have been attributed to the actigraph falling off the infant in-between routine cares, as well as inability of the actigraph to detect activity well due to the loose fit. It was important to alleviate this issue because it created the potential for sleep disruption when the nurse disturbs the infant during the protected sleep periods between routine care times to reapply the device. This was also a concern in the study by Orsi et al., (2017), where 38% of handling was to adjust the PSG leads during the study.

To address this issue, the wristbands were taken off the actigraph and the actigraph was taped directly to the soft band that was previously being used as a barrier between the actigraph and the infant's skin without restricting access to the time stamp buttons or the light sensor (Figure 2). This allowed for a snugger fit with continued skin protection for the infant. After this change, actigraph data was more complete. Other researchers have done something similar, including placing the device in specially designed sleeves that were then placed on the infant (Lan et al., 2019; Unno et al., 2022; Yates et al., 2014)

Another lesson learned was related to relying on markers that needed to be implemented by busy nurses. There were inconsistencies in the nurse pushing the marker button on the actigraph to time stamp the beginning and ending of routine care. While the time stamp was considered the highest-ranking marker for routine care times, the missing data demonstrate why it is imperative to use additional markers to supplement the time stamps, in order to establish the most reliable intervals for care times versus protected sleep periods for accurately editing the actigraphy data. When doing research in a level IV NICU, the high level of acuity of care required for each patient can make it difficult for the nurse to remember the needs of a research project. In addition, it is not feasible to have a research team member available 24/7.

The use of sleep journals is recommended to supplement the use of actigraphy to deal with missing data and artifact (Schoch et al., 2021). For this study, an infant care journal was developed to capture the different type of care activities that can occur in the NICU including and in addition to routine care. It also captures whether the infant was asleep or awake prior to and after each care activity, as well as timing and length of the activities. Infant care journals were filled out by the bedside nurse. Similar to nurses forgetting to push the marker button on the actigraph, there was issue with nurses remembering to complete care journals consistently. This issue has been seen in many studies where parents were instructed to fill in sleep journals for their babies. The care journal was extremely helpful in interpreting the actigraph data. Data from the infant care journals and ambient light level data recorded by the actigraph provided additional markers to confirm activity when time stamps were not available (Folleso et al., 2021).

5.5 Limitations

This study has several limitations. The first limitation is the small sample size of 10 infants. Level of nurse experience may cause subjectivity in assessment and documentation of sleep. Because of this, the data collected may not have been as accurate and complete with lesser experienced nurses, in that there may have been additional activities that the infant endured that were not documented. To address this, future studies could include education for parents to also document in the journals.

Despite the NICU setting admitting a large number of preterm infants, the COVID 19 pandemic research restrictions stopped recruitment and then required research revisions in both recruitment and conduct of the research. Thus, recruitment was very challenging. Having a baby in the NICU is extremely stressful for parents, and having their baby participate in the research study can certainly elevate that stress, adding to the difficulty of recruitment. These unforeseen issues lead to a smaller than expected sample size. Yet, this was a feasibility study and 84 hours of data were collected reflecting 265 care activities across the 10 infants.

Initially, part of this study included more statistical assessment correlating types and length of infant care activities with sleep/wake patterns. Due to the smaller than expected sample, this was not possible. However, this is an important area of investigation, and the investigator plans to pursue this in a future study.

The amount of missing data was also a limitation. Inconsistencies in amount of missing data in both actigraphy data (primarily time stamps) and in care journals (documentation of routine care times) was higher than expected. The importance of ongoing data quality assessments and re-education are essential when developing methodology for future studies. It is also helpful to download and review actigraphy data after each infant. By doing this, actigraph placement was adjusted early in the study and greatly improved the amount of usable data that was collected.

