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Infant Activity: Objective Measurement and Impact on Growth

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Abstract

Background: The impact of activity on weight gain in premature infants has been controversial. We assessed this relationship using an objective measure of activity.

Methods: We conducted a prospective pilot study among infants who were at least 34 weeks gestation and had no medical problems that might affect activity, caloric intake or weight gain. Activity was counted using an actimeter.

Results: At baseline, the average gestational age of the 8 infants was 36.4 weeks and weight was 2279 ± 420 grams. Over 5 days, the averages for weight gain, caloric intake and activity were 16.5 ± 5.2 grams/kg-day, 129 ± 32 cal/kg-day and 3031 movements/hour. Weight gain was negatively associated with activity (r = -0.64) and positively correlated with caloric intake (r = 0.51).

Conclusions: Objectively measured activity is negatively correlated with weight gain. Future studies need to determine the impact of activity in larger, diverse groups over longer time periods.

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BACKGROUND

Inadequate growth in infants born prematurely is predictive of later growth delay and poor neurodevelopment([1,2,3]). Unfortunately, postnatal growth failure is common in very low birth weight infants([4]). At the time of hospital discharge, the majority of infants born between 24-29 weeks gestational age weigh less than the 10th percentile for infants of a similar gestational age, indicating that a slowing of growth occurs during hospitalization([4]).

Growth is influenced by caloric intake and energy expenditure in children and adults. The main sources of energy expenditure are digestion, thermoregulation, growth and physical activity([5, 6]). To manage weight gain and weight loss, attention is focused primarily on caloric intake and physical activity in older children and adults. Illness also increases energy expenditure. For example, preterm infants with chronic lung disease have been found to have increased caloric needs for growth([7, 8]).

In preterm infants, the primary approach to improving growth has been focused on enhancing caloric intake. Less attention has been paid to activity because it is thought to consume relatively little energy in infants. Using indirect calorimetry to measure energy expenditure and visual observation to detect activity, Freymond, et al reported that physical activity accounts for only 3.6 cal/kg/day or only approximately 5.3% of caloric expenditure in infants([9]). Similarly, Billeaud, et al found that oxygen consumption as a measure of caloric expenditure did not significantly increase with physical activity in infants([10]). However, it is plausible that excessive activity can impair growth.

Studies that have evaluated the influence of changes in physical activity on energy expenditure in infants used a scoring system to quantify visual observations of movement([9,10,11]). More reliable measurements of physical activity in infants might be obtained using actigraphy. Actigraphy involves using an actimeter, which is an electronic device attached to an extremity that can provide a continuous measure of movement over a prolonged period of time. Actigraphy has been used to assess populations with known disorders in circadian organization of activity, such as depression([12]) and sleep disorders([13, 14]). Wristwatch actigraphy has been shown to be a reliable non-invasive method to record both gross activity levels and circadian organization of activity cycles with high concordance with physiological measures such as polysomnography([15, 16]). Recently a number of studies have used the method to target the developmental trajectories of activity and sleep-wake states in infants and children([17,18,19,20,21]).

To better understand the contributions of activity as well as nutrition as a contributor to weight gain in premature infants, we conducted a pilot prospective cohort study. The goals of this study were to a) assess the feasibility of measuring infant activity over several days; and b) measure the association between infant activity and growth.

METHODS

This was a prospective cohort pilot study conducted in the intermediate care nursery (ICN) at a tertiary care children's hospital between July, 2005 and August, 2006.

Infants were eligible if they were born between 25 and 36 weeks gestational age, were at least 34 weeks gestational age by the time of enrollment, had been medically stable in the intermediate care nursery for at least three days, but were expected to remain in the intermediate nursery for at least five more days to achieve stable body temperature, taking full oral feedings and free of apnea and bradycardia spells. Infants were excluded if they had any medical condition known to adversely affect either the central nervous system (e.g., intraventricular hemorrhage of Grade II or higher), cardiac or adrenal function (e.g. major cardiac anomaly) or movement (e.g. spasticity, hypotonia, or fractured clavicle) or if there was any ongoing need for stressful or invasive medical procedures or steroid medications.

