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Circadian Research in Mothers and Infants: How Many Days of Actigraphy Data Are Needed to Fit Cosinor Parameters?

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Abstract

Background and Purpose: To determine the number of days of actigraphy data required to portray circadian rhythm in mothers and their young infants.

Methods: Continuous actigraphy monitoring was performed in 20 mothers-infant pairs over a four-day period. Cycle mesor, amplitude, acrophase, and R^2 , calculated using from one-to-four days of data, were compared. Parameters, based on four days of data, were correlated with parameters derived from one to three days of data.

Results: There were no differences among mother or infant cosinor parameters except infant acrophase which stabilized after ≥ 2 days of data. Acceptable reliability ($r \geq 0.80$) was achieved with ≥ 2 days of data.

Conclusions: A recording period of two days adequately depicted circadian rhythm of actigraphy in mothers and infants.

Keywords

circadian rhythm; cosinor analysis; method; actigraphy; mother-infant dyad

Introduction

Circadian rhythm is an important area of nursing research. Timing of human function in relation to environmental external temporal pattern has significant health implications (Turek, Dugovic, & Zee, 2001). Maternal entrainment of infant circadian rhythm is important in synchronizing the developing infant with the home environment. Research depicting mother and infant rhythms requires specification of measurement strategies that adequately portray circadian cycle. Actigraphy is an easily applied, non-invasive measure of activity and results demonstrate strong circadian pattern. There are few directives in the current literature suggesting the number of days of actigraphy data needed to produce consistent and reliable estimates of cycle parameters in mothers and infants. Duration of data collection increases subject burden and may limit recruitment, in addition to increasing the volume of data collected. The purpose of this research was to determine the number of days of actigraphy needed to portray mother and infant circadian rhythm.

Background and Conceptual Framework

The study of circadian rhythm involves repeated measurement of a variable throughout at 24-hour day. Cosinor analysis is subsequently employed to determine circadian rhythm characteristics of the chosen variable. In this approach a cosine curve is fitted to the data using linear regression with cycle period specified as 24-hours. Rhythm parameters derived from cosinor analysis include the cycle mesor (cycle mean), amplitude (difference between mesor and peak), acrophase (clock time of the peak value), and R^2 (variance explained by the cosine fit). When studying mother and infant actigraphy records, the circadian cycle mesor reflects the mean activity count across a 24-hour period. Amplitude measures the peak amount of activity while acrophase is the time within the 24-hour day when peak activity occurs. R^2 is a measure of how well the data fits into the 24-hour circadian pattern. Circadian and all biorhythm measurement raise two measurement concerns: (1) the frequency of data collection within the cycle or epoch length (e.g., how often to collect data), and (2) the number of daily cycles to replicate (e.g., the duration of data collection). While both frequency and duration of measurement should be tailored to the cycle of interest, this article focuses on duration of measurement.

In circadian work, a minimum of one complete cycle (24-hour period) is desired for cosinor analysis. While one 24-hour day is sufficient given adequate sampling within the day, common opinion holds that more than one day of data is needed. There are few guidelines suggesting number of days of data collection (Littner et al., 2003; Ancoli-Israel et al., 2003). Duration of data collection, a measurement issue, is interrelated with subject burden, an issue related to human subjects approval, recruitment, and retention. This article addresses duration of data collection in a study of maternal and infant circadian rhythm of activity measured by actigraphy. The research aim was to compare mesor, amplitude, acrophase, and R^2 of both infant and maternal actigraphy circadian rhythm computed using between one and four day's of data. Findings directly inform similar circadian research among mothers and infants. Additionally findings illustrate the need for pilot work to determine appropriate duration of data collection assuring both adequate depiction of the circadian rhythm and reduction of subject burden.

Activity, as recorded with actigraphy, demonstrates a robust circadian rhythm (Brown, Smolensky, D'Alonzo, & Redman, 1990; Ancoli-Israel et al., 2003). Continuously recorded actigraphy data serves as the basis for assessing circadian rhythm. Additionally sleep-wake pattern may be determined from actigraphy, however the duration of recording needed for depiction of circadian rhythm may differ from that required for accurate assessment of sleep-wake pattern. The rationale supporting investigation of maternal and infant circadian rhythm was based on mothers' instrumental role in shaping their infant developing circadian rhythm and therefore sleep-wake pattern. Study design choices in investigating maternal-infant rhythm weigh adequate data collection period against the inconvenience of continuous monitoring. Although actigraphy has been used in the study of mother and infant circadian rhythm, few studies have specifically examined duration and there are few recommendations regarding the number of days of recording. This study offers empirical evidence substantiating measurement duration for future research of maternal and infant circadian rhythm.