While findings from this study can be generalized to very low birth weight infants in a level III and IV NICU, generalizability to lower level NICUs and of different age ranges may be limited. This study was carried out in a level IV NICU where the standard of care is for medically stable infants to be fed and receive hands-on care every 3 hours with clustering of care to protect sleep time is promoted. These practices are not being done universally in NICUs, depending on NICU level and geographical location, so these results may not be generalizable to the general NICU population. Furthermore, the sample studied here was unique as it included a cohort of infants with a lower gestation than the current research. Premature infants that are very low birth weight receiving care in a level IV NICU have unique medical needs and require scheduled care routines. The data from this study is important in that it sets the groundwork for understanding the how necessary care in the NICU can impact sleep development in this venerable population.

In addition to examining sleep/wake patterns of preterm infants in the NICU using actigraphy, this study was originally planned to include analyzing relationships between sleep and wake variables with neurodevelopmental outcomes. Unfortunately, because of the impact on staffing shortages and the need to transfer infants to lower level of care facilities sooner than would have usually been done due to the COVID-19 pandemic, long term follow-up was unable to be done. Examining these potential relationships is a next step in the use of data from sleep research in preterm infants.

5.6 Implications for future research

To help gain more understanding regarding characteristics may affects infant sleep, future research could include infant outcomes such as length of stay and time to all bottle feeding. It would also be helpful to use additional data from the electronic medical record to assist with gaining complete data. These could include time-varying covariates (e.g. caffeine dose, infant being swaddled) which could be analyzed using a generalized linear model. Examining documentation by nursing staff for vital signs and feedings could be helpful to use in addition to hierarchical markers when setting rest intervals.

A review of 228 papers using actigraphy in pediatric sleep research noted a major issues in reporting methodology of actigraph use were setting parameters and measured variables (Meltzer et al., 2012). An updated review showed that these issues continue to persist in using actigraphy in assessing sleep in the pediatric population. Issues included length of epoch used, the algorithm used, how artifacts were identified, issues with data loss, and how variables were defined (Schoch et al., 2021). This study adds to the literature by providing a detailed methodology in scoring actigraphy data in preterm infants 28-32 completed weeks who are medically stable and who are being cared for in a level IV NICU. Having a stringent methodology is crucial to further the use of actigraphy in preterm infants to ensure reducibility and comparability of studies. This is extremely important as the research community continues to assess the validity of using actigraphy in the preterm infant population to measure sleep and to then study the relationship of sleep to other outcomes.

As this study supports the feasibility of using actigraph and infant care journals in preterm infants, it would add to the literature to perform a study over a longer period of time. Other studies have had study periods of over a week in older infants. Having the actigraph attached to a soft band such as the one used in this study, and ensuring appropriate assessment of infant skin, longer study periods are likely to be well tolerated by preterm infants. Longitudinal studies could also be done using actigraphy and infant care journals to assess sleep development over time, which could include the use of an amplitude-integrated electroencephalogram.

As an immediate next step, this study could be expanded upon by continuing to assess the feasibility of using actigraphy and infant care journals by repeating this study with a larger sample size. The study procedures could be improved based on the lessons learned from this study to help increase the sample size, as well as potential improvement in completion of infant care journals and decrease the amount of missing time stamps in the actigraphy data. Similar to the process of developing scoring rule of Folleso et al. (2021) and Chow et al. (2016), an important next step would be to test the scoring rule for this study for inter-rater reliability. In the future, it would be important to test actigraphy outcomes calculated based on the scoring rules for this study against the outcomes from polysomnography.

With funding, research teams can be expanded to provide research team members to observe the infant’s environment. This can help with ensuring all care activities are accounted for in the infant care journals, as well as accurately marking whether infants are asleep or awake prior to and after care activities. This can expand upon the results that were reached in the current study. Another option to direct observation by a research team member is the use of video recorders. While this will also allow for direct observation of the infant and their environment, maintenance of the camcorder in the infants’ room may be an added burden to the NICU staff. Additional research that can be explored include using actigraphy to examine effects of music and sounds, such as maternal heartbeat, on preterm infant sleep.

