Infant and Caregiving Factors Affecting Weight-for-Age and Motor Development of Full-Term and Premature Infants at 1 Year Post-Term

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Received 2 December 1997; accepted 10 June 2002

Abstract: Guided by a theoretical process model, we examined direct and indirect effects of infants’ biologic condition and experience, the caregiving environment, and caloric intake variables on two outcomes, weight-for-age and motor development, for 52 full-term and 47 premature infants at 12 months post-term age. For full-term infants, birth weight and infant expression of positive affect and behavior during feeding had predicted positive direct effects on weight-for-age. Infant regulation of negative affect and behavior had an unexpected negative effect on this outcome. For premature infants, severity of acute illness, mother’s regulation of negative affect and feeding behavior, and caloric intake affected weight-for-age in unpredicted directions. Caregiving variables had indirect effects, through caloric intake, on both outcomes only for premature infants. The findings suggest the theoretical process model differs for premature infants and full-term infants, both in the contributing variables and in the processes of effects. © 2002 Wiley Periodicals, Inc. Res Nurs Health 25:394–410, 2002

Special appreciation is expressed to the families that participated in the study; to Audrey Chang, PhD, for contributions to the research design; to Chin-Yu Lin, PhD, and Yiu-ming Chiu, PhD, for assistance with data analysis; to Nellie Laughlin, PhD, for editing; and to Kay Lynn Martin for preparation of the manuscript.

Contract grant sponsor: National Institute of Nursing Research; contract grant number NR02348-02.

Contract grant sponsor (to University of Wisconsin Medical School): National Center for Research Resources; contract grant number: M01 RR03186 (NIH Grant No.).

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Published online Wiley InterScience (www.interscience.wiley.com)
DOI: 10.1002/nur.10047
The importance of infant growth and development as indicators of health is underscored by the intensity of clinical efforts directed toward them (Casey, Yogman, & Kraemer, 1997; Green & Palfrey, 2002; Gross, 1997; McCormick & Richardson, 2002). An infant’s growth in weight relative to a population of infants the same age (i.e., weight-for-age) is the most commonly used index of growth adequacy to gauge growth and index well being (Kessler, 1999; Rider & Bithoney, 1999). Both an infant’s body mass and motor development support exploratory behavior and cognitive, social, and emotional development (Bertenthal & Campos, 1990; Pelligrini & Smith, 1998; Thelen, 2000, Wachs, 1993). For young infants, both weight-for-age and motor development reflect multiple personal and environmental factors, including maturity at birth (Hack et al., 2000), maternal and family resources, interactional experience, caloric and protein intake (Rider & Bithoney), and maturation with increasing age (Lamb, Bornstein, & Teti, 2002; Malina & Bouchard, 1991; Thelen).

The multiple personal and environmental factors that contribute to weight-for-age and motor development and the processes through which these contributions are made may differ for premature and full-term infants. Premature infants with birth weight <2000 g and neonatal lung disease are at higher risk than other infants for poor growth in weight and for neurologic problems that could affect motor development. Assuming that a premature infant’s birth weight is appropriate for gestational age, the risk increases as birth weight decreases (Bennett, 1997; Casey, Kraemer, & Bernbaum, 1991; Casey et al., 1997; Chye & Gray, 1995; deRegnier, Guilbert, Mills, & Georgieff, 1996; Farrell & Fiascone, 1997; Hack, Klein, & Taylor, 1995). The lung disease associated with prematurity may be either acute and resolved respiratory distress syndrome (RDS) or bronchopulmonary dysplasia (BPD). BPD is more likely than RDS to be associated with chronic derangements of pulmonary function through the infant’s first year post term age (PTA). However, premature infants with a history of resolved RDS also may have undetected pulmonary effects (Greenspan, Abbasi, & Bhutani, 1988) and are at high risk for growth faltering and developmental deficiencies (e.g., Meisels, Plunkett, Roloff, Pasick, & Stiefel, 1986). Intraventricular bleeds during the neonatal period also may affect growth and development in premature infants, particularly if severe (i.e., Grade III or IV; Hack et al., 2000). Researchers have suggested that the predictors of growth and motor development differ for premature and full-term infants (e.g., Casey et al., 1991) and that biological variables may contribute more to these processes than social variables (see, for example, Bradley, Casey, & Caldwell, 1997). However, the contributions of personal and environmental factors to outcomes and the processes involved have not been compared for premature and full-term infants.

The study reported here explores a theoretical model of processes through which personal and environmental factors could contribute to weight-for-age and motor development for premature and full-term infants. This model is consistent with Bronfenbrenner’s (1993) claim that development occurs in a context constructed of the personal and environmental factors that are specific to a child. Several research investigations have resulted in the specification of process models in which nutrition is a major influencing factor for somatic growth and cognitive development (Pollitt, Gorman, Engle, Martorell, & Rivera, 1993; Wachs, 1993). These models assumed that the young children were healthy, and they did not consider neonatal biological conditions, such as maturity status at birth, as factors influencing outcomes. Miceli et al. (2000) applied a process model to examine factors contributing to the mental and motor development of premature, very-low-birth-weight infants. In this model medical complications at special care nursery discharge were mediators of the relationship with developmental outcomes of birth status (birth weight and gestational age) and the social environment (maternal distress and support). Casey et al. (1997) in a large-sample study used multiple regression to examine the effect of infant factors, including medical complications, infant gender, and genetic makeup (parent size), and environmental (sociodemographic) factors—maternal education and race—on growth status at 12 months and rate of somatic growth across the first year. Neither infant experience nor the immediate caregiving environment in the form of mother–infant interaction were included in any of the process models reviewed.