Performing more than one day data collection is based on the premise that replication of the circadian cycle will improve the estimates of circadian parameters. Many of the current suggestions for duration of actigraphy monitoring come from determining sleep-wake pattern and may not directly apply to circadian rhythm research. For example, Acebo et al. (Acebo et al., 1999) in a study of sleep in infants 12 months of age found that four or more nights of actigraphy data were needed to obtain reliable sleep measures. Conversely Scher et al. (Scher, Tirosh, & Lavie, 1998) found no difference between one and two days sleep parameters derived

from actigraphy in infants 12 months of age. Neither of these studies examined duration of data collection in circadian rhythm research.

Duration of data collection in circadian research is informed by conceptual and statistical modeling considerations. A rhythm assessed under natural conditions (e.g., the “lived rhythm”) day is a realization of the underlying circadian rhythm generator and reflects entrainment to the external environment. From a sampling standpoint we are interested in how any particular day reflects the entrained circadian rhythm in general and the stability and reliability of circadian parameters over time. Sollberger (Sollberger, 1969) recommends data collection duration of at least two cycles which allows estimation of baseline slope. Although short duration of data collection reduces subject burden replication of the circadian cycle is limited. More is not better however. Extended duration of data collection raises issues of stationarity as the effects of noise and other trends are compounded over time (Padhye & Hanneman, 2007). In addition to external perturbations that may influence daily rhythm, extended duration may capture the influence of cycles with long periods such as menstrual cycle or season.

Measurement decisions involving mother-infant dyads incorporate knowledge of both mother and infant circadian pattern of actigraphy. While actigraphy has been used to study infant circadian rhythm in a number of studies, duration of data collection has varied from 20 hours to 3 weeks (Rivkees, Mayes, Jacobs, & Gross, 2004; Korte, Wulff, Oppe, & Siegmund, 2001; Pollak, Tryon, Nagaraja, & Dzwonczyk, 2001; Gnidovec, Neubauer, & Zidar, 2002; Ferber, Laudon, Kuint, Weller, & Zisapel, 2002; Wulff & Siegmund, 2000). None of these previous studies specifically examined duration of data collection to obtain circadian cosinor parameters. Although the effect of subject burden due to the number of days of data collection has not been studied, attrition in longitudinal studies of infant circadian rhythm is noted (Gnidovec et al., 2002; Rivkees et al., 2004). There is minimal work describing circadian rhythm following childbearing and lack of recommendations for duration of data collection. In an 8 day study of 15 healthy female adults living conventionally Waterhouse et al. found daily variation of activity acrophase within approximately 1 hour range (Waterhouse et al., 2000), however this study did not examine the minimum number of days needed for determining acceptable cosinor parameters.

Duration of data collection constitutes respondent or subject burden. Reducing duration to the minimal number of days that will adequately portray circadian rhythm may improve recruitment and retention. In a study of parent and child enrollment in clinical research protocols Gattuso (Gattuso, Hinds, Tong, & Srivastava, 2006) found the burden of research method to be the most common reason for refusal. Similarly Ransom (Ransom, Azzarello, & McMillan, 2006) in a study on participation in cancer pain research reported perception of burden as a significant factor influencing subject recruitment.

Method

Design

Mother and infant activity were recorded continuously over a four day period in the home environment using an intensive within-subject design.

Sample and Setting

Twenty healthy mother-infant pairs were studied. Selection criteria for mothers included age 18 to 40 years and no antepartum or postpartum health issues. Mean (SD) maternal age was 30.7 (5.7) years. Infants were singleton and term gestation with no postnatal health problems. Mean (SD) values for infant birth weight and postnatal age were 3630 (586) gm and 58.7 (10.6) days, respectively. The infant sample included 13 males (65%) and 17 (85%) of the infants

were breastfed. Racial and ethnic distribution for both mothers and infants groups was as follows: Asian, 5; Black, 1; white, 14.

Instruments

Infant and maternal activity were recorded using small, light weight actigraphy monitors that resemble digital watches (Actiwatch 64, Mini Mitter, Bend, OR). Mothers wore the monitor on the non-dominant wrist while the monitor was applied to the infant's ankle. Monitors were attached to nylon watch bands with loop and hook fabric closures. The actigraphy monitor is an accelerometer detecting occurrence and degree of motion. Motion is recorded as activity count over a predetermined epoch or period; 15 second epochs were employed. The monitor sampling rate is 32 Hz and the lower limit of sensitivity is 0.01 g. In addition to actigraphy monitoring, mothers maintained a diary recording sleep-wake periods, periods of external motion, and feedings.