5.7 Implications for Clinical Practice

The results of this feasibility study support the findings of previous studies, that preterm infants in the NICU continue to be at high risk for sleep disruption and that the amount of sleep that these infants get is less than the normal for this age. While the majority of documented care activities were routine care or were clustered with routine care, it is important to continue to provide NICU staff education on the importance of actively providing clustered care for this population. While multiple interventions have been shown to be beneficial for promoting and protection sleep in the NICU, it would be useful for NICUs to develop policies to provide staff guidance on how to best utilize these interventions and to provide continuity in how the interventions are provided across different caregivers.

As a device that measures activity, the actigraph could potentially be used to examine infant irritability. Infants in the NICU can require multiple painful procedures that can cause irritability and agitation. A particular population of interest are infants with neonatal abstinence syndrome since they are also at increased risk for irritability due to withdrawal. This is also true for infants that required prolonged use of opioids for pain treatment during their NICU stay. Actigraphy could be used to provide an objective measure of activity in these infants and can help guide treatment and care to decrease irritation and agitation symptoms.

5.8 Next Steps

The information obtained through this study is a valuable addition to the field of sleep research in the neonatal population. In planning for next steps at the conclusion of this dissertation, at least two manuscripts will be written. The first manuscript will be a methodology manuscript to share the details of the suggested methods outlined for this study that can be used as a resource for future research. The other manuscript will be written to share the results of the sleep and wake data, as well as the care activity data. One of the journals of interest is Neonatal Network. Neonatal Network is the official journal of the Academy of Neonatal Nurses. The second journal of interest is Advances in Neonatal Care, which is the official journal of the National Association of Neonatal Nurses. Both organizations host bi-annual conferences, allowing for many opportunities to present the findings of this study to the neonatal community via poster and oral presentation. Another conference that would be appropriate for dissemination is the ONE conference hosted by Synapse Care Solutions, which focuses on brain care for infants at highest risk for brain injury. As an employee at University of Maryland Medical Center, I also plan to present this study at Advanced Practice Provider Grand Rounds.

To further my research, I hope to apply for research grants to facilitate advancing what I have accomplished with this research project, to achieve some of my initial goals of examining correlations between specific care activities and sleep/wake variables, as well as associations and relationships between sleep and wake patterns and long-term neurodevelopmental outcomes.