A single study nurse collected baseline data including the infants' gestational age at birth, gender, weight, and medical problems. The study nurse asked each infant's mother to complete a brief questionnaire to ascertain self-reported race/ethnicity. The study nurse also collected daily information on weight gain, feeding type and amount of feedings for five days from the nursing records.

Caloric intake by kilogram of body weight was calculated for each day of the study period using the volume of feedings multiplied by caloric density of the feeding for each 24 hour period. Caloric intake from breastfeeding was not calculated because we could not determine accurately the quantity of breastmilk ingested. Thus, caloric intake for infants who were fully or partially breastfed are likely to be underestimates.

Measurement of behavioral activity was collected using a wrist-watch actimeter (Actiwatch Model-64, Respironics Inc., Figure 1).

Figure 1. Actiwatch

Figure 1

Actimeters measure movement by the displacement of an omni-directional piezoelectric force transducer with a sensitivity of 0.01g force. The Actiwatch was placed on the infant's lower leg in a terry cloth sleeve and remained in place throughout the five day study period with the exception of brief periods when the unit was removed to bathe or otherwise care for the infant. Each measured movement is summed over a user determined sampling epoch which is defined as an “activity count”. Activity counts were recorded in 15 sec sampling epochs and the resulting data were used to calculate average movements per hour. Twelve hours of continuous data were collected between the hours of 08:00 and 20:00 daily for each subject. Infants were handled for daily care needs and by parents during visits. The remainder of the time, they lay in their cribs loosely swaddled or covered with blankets.

The activity data were downloaded from the actimeters using Actiware-Sleep® software (Vers. 3.2, Respironics, Inc.) which extracted the data from an actimeter via FM signal, calculated average movements per hour and output the resultant values using a standard delimited format for import to statistical software.

Biweekly, the research nurse entered all study data using Access 2000. Validation checks were performed monthly.

Statistical analysis included means and standard deviations for continuous data, means and standard error for activity data measured over several days separately for each infant, and Pearson correlation coefficients between continuous variables. Data were analyzed using SAS® version 9.1.

This study was approved by the Institutional Review Board of the Wake Forest University School of Medicine (WFUSM) IRB and informed consent was obtained from the parents of all participants.

RESULTS

Eight infants met criteria for the pilot study. The attributes of the study sample are summarized in Table 1. All infants were born prematurely and were recovering from pulmonary illness, but were medically stable by the time of study enrollment. Two infants breast fed on at least one day during the study period and several infants received dietary supplements such as Polycose® and rice cereal (Table 2).

Figure 2

Table 1: Description of Study infants

Characteristic	**Average ± SD or N=8 (100%)**
Gestational age at birth (weeks)	28.5 ± 4.5
Birthweight (grams)	1370 ± 756
Males	7 (88%)
Race	
African American	2 (25%)
Caucasian	6 (75%)
Gestational age at study baseline (weeks)	36.4 ± 1.8
Weight at study baseline (grams)	2279 ± 420
Diagnoses since birth	
Respiratory distress syndrome	8 (100%)
Sepsis or meningitis	4 (50%)
Bronchopulmonary dysplasia	2 (25%)
Gastroschisis	2 (25%)
Necrotizing enterocolitis	2 (25%)
Patent Ductus Arteriosus	2 (25%)

Figure 3

Table 2: Infant Feeding

Feeding Type	**N=8 infants**
Breastfed (at least some)	2
Formula	
Preterm formula (SC)	3
Enfamil AR	1
Prosobee®	1
Neosure	1
Mixed	3
Supplements	
Rice cereal	1
Polycose®	1
Human Milk Fortifier	1
Beneprotein®	1
Hyperalimentation	1