Procedure

Subjects were recruited through community advertisement. A home visit was conducted to initiate study procedures. Informed consent was obtained and the study received IRB approval. Actigraphs were applied to mother's wrist and infant's ankle. Mothers were instructed to remove actigraphy monitors for bathing, otherwise monitors were worn continuously. Data collection continued over four sequential 24-hour days. Typical infant care patterns and home routines were maintained throughout data collection.

Analysis

For infants, epochs containing forms of external motion were eliminated from the analysis. Actigraphy counts were log transformed. Circadian parameters (mesor, amplitude, acrophase, and R^2) for both mother and infant were derived within subject from cosinor analysis in which a cosine curve with period length equal to 24-hours was fitted to the data using linear regression. These circadian parameters were calculated sequentially using from one to four days of data. These parameters were then compared using analysis of variance for repeated measures. Cosinor parameters calculated using from one to three days of data were also correlated with those derived using four days of data.

Results

For infants the number of days of data collection produced no statistically significant differences in mesor, amplitude, or R^2 (Table 1). The estimate of infant acrophase differed by number of days of data collection with a 0.6 hour (36 minutes) difference between acrophase based on 1 versus 4 days of data. Acrophase based on 2 to 4 days of data was consistent within 0.3 hours (18 minutes). Mothers did not evidence differences among any of the circadian parameters calculated using between one and four days of data. Acrophase for mothers was consistent within 0.2 hours (12 minutes).

Correlations among cosinor parameters calculated using increasing number of days of data are provided in Table 2. Acceptable reliability was defined as $r \geq 0.80$. For mothers and infants two or more days of data generally produced acceptable reliability.

Discussion

With the exception of infant acrophase, there were no statistically significant differences among cosinor parameters calculated with between one and four days of data. A two day period improved estimation of infant acrophase. Correlation results demonstrate that a two day data collection period provides adequate reliability. Taken together findings suggest that in this

study sample a two day collection period is sufficient to portray mother and infant actigraphy circadian rhythm.

Findings illustrate the need for preliminary studies characterizing circadian cycles and testing measurement strategies. Identifying a sufficient data collection period is important not only as a measurement issue but also from the standpoint of subject burden and its relation to recruitment and retention.

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Differences in Mean (SD) Maternal and Infant Actigraphy Cosinor Parameters Based on One to Four Days of Data Using ANOVA for Repeated Measures (n = 20 mothers, 20 infants).

	Mother Days				Infant Days			
	1	2	3	4	1	2	3	4
Amplitude	1.61 (0.40)	1.61 (0.32)	1.58 (0.32)	1.56 (0.32)	1.12 (0.64)	1.09 (0.56)	1.11 (0.55)	1.09 (0.53)
Mesor	2.05 (0.29)	2.06 (0.26)	2.04 (0.24)	2.05 (0.24)	1.49 (0.58)	1.45 (0.50)	1.48 (0.49)	1.47 (0.47)
R ²	0.468 (0.152)	0.454 (0.115)	0.442 (0.115)	0.434 (0.116)	0.300 (0.188)	0.290 (0.151)	0.290 (0.150)	0.279 (0.146)
Acrophase ^a	15.0 (1.2)	15.1 (1.3)	15.2 (1.2)	15.2 (1.3)	13.8 (2.7)	14.3 (1.7)	14.6 (1.5)	14.4 (1.5)

Note. Log transformed values of activity counts.

^aDecimal clock time (hrs).

* p < .000, F=481.5 (3,17) RM-ANOVA

Table 2

Pearson correlation of cosinor parameters based on 4 days data with sequential increase in duration of data collection (n = 20 mothers, 20 infants).

		Data Collection Duration		
		3 days	2 days	1 day
Mother	Mesor	0.982	0.904	0.623
	Amplitude	0.923	0.905	0.719
	R ²	0.889	0.885	0.774
	Acrophase	0.992	0.934	0.802
Infant	Mesor	0.978	0.926	0.876
	Amplitude	0.973	0.923	0.875
	R ²	0.957	0.878	0.842
	Acrophase	0.932	0.794	0.799

Note. All r values represent $p < 0.01$. Shaded areas represent reliability $r < 0.80$.