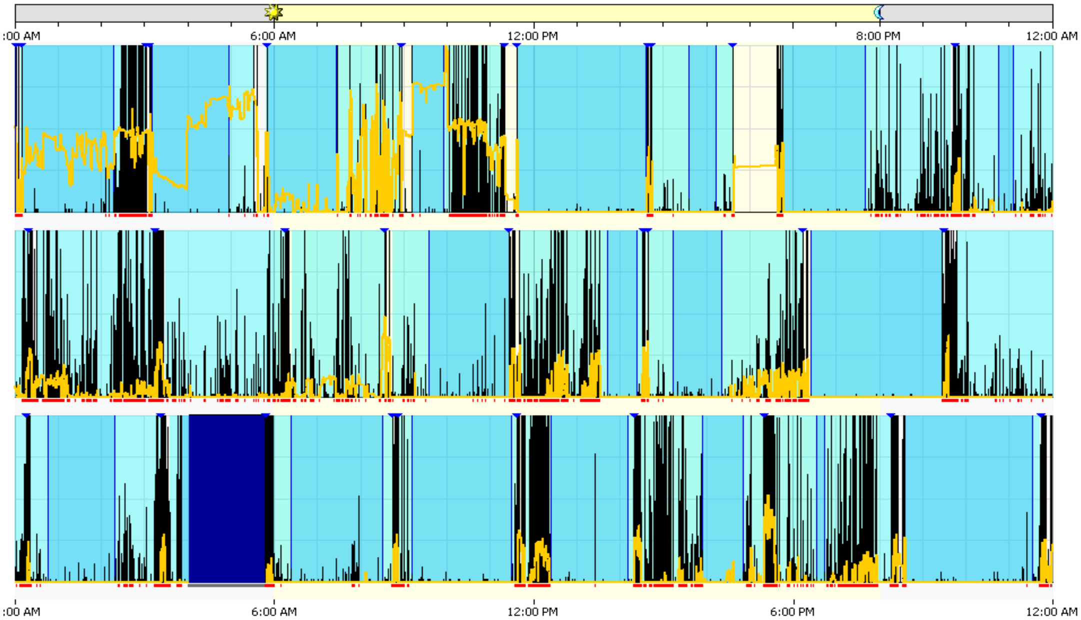
5.9 Conclusion

This feasibility study was able to successfully assess sleep and wake patterns in preterm infants in the NICU, with similar results as other studies, though the amount of care activities seemed to be less than other studies. With modifications in actigraph placement, this study supports the feasibility of using actigraphy to examine infant sleep and wake patterns in preterm infants, as well as utilizing infant care journals completed by bedside nurses to examine the amount of care infants received. Better sleep data can support studies examining risk factors for poor sleep, long-term effects of poor sleep, and interventions to support neonatal sleep.

APPENDICES

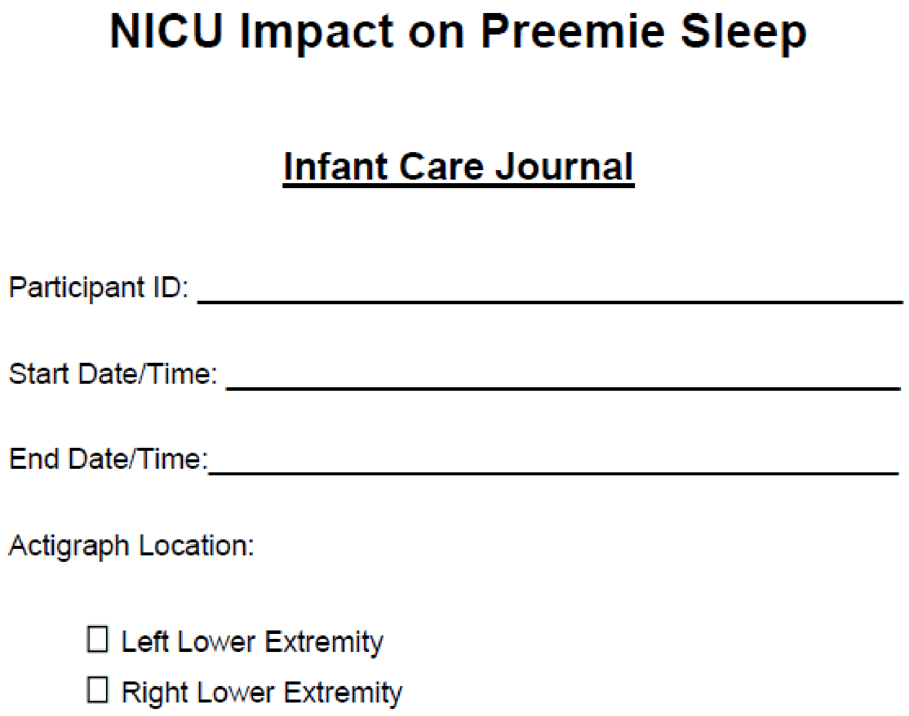
Appendix 1. Actograms for the youngest and oldest infants in the study.

Appendix 1a. Actogram of an infant with gestational age of 28 weeks (activity scale max 100).



Appendix 1b. Actogram of an infant with gestational age of 32 weeks (activity scale max 100).