**Theoretical Process Model**

The theoretical model examined in this study (see Fig. 1) portrays the processes through which
FIGURE 1. Theoretical process model of the paths among infant biologic condition and experience, caregiving environment, nutritional intake and weight-for-age and motor development at 12 months.
the biological condition and experience of the infant and the caregiving environment were presumed to affect weight-for-age and motor development. Nutritional intake was proposed as the mediating variable and outcomes were assessed at 12 months PTA. Because we wanted to assess the applicability of the theoretical model to both premature and full-term infants, maturity/lung health status, a biologic condition, was not included as a variable in the model. Instead, the model was examined independently for full-term and for premature infants. All premature infants had a history of lung disease beginning during the neonatal period. Because acute respiratory distress syndrome and its residual effects in the form of chronic lung disease occur so frequently in low-birth-weight, premature infants (Bennett, 1997), only premature infants with a history of lung disease were included in order to have an adequate sample size for the study. Other infant biologic conditions that have been found to have an interactional effect with maturity status at birth on somatic growth also were not included in the model. These include gender, genetic makeup (parent size; Casey et al., 1997), and intraventricular bleed (Hack et al., 2000; Landry, Fletcher, Denson, & Chapieski, 1993).

**Infant biologic condition.** For premature infants, birth weight contributes to the prediction of motor development (Brazy, Eckerman, Oehler, Goldstein, & O’Rand, 1991). The lower a premature infant’s birth weight, the greater is the likelihood of delays in motor development. For infants in general, a greater weight-for-age at 12 months PTA can be expected for infants who are larger at birth, assuming appropriate weight for gestational age at birth (Casey et al., 1997; Fomon, 1993). Larger infants are more likely than smaller infants to be given opportunities by their caregivers to develop and practice motor skills (Wachs, 1993). Therefore, a weight-for-age effect at 12 months PTA on motor development may be more likely for premature infants than it is for full-term infants. Premature infants, particularly those of very low birth weight, are vulnerable to chronic growth faltering in weight and consequent long-term alteration in caregiving that may affect motor development, whereas growth faltering for full-term infants, if it occurs, is likely to be acute and time-limited.

**Infant experience.** Infant experience that may contribute to weight-for-age and motor development includes episodes of acute illness (McCormick & Benasich, 1997). Acute illness requires alteration of day-to-day care for the infant and may have a detrimental effect on appetite, nutrient intake, somatic growth, and motor development. Acute illness may directly retard growth and motor development during illness episodes because of inflammatory processes and reduced capacity to engage in motor behaviors (Allen, 1993; Parmelee, 1989). Decreased nutrient intake, which is often associated with acute illness, may indirectly increase its retarding effect on growth in weight and motor development (Pollitt, 1983; Wachs, 1993). The more severe the acute illness, the greater the potential effect of illness on weight-for-age and motor development. Johnson, Cheney, and Monsen (1998) found that infants with BPD had a higher risk of growth failure when the number of parent-reported days of illness was higher.

Feeding is an infant experience potentially related to weight-for-age and motor development (Pollitt et al., 1993; Wachs, 1993). Researchers conducting animal and psychophysiologic studies (Hofer, 1995; Porges, 1996) have supported the idea that an infant’s feeding behavior contributes to growth in weight and motor development. Both Hofer (1995) and Porges (2001) claimed that neurohumoral mechanisms linked with social, emotional, and motor behaviors that occur during feeding directly affect growth. Infant feeding behavior not only supports or interferes with growth but also with the practice of motor skills. Feeding behavior includes expression of positive affect and regulation of negative affect, attentiveness to and engagement in feeding, alertness, social initiative, and responsiveness to the mother’s initiatives (Clark, Paulson, & Conlin, 1993; Cole, Michel, & Teti, 1994; Demos, 1982; Emde, 1989).

Infant feeding behavior with these characteristics is likely to support both a mother’s engagement in feeding and the infant’s intake and metabolism of nutrients (Porges, 2001; Singer, Nofer, Benson-Szekely, & Brooks, 1991).