Activity measurements were obtained for 27 twelve hour intervals among the 8 infants. One infant had activity measured for only one 12 hour period. The actimeter was lost for this infant, presumably in the hospital laundry after removal in the evening prior to the infant's bath. Two infants had their Actiwatch removed for an extended period of several hours when a parent and/or care provider did not replace it after handling the infant. In both of these instances this occurred during the 3rd 12hr sampling period, therefore, that entire 12hr period was excluded from the analysis. For all infants over all observation periods, the average activity count was 3031 movements per hour with a range of 2088 to 4724 movements per hour for different infants. The Actiwatches were removed during feeding and daily care sessions. The mean frequencies of Actiwatch removal over the entire 5 day sampling period for all subjects was 27.5 times (Min-Max: 15-44 times).

The average caloric intake was 129 ± 32 calories per kilogram body weight per day, and the average weight gain was 16.5 ± 5.2 grams per kilogram body weight (Table 3). There was a moderate negative correlation (r) between weight gain and activity (r = -0.64) which was similar in magnitude to the positive correlation between weight gain and caloric intake (r = 0.51).

Figure 4

Table 3: Relationship between caloric intake, activity and weight gain

Infant	Baseline weight (grams)	Average Caloric intake (kcal/kg/day)	Average Activity (counts/hr)	Average Weight gain (gm/kg/day)
1	2453	110	2505	16.0
2	2018	140	2088	24.9
3	1824	175	2112	16.4
4	3068	109	4724	13.9
5	1912	175	1772	21.8
6	2048	122	3484	17.2
7	2620	118	3462	7.7
8	2292	86	4102	14.0
AVERAGE	2279 ± 420	129 ± 32	3031 ± 583	16.5 ± 5.2

DISCUSSION

This is the first study to assess the relationship between weight gain, caloric intake and activity level as reflected in actimeter readings in stable premature infants. Measuring activity using an actimeter is feasible; however, some degree of vigilance is required to ensure that the small actimeter device is not lost when it is removed during bathing or other care activities. As expected, there was a positive correlation between caloric intake and weight gain. The negative correlation between activity and weight gain were of similar magnitude. Thus, activity, when measured objectively has a non-trivial effect on weight gain in premature infants.

Previous studies of activity in neonates that used visual observations of movements to measure activity concluded that activity was not as influential a factor in the growth of infants as caloric intake(9,10,11). Wrist-watch actigraphy is likely to be a more reliable measure of activity than simple observation since activity can be accurately measured continuously for prolonged periods of time. Several studies have used actigraphy to study the development of sleep-wake patterns in infants and children (17,18,19,20,21).

The limitations of this study included a small heterogeneous sample with a relatively short follow-up and only 12 hours of activity data per day per infant. After one actimeter was lost, we decided to remove the actimeters and secure them each evening to avoid instrument losses when study personnel were not available. Obtaining activity data for only 12 hours a day might be expected to bias the results against finding an association between activity and weight gain; however, since we found a moderately strong association even with this limited data, the size of the effect may be larger than reported here. Similarly, two infants were breastfed for part of the study, and their caloric intake from this source could not be accurately determined, potentially biasing results toward a weakening of the association between caloric intake and growth. Larger samples with longer follow-up and more complete assessment of intake and activity over 24 hour periods are desirable.

Despite these limitations, this study has demonstrated that it is feasible to measure infant activity using wrist-watch actigraphy over several days. The study also validates previous studies which showed a strong association between caloric intake and growth in premature infants (9,10,11). It demonstrates a similar relationship between activity and weight gain that had not been reported in earlier studies relying on subjective observational data.

AUTHORS' CONTRIBUTIONS

Cherrie Heller participated in the design of the study and drafted the background, tables and discussion.

Peter Pierre participated in the study design, analysis of the actimetery data, and drafted portions of the background and methods section of the manuscript.

Teresa Shaw participated in the study design, collected the data and reviewed drafts of the manuscript.

Kathi Kemper designed the study, supervised the study, analyzed the data, and participated in drafting, editing and revising all portions of the manuscript.

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