Appendix 2. Infant Care Journal



NICU Impact on Preemie Sleep

Infant Care Journal

Participant ID: ______________________________

Start Date/Time: ______________________________

End Date/Time: ______________________________

Actigraph Location:

- ☐ Left Lower Extremity
- ☐ Right Lower Extremity

Begin Date/Time	**Begin Sleep or Awake**	**Activity**	**End Date/Time**	**End Sleep or Awake**
	☐ Sleep ☐ Awake	☐ RC ☐ MP ☐ PA ☐ P/F ☐ LD ☐ A/B/D ☐ Rad ☐ Other ______		☐ Sleep ☐ Awake
	☐ Sleep ☐ Awake	☐ RC ☐ MP ☐ PA ☐ P/F ☐ LD ☐ A/B/D ☐ Rad ☐ Other ______		☐ Sleep ☐ Awake
	☐ Sleep ☐ Awake	☐ RC ☐ MP ☐ PA ☐ P/F ☐ LD ☐ A/B/D ☐ Rad ☐ Other ______		☐ Sleep ☐ Awake
	☐ Sleep ☐ Awake	☐ RC ☐ MP ☐ PA ☐ P/F ☐ LD ☐ A/B/D ☐ Rad ☐ Other ______		☐ Sleep ☐ Awake

Activity Codes:

RC – Routine Care	PA-Provider Assessment
LD – Lab Draw	Rad – Imaging
MP – Medical Procedure	P/F – Parent/Family Interaction

A/B/D – Apnea/Bradycardia/Desaturation Event requiring Stimulation

Activity Abbreviations:

RC – Routine Care
PA-Provider Assessment
LD – Lab Draw   Rad – Imaging
MP – Medical Procedure
P/F – Parent/Family Interaction
A/B/D – Apnea/Bradycardia/Desaturation Event requiring Stimulation

Definitions:

Begin Time - Time that any activity begins
End Time – Time that any activity ends
Sleep – Infant visibly sleep with eyes closed with little to no body movement.
Awake – Infant visibly awake with body movement.
Routine Care (RC) – Infant Care given during scheduled feeding times every 3-4 hours
Provider Assessment (PA) – Activity where any provider (MD/NP/PA) assesses infant
Lab Draw (LD) – Activity where the infant is having labs drawn directly from infant (ex. heel stick) or from line access (ex. PAL, UAC) by any person (ex. provider, nurse, phlebotomy)
Imaging (Rad) – Activity where infant is have any imaging done (ex. X-ray, Ultrasound, ECHO)
Medical Procedure (MP) – any invasive medical procedure (ex. Arterial puncture, umbilical lines, PICC line placement, lumbar puncture)
Parent/Family Interaction (P/F) – Any interaction with parents or family (ex. Talking to infant, holding infant, hands on infant)
Apnea/Bradycardia/Desaturation Event requiring Stimulation (A/B/D) – Any time the infant has an apnea, bradycardia, or desaturation event that **requires stimulation**
Other – Any activity that is not included in the above options, please write in.

Appendix 3. Routine Care Time Table

Example of the routine care table for a study participant. Start and end times documented for each hierarchical marker. The green shaded cells indicate the times that were used as the final time used for analysis. Yellow shaded cells indicate a value that need to be calculated.

Scheduled	1. Time Stamp		2. Journal		3. Light		4. Activity		Calculated/Final		Avg time
Start	Start	End	Start	End	Start	End	Start	End	Start	End	13mins
0000	0030	0042	0029	0043	0029	0042	0029	0042	0030	0042	12
0300	0244		0241	0301	0246	0257	0244	0252	0244	0301	19
0600	0556	0612	0556	0612	0557	0612	0556	0615	0556	0612	16
0900	0846	0901	131	0906	0846	0902	0845	0902	0846	0901	15
1200	1214		1212		1214	1220	1206	1220	1214	1220	6
1500	1457	1509	1457	1510	1456	1509	1501	1506	1457	1509	12
1800	1752	1811	1750	1811	1751	1808	1751	1808	1752	1811	19
2100	2050	2121	2045	2104	2051	2101	2052	2058	2050	2104	14
0000	2348	0001	2347	0001	2348	0005	2348	0001	2348	0001	13
0300	0249		0247	0305	0250	0305	0245	0302	0249	0305	16
0600	0551	0610	0550	0609	0549	0610	0547	0600	0551	0610	19
0900	0832	0849	0832	0850	0826	0850	0825	0847	0832	0849	17
1200	1206	1219	1206	1220	1206	1223	1206	1218	1206	1219	13
1500			1426		1438	1458	1426	1441	1426	1439	
1800	1737	1750	1737	1750	1736	1754	1737	1750	1737	1750	13