Both growth in weight and motor development have been positively linked to nutrient intake in full-term infants (Pollitt et al., 1993; Wachs, 1993). For premature infants, however, this relationship is not well established (Georgieff, Sasanow, & Pereira, 1987). Infants regulate their intake through the caloric rather than the protein content of their diet (Fomon, 1993). However, if caloric intake is too low for the infant’s energy requirements, protein intake may be used to supply energy rather than to build body tissues (Allen, 1993; Chwals, 1994). Both calories and protein are needed for the development of lean body mass, including muscle (Matthews, 1999). The extent of the infant’s muscle mass and energy for motor activity directly affects motor development (Bendersky & Lewis, 1994; Thelen, 2000; Wachs).
Caregiving environment. An infant’s caregiving environment is structured by a mother’s personal resources (Belsky, 1983; Belsky & Vondra, 1989). The caregiving environment includes a mother’s education, which is an index of her cognitive resources and has been shown to have a positive impact on her child’s growth in weight (Eiben, 1988) and motor development (Brazy, Goldstein, Oehler, Gustafson, & Thompson, 1993). The caregiving environment also includes a mother’s emotional and verbal responsiveness to the infant, in general, and the quality of her task and social-emotional behavior during feeding, in particular. Responsiveness refers to the appropriateness and sensitivity of a mother’s verbal and affective behavior with her infant (Bornstein & Tamis-LeMonda, 1989; Bradley et al., 1994) and can be expected to have a positive effect on infant weight-for-age and motor development. Counterintuitively, Schraeder (1986) found that, at 12 months, a mother’s emotional and verbal responsiveness was a negative predictor of infant motor development for premature infants. This relationship, however, was examined in isolation from other variables and did not include a path through nutrient intake.

Feeding is a frequent, regular, and time-intensive activity in the infant’s first year (Stevenson, Roach, Ver Hoeve, & Leavitt, 1990). Hofer’s (1995) studies of the regulatory, physiologic effects of rat mothers on their pups suggest a direct, positive link of adaptive qualities of a mother’s social-emotional and task-related feeding behavior with an infant’s weight-for-age and motor development. A mother’s affect and behavior during feeding can express positive qualities, such as sensitivity and responsiveness, and regulation of negative qualities. Both expression of positive qualities and regulation of negative qualities are adaptive to infant needs and can enhance an infant’s nutrient intake (Clark et al., 1993; Emde, 1989).

The relationship between maternal feeding behavior and somatic growth may differ for premature and full-term infants. De Witt et al. (1997) found that, although a mother’s warm, sensitive behavior was not related to the rate of weight gain of the premature infants studied, it had an unexpected negative effect on the rate of gain of the full-term infants. De Witt and her colleagues did not examine indirect effects, through nutrient intake, of the mother’s feeding behavior on infant gain in weight.

We hypothesized that, at 12 months PTA for both premature and full-term infants, infant birth weight and adaptive affect and behavior during feeding would have positive direct and indirect effects on weight-for-age and motor development (Fig. 1) and that severity of acute illness would have negative direct and indirect effects on weight-for-age and motor development. Furthermore, we hypothesized that a mother’s education, emotional and verbal responsiveness, and adaptive affect and behavior during feeding would have positive direct and indirect effects on weight-for-age and motor development. All indirect effects were proposed to be mediated by caloric and protein intake. The knowledge provided by such a model could aid in the design of effective clinical interventions specific to both premature and full-term infant populations.

METHOD

This study was a component of a longitudinal, descriptive study of correlates of infant nutritional intake, growth, and development for premature and full-term infants through the first post-term year (Pridham, Sondel, Clark, Green, & Brown, 1994). The study was approved by a university human subjects committee and by the institutional review boards of participating hospitals.

Participants

Mothers of premature infants were recruited shortly before the infant’s discharge from one of three neonatal intensive care units. All premature infants were 32 weeks’ gestation or less at birth with weight appropriate for gestational age and with a history of lung disease (RDS and/or BPD). Mothers of full-term infants were recruited from family practice clinics, a pediatric primary care clinic, and a WIC Clinic (Special Supplemental Food Program for Women, Infants, and Children). The percentage of eligible families of premature infants recruited to the study was approximately 86%. About 67% of eligible families of full-term infants were recruited. Of the 135 mothers who consented to participate in the study, 114 (84.4%) completed it. Of the 21 noncompleting mothers, 14 were mothers of premature infants and 7 of full-term infants. Mothers most frequently reported lack of time as the reason for not continuing in the study. Noncompleting mothers of full-term infants tended to be younger than completing mothers.

On average, full-term infants weighed 3,518 g ($SD = 547$; range 2,490–5,075 g) at birth; premature infants weighed 1120 g ($SD = 310$; range 615–1722 g) and, hence, were predominantly

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very low birth weight (Table 1). Approximately 47% of both the premature and the full-term infants were male. About half the premature infants had recovered from RDS, and half had a diagnosis of BPD. Mothers were at least 18 years old and able to speak and read English. Mothers of full-term and premature infants were very close in age ($M = 29.2$ years, $SD = 5.1$ years; $M = 29.9$ years, $SD = 5.9$, respectively) and in education ($M = 14.8$ years, $SD = 2.82$; $M = 14.5$, $SD = 2.72$, respectively). About 80% of the mothers of the premature infants and 79% of the mothers of the full-term infants were married. In both groups 88% of the mothers were white. The remainder of the mothers ($n = 12$) were African American, except in the premature group, which had one mother who was Latina and one who was Asian.

### Measures

**Infant outcomes, biological condition, and experience.** Motor development was examined at 12 months PTA using the Bayley Psychomotor Scale of Infant Development (BSID-I; Bayley, 1969). This scale has been widely used for the assessment of gross motor development and is one of the best standardized developmental scales available (Scott, 1997). Although the BSID-I standardization sample did not include premature infants (Culbertson & Gyurke, 1990), Ross (1985) determined that the Bayley scale was useful for assessing the motor ability of premature infants. The psychomotor scale has acceptable levels of internal consistency and interrater reliability (Yang & Bell, 1975).

An infant’s nude weight for 12 months PTA was obtained with a Mettler (PM15) electronic scale, which weighs mass to the nearest gram and averages fluctuating weights sampled over a 5-s interval. Weights were repeated until two assessments were within 3 g of each other. The reported weight was the mean of these two assessments. A $z$ score was computed for the infant’s weight-for-age at 12 months PTA (WAZ12) using the median value of the reference population according to the National Center for Health Statistics (NCHS/Hamill et al., 1979).

Infant birth weight, assessed with an electronic scale, was obtained from the hospital record. A measure of severity of acute illness, or acuity measure, was designed for the study due to the lack of a prospective measure that included illnesses observed by mothers and not brought to the attention of medical personnel. The acuity measure was obtained from the mother’s calendar record, kept with investigator-provided printed instructions (Pridham et al., 1992). The illness signs that mothers were asked to record were derived from literature concerning premature infants (Termini, 1969).

### Table 1. Descriptive Statistics on Study Variables and t Tests of Differences Between Full-Term and Premature Infants

<table>
<thead>
<tr>
<th></th>
<th>Full-Term Infants ($N = 52$)</th>
<th>Premature Infants ($N = 47$)</th>
<th>$t$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infant variables</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Birth weight (grams)</td>
<td>3517.73 (547.07)</td>
<td>1120.51 (310.50)</td>
<td>26.97</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Severity of acute illness</td>
<td>.06 (.07)</td>
<td>.11 (.15)</td>
<td>2.08</td>
<td>.04</td>
</tr>
<tr>
<td>Positive affect/behavior$^1$</td>
<td>3.46 (.49)</td>
<td>3.54 (.56)</td>
<td>.73</td>
<td>.46</td>
</tr>
<tr>
<td>Regulation of negative affect/behavior$^1$</td>
<td>4.25 (.76)</td>
<td>4.15 (.63)</td>
<td>.72</td>
<td>.18</td>
</tr>
<tr>
<td>Kilocalories/kilogram/day</td>
<td>89.13 (28.10)</td>
<td>92.40 (23.50)</td>
<td>.63</td>
<td>.53</td>
</tr>
<tr>
<td>Grams of protein/kilogram/day</td>
<td>2.17 (.97)</td>
<td>2.29 (1.05)</td>
<td>.63</td>
<td>.53</td>
</tr>
<tr>
<td>Weight-for-age Z score</td>
<td>-.38 (1.04)</td>
<td>-.96 (.94)</td>
<td>2.90</td>
<td>.005</td>
</tr>
<tr>
<td>Motor development$^2$</td>
<td>106.27 (13.06)</td>
<td>89.67 (20.45)</td>
<td>4.75</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Mother variables</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Education</td>
<td>14.81 (2.82)</td>
<td>14.53 (2.72)</td>
<td>.49</td>
<td>.63</td>
</tr>
<tr>
<td>Responsiveness$^3$</td>
<td>10.27 (1.01)</td>
<td>10.25 (1.31)</td>
<td>.06</td>
<td>.95</td>
</tr>
<tr>
<td>Positive affect/behavior$^1$</td>
<td>3.05 (.69)</td>
<td>3.11 (.69)</td>
<td>.50</td>
<td>.62</td>
</tr>
<tr>
<td>Regulation of negative affect/behavior$^1$</td>
<td>4.17 (.49)</td>
<td>3.91 (.59)</td>
<td>2.41</td>
<td>.02</td>
</tr>
</tbody>
</table>

Note: Degrees of freedom = 97.

$^1$Parent-Child Early Relational Assessment (Clark, 1985).

$^2$Bayley I Psychomotor Scale (Bayley, 1969).

$^3$Emotional and Verbal Responsiveness, HOME Scale (Caldwell & Bradley, 1984).
Mothers also recorded the type of care that the infant had received for the illness. Each type of care option was weighted as follows: (a) a day without illness (0); (b) a day with illness, but no treatment (1); (c) a day of illness with home treatment (1.38); (d) a day with a call to the physician about the illness (1.78); (e) a day with a doctor’s visit for the illness (2.49); and (f) a day of hospitalization (4.05). The assigned weights were obtained by normalizing and averaging the acuity attributed to each of the six care options by 10 physicians (two family physicians, six pediatricians, and two pediatric pulmonologists). To obtain the acuity measure, the highest weight for each day of illness was summed and averaged for a 4-month period. For this study the average for the 4-month period from 4 to 8 months was used. To support the completeness and accuracy of recording illnesses, the contents of the calendar and recording process were reviewed with the mother at each data collection visit. The reliability of the calendar was checked with the mothers’ responses to an open-ended question concerning an infant’s health between data collection visits. This review also emphasized the importance of the calendar to the study and of the mother’s accuracy in maintaining it (Verbrugge, 1980).