Appendix 4. Actigraph Scoring Rules

Actigraph Scoring Rules

NICU Impact on Sleep in Preterm Infants Study – N. Hunt

- **Setting Up Actiware Software**
    - Setting Parameters
        - Wake Threshold –Med (40)
        - Sleep Interval Detection Algorithm – Immobile Minutes for 10 minutes
        - Immobile minutes for Sleep Onset – 10 minutes
        - Immobile minutes for Sleep Offset – 10 minutes
        - Start of 24-Hour Period should be changed depending on what time the data is started for each patient (if the data being analyzed from 3am-3am, then this should be changed in the Actiware).
- **Excluding Data**
    - Any period with consecutive activity counts of "0" for 60 or more continuous minutes, allowing for 2 non-zero interruptions, is considered "off-wrist" time and labeled as an excluded interval. (Sherar et al., 2011)
    - Any 24-hour period with more than 4 hours of missing actigraphy data (Adams et al., 2019)
    - Exclude study participant with less than 2 qualifying 24-hour periods of actigraphy recording.
- **Prepare Actogram for Editing**
    - Clear all intervals
    - Exclude all data prior to and after the study time frame, and any period with missing data
    - Change number of day under *Actogram Length* to view only days with data
    - Set "Activity Scale" to 100 (along right side of screen). May try other scales to best observe the pattern of activity counts (e.g. accelerations/decelerations, quiet periods vs off-wrist time) on the actogram, usually 100-200 works well.
- **Viewing Graph**
    - Gives a closer look at the actigraph data to assess changes in light and activity
    - View - Graph
    - Graph Width – 6 hours
    - Activity Scale – Max: 100
- **Setting Start and End times for Rest Intervals**
    - The hierarchy (priority) of "reliable markers" for setting the start/end of the Rest Interval will be as follows: 1. Time stamp, 2. Journal entry time, 3. Sudden drop (start of rest interval) or increase (end of rest interval) in light level, 4. Sudden drop (start of rest interval) or increase (end of rest interval) in activity counts. (Folleso et al., 2021)
        - If $\geq$ 2 markers are in agreement within 15 minutes of each other, the highest ranked marker will define the start/end of the rest interval (Folleso et al., 2021; Patel et al., 2015)

    - If 2 pairs of markers are in agreement for different times (e.g. time stamp and journal suggest a 10am start time and light and activity markers suggest 10:20am marker), the highest ranked marker (i.e. time stamp) will define start/end of the rest interval. (Patel et al., 2015)
    - If there are no markers in agreement within 15 mins, the mean time of routine care for that infant will be calculated and that amount of time will be either
        - Added to a marker determined start time
        - Subtracted from a marker determined end time
        - If there are no markers can be used to determine start/end times for the rest intervals, the start time will be inputted as the standard start times for routine care (12, 3, 6, 9 am/pm) and the mean time for routine care will be added to that time.
    - Calculating Routine Care Times
        - If start/end of routine care is missing, will calculate the average
        - Regular routine care times in the NICU are 12, 3, 6, 9 AM/PM. To calculate the average length of time for routine care:
            - The amount of time will be calculated for each separate routine care interval that has a start and end time
            - The total amount of minutes from each of the routine care intervals is divided over the number of routine care intervals
- Changes in Light and Activity levels
    - Patel (2015) suggests drop in light level < 1 lux or lowest intensity observed for that day. In the NICU, there may not consistent light levels throughout a 24-hour period. Because of this, a rule of a sudden change in lux (could be from 0.2 to 1.2 or 1 to 43, as seen with this data)

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