The quality of infant affect and behavior during feeding was examined using items of an observational instrument, the Parent–Child Early Relational Assessment (PCERA; Clark, 1985; Clark et al., 1993). This instrument was chosen because it has been widely used with populations of mothers and infants similar to those of our study (e.g., Black, Hutcheson, Dubowitz, Starr, & Berenson-Howard, 1996; Teti & Gelfand, 1991) and has demonstrated interrater and consistency reliability as well as discriminant and concurrent validity (Clark, Hyde, Essex, & Klein, 1997). Theoretically derived scales from the 65 items were empirically confirmed by factor analysis of data from a large sample study involving full-term infants (Clark et al., 1997). The quality of each infant’s feeding behavior was assessed with the 12-item scale Infant Positive Affect and Behavior (IPAB) and with the 10-item scale Infant Regulation of Negative Affect and Behavior (IRNAB). IPAB items include expressed positive affect, alertness, social initiative and responsiveness, robustness, and communicative competence. IRNAB items concern regulation of negative affect and avoiding or averting behavior and attentional abilities, self regulation, organization, and consolability. Alpha coefficients for the study sample were .90 for IPAB and .88 for IRNAB.

Each infant’s caloric intake and protein intake were assessed with a 4-day food record kept by the mother just prior to the data collection visit. A food record that spans this period of time is likely to avoid bias due to daily variations in diet (Piwoz, de Kanashiro, de Romano, Black, & Brown, 1995). Mothers received printed instructions for recording data, including how to estimate the amount of food the infant spit up. During each assessment visit the food record was reviewed with the mother for completeness. Instructions for recording data were reviewed with the mother prior to each data collection visit. After the visit the food record data were organized for computer analysis by a nutritionist who contacted the mother for more information when there were questions about entries. The Nutritionist III program (North, 1988) was used to compute kilocalories/kilogram/day (Calories) and grams of protein/kilogram/day (Protein) intake.

Caregiving environment. Mothers reported their years of education on a demographic data form. A mother’s responsiveness to her infant (response) was assessed with the 11 binary items (yes, no) of the emotional and verbal responsiveness subscale of the Infant-Toddler Home Observation for Measurement of the Environment Scale (HOME; Caldwell & Bradley, 1984). Observational items include the mother’s spontaneous and responsive vocalization to the child and qualities of verbal and emotional responsiveness expressed directly to or about the child. The one interview item assesses a mother’s permission to do messy activities. The Kuder–Richardson reliability coefficient for the response variable for the study sample was .62. Interrater agreement, computed on approximately 7% of the assessments, averaged 97.1%. Evidence supporting the reliability and validity of the HOME for both typical and atypical infants has been reported by Bradley et al. (1989) and by Caldwell and Bradley.

The quality of each mother’s feeding behavior was assessed with the 16-item PCERA scale, Mother’s Positive Affect and Behavior (MPAB), and the 14-item scale, Mother’s Regulation of Negative Affect and Behavior (MRNAB). Items on the MPAB scale include the warmth and kindness of the mother’s tone of voice, her enjoyment and pleasure with the infant, positive physical contact, social initiative, sensitive and appropriate responses to infant cues, and engagement with and interest in the infant. MRNAB items concern regulation of expressed negative affect and include tenseness; irritation, frustration, or
annoyance; intrusiveness; quality of physical contact; appropriate handling and structuring of the feeding; flexibility; and consistency. Alpha coefficients for the study sample were .93 for MPAB and .89 for MRNAB.

Each PCERA item was rated on a 5-point scale from the second 5-min interval of a videotaped feeding interaction. The low end of each item scale designates clinical concern, and the high end of the scale designates strength and display of adaptive behavior. Item scores were summed to obtain a total score for each of the four PCERA scales used in the study (two infant and two maternal scales). For each of these scales, a higher score indicates more adaptive social-emotional behavior. Using categorical agreement (1–2 = area of concern, 3 = area of some concern, 4–5 = area of strength) as the criterion, the overall percentage of interrater agreement between pairs of raters for 20% of the videotaped feedings was .80.

**Procedure**

Signed informed consent was obtained from the mother and, if available, the father at the time of a family’s recruitment into the study. The mother’s education and her infant’s birth weight were obtained at recruitment. All other data were collected in the infant’s home at 1, 4, 8, and 12 months PTA. Each data collection visit was conducted by two nurses who were trained in data collection methods. To permit assessment of directionality of effects on motor development and weight-for-age, infant experience and nutritional intake and time-varying caregiving variables were assessed at 8 months PTA, and motor development and weight-for-age were assessed at 12 months PTA. Mothers completed a diet record for 4 days prior to the visit and kept a calendar on a daily basis throughout the infant’s first 12 post-term months. During the home visits, infants were weighed prior to a feeding, and the home environment was assessed. The mother fed the infant whenever she determined it was time for a feeding. The entire feeding interaction was videotaped for later analysis in the project laboratory.

**Data Analysis**

A path analysis using a noniterative procedure, two-stage least squares (Joreskog & Sorbom, 1993a), was employed to estimate the parameters of the relationships among variables. For this procedure three simultaneous regression equations were constructed to examine two models. The two-stage least-squares estimation procedure was selected because the use of an iteration procedure (e.g., full information maximum likelihood/FIML) sometimes produces unstable estimates when the sample size is small, which was the case in this study. Brown (1990) has shown that the use of the two-stage least-squares procedure is a satisfactory substitute for FIML. To use as much data in the model as possible, missing data were assumed to be missing at random and were imputed using Joreskog and Sorbom’s (1993b) similar response pattern imputation procedure (see Brown, 1994, for details). Approximately 6% of the data for illness acuity were imputed for full-term infants. About 8.5% of the data for motor development were imputed for premature infants. Because the purpose of the study was a preliminary, rather than a definitive, test of the theoretical model, it was important to retain promising relationships. Therefore, an alpha of .10 was used as the level of rejection.

**RESULTS**

Descriptive statistics for study variables for the full-term and premature infant groups are shown in Table 1. The significantly smaller weight at birth for preterm infants relative to full-term infants was still true at 12 months PTA. In addition, the average WAZ12 score for the premature infants was almost 1 standard deviation below the median value for the reference population of infants the same age, whereas for full-term infants the average WAZ12 score was only .38 of a standard deviation below the median value. Not unexpectedly, the severity of acute illness was also significantly greater for premature infants than for full-term infants. Although the mean motor development index was within 1 standard deviation of the norm (score of 100, $SD = 15$) for both premature and full-term infants, the index score was significantly smaller for premature infants than for full-term infants. In addition, the standard deviation of the motor development index for the premature infants was relatively large compared with that of the full-term infants. Mothers of the full-term infants had significantly higher scores on regulation of negative affect and behavior during feeding.

The matrix of correlation coefficients for the relationships among predictor and outcome variables for full-term infants is shown in Table 2 and for premature infants in Table 3. The relationship between motor development and the WAZ12
Table 2. Correlation Matrix of Study Variables for Full-term Infants (N = 52)

<table>
<thead>
<tr>
<th></th>
<th>BWT</th>
<th>ACUITY</th>
<th>MEDU</th>
<th>RESPONSE</th>
<th>MPAB</th>
<th>MRNAB</th>
<th>IPAB</th>
<th>IRNAB</th>
<th>CALORIES</th>
<th>PROTEIN</th>
<th>WAZ12</th>
<th>MOTOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>BWT</td>
<td>1.00</td>
<td>.07</td>
<td>.12</td>
<td>-.29*</td>
<td>-.14</td>
<td>-.11</td>
<td>-.04</td>
<td>.05</td>
<td>-.02</td>
<td>-.06</td>
<td>.29*</td>
<td>.26</td>
</tr>
<tr>
<td>ACUITY</td>
<td>1.00</td>
<td>.17</td>
<td>-.25</td>
<td>.06</td>
<td>.05</td>
<td>.01</td>
<td>-.01</td>
<td>-.18</td>
<td>-.10</td>
<td>.23</td>
<td>-.14</td>
<td></td>
</tr>
<tr>
<td>MEDU</td>
<td>1.00</td>
<td>.29*</td>
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<td>.28*</td>
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<td>.20</td>
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<td>.28*</td>
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<td>-.17</td>
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Note: Key to variable names: BWT, infant birth weight; ACUITY, extent/severity of an infant’s acute illness; MEDU, mother’s education; RESPONSE, mother’s emotional and verbal responsiveness to her infant; MPAB, mother’s positive affect and behavior during feeding; MRNAB, mother’s regulation of negative affect and behavior during feeding; IPAB, infant positive affect and behavior during feeding; IRNAB, infant regulation of negative affect and behavior during feeding; CALORIES, kilocalories/kilogram/day; PROTEIN, grams of protein/kilogram/day; WAZ12, weight-for-age z score at 12 months; MOTOR, motor development.

*p < .05. **p < .01. ***p < .001.

Table 3. Correlation Matrix of Study Variables for Premature Infants (N = 47)

<table>
<thead>
<tr>
<th></th>
<th>BWT</th>
<th>ACUITY</th>
<th>MEDU</th>
<th>RESPONSE</th>
<th>MPAB</th>
<th>MRNAB</th>
<th>IPAB</th>
<th>IRNAB</th>
<th>CALORIES</th>
<th>PROTEIN</th>
<th>WAZ12</th>
<th>MOTOR</th>
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<td></td>
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</table>

Note: Key to variable names: BWT, infant birth weight; ACUITY, extent/severity of an infant’s acute illness; MEDU, mother’s education; RESPONSE, mother’s emotional and verbal responsiveness to her infant; MPAB, mother’s positive affect and behavior during feeding; MRNAB, mother’s regulation of negative affect and behavior during feeding; IPAB, infant positive affect and behavior during feeding; IRNAB, infant regulation of negative affect and behavior during feeding; CALORIES, kilocalories/kilogram/day; PROTEIN, grams of protein/kilogram/day; WAZ12, weight-for-age z score at 12 months; MOTOR, motor development.

*p < .05. **p < .01. ***p < .001.
score was negligible for both full-term and premature infants \((r = -0.06\) and \(r = 0.02\), respectively), indicating that at 12 months these outcome variables were independent of each other. The correlations among predictor variables were weak to moderate, except for the relationship between the two maternal feeding variables (MPAB and MRNAB) and the relationship between the two nutritional intake variables, kilocalories/kilogram/day (Calories) and grams protein/kilogram/day (protein). Because of these collinearities, only one maternal feeding variable and only one nutritional intake variable were selected for the path analysis. MRNAB was selected because it included appropriate handling and structuring of the feeding (Emde, 1989), and Calories was included because of its role in regulating intake.

The theoretical model, shown in Figure 1, was fitted sequentially to two sets of data, one for the full-term infants and one for the premature infants. The significant paths \((p < .10)\) are shown in Figure 2 for the full-term infants and in Figure 3 for the premature infants. For both the full-term and the premature infant groups, the root mean square residual for the path model was .007, showing acceptable goodness of fit for the entire model for each group. The standardized estimates for gamma predictors (infant biologic condition, infant experience, and caregiving environment) and beta predictors (caloric intake) of WAZ12 scores and motor development and for gamma predictors of caloric intake at 8 months are shown in Table 4.

Neither infant nor caregiving variables contributed significantly in the process model to the caloric intake of full-term infants. For premature infants mother’s education and mother’s regulation of negative affect and behavior during feeding contributed significantly and negatively to caloric intake, an unexpected effect. The more years of education a mother had and the better regulated her negative affect and feeding behavior, the lower was the infant’s caloric intake.

Predictors of weight-for-age also differed for the two groups of infants (see Table 4). For the full-term infants, birth weight and both infant feeding variables (IPAB and IRNAB) had significant effects on the WAZ12 score. The effects of birth weight and IPAB were in the predicted positive direction, but the effect of IRNAB was, unexpectedly, negative (see Table 4). The better regulated the infant’s feeding affect and behavior, the lower was WAZ12.

For the premature infants, three variables made a significant, direct contribution to WAZ12 (see Table 4). These variables were (a) illness acuity, (b) mother’s regulation of negative affect and behavior during feeding, and (c) caloric intake. The effect of illness acuity was unexpectedly positive. The higher the infant’s illness acuity score, the less the infant’s weight deviated in a negative direction from the population median. Both mother’s regulation of negative affect and behavior and caloric intake had an unexpected negative effect on WAZ12. The more regulated the mother’s negative affect and behavior during feeding and the greater the infant’s caloric intake, the more the infant’s weight deviated in a negative direction from the population median. Of the infant and caregiving variables, only mother’s regulation of negative affect and behavior had a significant indirect effect on the premature infants’ WAZ12 score. This effect was negative and mediated through caloric intake. The higher an infant’s caloric intake, the less negative was the effect of a mother’s regulation of negative affect and behavior on WAZ12.

For full-term infants, only one caregiving variable—maternal responsiveness—had a significant effect on motor development (see Table 4). The direction of this effect was unexpectedly negative; the more sensitive and warm the mother, the slower was the motor development of her child. For premature infants, three predictor variables—illness acuity, maternal responsiveness, and caloric intake—had a significant direct effect on motor development (see Table 4). The effect of illness acuity was negative, and the effect of responsiveness was positive. The directions of these effects were expected, but the negative effect of caloric intake was not. Total indirect effects of the gamma predictors on motor development through caloric intake were not significant for either full-term or premature infants.

**DISCUSSION**

The goal of this study was to explore the applicability of a theoretical process model of the multivariate infant (person) and caregiving (environment) effects on weight-for-age and motor development for both full-term and premature infants at 12 months PTA. The findings contribute to understanding the types of factors and path relationships involved in motor development and weight-for-age and the differences in model specification and path relationships for full-term and premature infants. In light of the small number of mother–infant dyads, results of this study must be viewed as suggestions for examination with a larger sample.
FIGURE 2. For the full term infants, significant paths in the theoretical model.
FIGURE 3. For the premature infants, significant paths in the theoretical model.
Power for the full-term and premature infant models was explored post-hoc (Saris & Stronkhorst, 1984). The standardized parameter estimates of the relationship of most predictor variables with outcome variables were small for both full-term and premature infants (see Table 4). Thus, when there was a relationship between two variables, the power of the analysis was not sufficient to detect it. For a sample the size of this study, a power of .80, and an alpha of .05, a standardized parameter estimate of approximately .42 would be needed for the full-term infants and .48 for the premature infants. Power was as high as .78 for the estimate for the direct path of IRNAB to WAZ12 for full-term infants and for the estimate for the direct path of severity of acute illness to WAZ12 for premature infants. That most parameter estimates are considerably smaller than the criterion values for a power of .80 does not mean the estimates are unimportant from a research standpoint. The maximum effect size may be relatively low when an outcome is determined by even a few factors (Ahadi & Diener, 1989), and the expectation of other than a small effect size for a specific variable may not be reasonable for a multifactorial study. In sum, the differences found in the direction and patterns of relationships for full-term and premature infants could result either from use of analytic modeling procedures on small samples sizes or from true differences. Explorations of an unexpected direction of significant direct and indirect effects for both full-term and premature infants would most usefully follow replication of the findings.

All the variables selected to represent the concepts of the model had a significant effect for one or both infant groups and for one or both outcomes. However, the direct and indirect paths predicted by the model to explain each of these outcomes were only partially demonstrated for both the full-term and the premature infants. Unexpected findings, including the negative effect for premature infants of a mother’s regulation of negative affect and behavior during feeding; IPAB, infant positive affect and behavior during feeding; IRNAB, infant regulation of negative affect and behavior during feeding; CALORIES, kilocalories/kilogram/day; WAZ12, weight for age z score at 12 months; MOTOR, motor development.

### Table 4. Standardized Estimates of Direct Effects for Full-Term and Premature Infants

<table>
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<tr>
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<th>Full-term Infants (N = 52)</th>
<th>Premature Infants (N = 47)</th>
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<td></td>
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<td>ACUITY</td>
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<td>Full-term Infants</td>
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<tr>
<td></td>
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<td>+(.14)</td>
</tr>
<tr>
<td></td>
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<td>−.33</td>
</tr>
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<td>MOTOR</td>
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<tr>
<td></td>
<td>(.13)</td>
<td>+(.13)</td>
</tr>
<tr>
<td></td>
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<td></td>
<td>(.12)</td>
<td>+(.13)</td>
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<tr>
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</tr>
<tr>
<td>Premature Infants</td>
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<td>+.07</td>
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<tr>
<td></td>
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<td>+(.14)</td>
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<td>MOTOR</td>
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<td></td>
<td>−1.49</td>
<td>+3.64***</td>
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Note: The standard error is shown in parentheses with the z value below it. Two-tailed probabilities: !p < .10, *p < .05, **p < .01, ***p < .001.

Key to variable names: BWT, infant birth weight; ACUITY, extent/severity of an infant’s acute illness; MEDU, mother’s education; Response, mother’s emotional and verbal responsiveness to her infant; MRNAB, mother’s regulation of negative affect and behavior during feeding; IPAB, infant positive affect and behavior during feeding; IRNAB, infant regulation of negative affect and behavior during feeding; CALORIES, kilocalories/kilogram/day; WAZ12, weight for age z score at 12 months; MOTOR, motor development.
weight gain on the two outcomes. A higher rate of weight gain, consistent with catch-up growth, could make a difference for the relationship of caloric intake with the two outcomes.

A more complex, multivariate model and larger samples of both full-term and premature infants is needed to more fully explain weight-for-age and motor development at 12 months PTA. The findings for premature infants indicate the process model should include both direct and indirect effects of infant and caregiving variables, through caloric intake on the two outcome variables. The findings for full-term infants suggest that infant social-emotional and task behaviors during feeding contribute to the outcomes. Although DeWitt et al. (1997) included mother’s caregiving behavior in their analysis of somatic growth for full-term and premature infants, they did not include either nutrient intake or infant feeding behavior.

The differences between the model for full-term infants and the model for premature infants support Bronfenbrenner’s (1993) claim that developmental processes differ for children whose personal and environmental factors differ. Birth maturity status is one of these factors. The significant direct effect of severity of acute illness and of caloric intake on both weight-for-age and motor development for the premature infants is one example of this claim. Another example is the effect of infant positive affect and behavior on weight-for-age for full-term infants. A mother’s feeding behavior may have more bearing on motor development and weight status for a premature infant than for a full-term infant. In contrast to premature infants, full-term infants may contribute more to these outcomes through their own feeding behavior.

The study findings have drawn attention to needed areas of research for better specification of the model of infant and caregiving factors and their nutrient intake–mediated contribution to growth and motor development. In this study the small sample precluded inclusion in the model of infant and maternal factors that may contribute to these outcomes. One infant biologic condition that may make a significant contribution is energy expenditure, which constitutes caloric need (Fomon, 1993). The medical status of the infant, beyond acute illness and including chronic lung disease, is another biologic condition that may need to be quantified in some way and added to the model. An additional maternal caregiving factor that could help to explain the quality of a mother’s affect and behavior during feeding concerns the expectations and intentions that she has for feeding, that is, her working model of caregiving in the context of feeding (Pridham, Schroeder, & Brown, 1999). Feeding expectations are rooted in a mother’s perceptions of her infant’s needs in light of his/her condition and of her ability to respond (George & Solomon, 1996) and determine her decisions about feeding. Examination of these expectations may explain why mothers of premature infants may not provide opportunities for premature infants to advance in self-feeding skills (Holditch-Davis, Miles, & Belyea, 2000). A mother of an infant whose weight-for-age is low may expect her infant to be less robust and thus intend to more actively manage feedings (see Wachs, 1993). Once identified, a mother’s expectations and intentions could be addressed by nurses who are equipped to problem solve with mothers.

REFERENCES


FACTORS AFFECTING INFANT DEVELOPMENT AT 1 YEAR / PRIDHAM ET AL. 409


