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The Effects of Perinatal Morbidity and Environmental Factors on Health Status of Preterm Children at Age 12

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Abstract

Children born prematurely have later morbidity, yet little is known about their health in adolescence. This study examined multiple dimensions of health at age 12 and the predictors of biological, behavioral, social, and physical environmental factors. ANOVA and logistic regression models were tested. Perinatal morbidity predicted health at age 12. Preterm status increases the risk of later alterations in health. Bronchopulmonary dysplasia, necrotizing enterocolitis, intraventricular hemorrhage, small-for-gestational age, parental perception of child health, and parental psychological distress affect later health. Prematurity and perinatal morbidity continue to impact child health 12 years after birth.

Over half a million infants were born prematurely in the United States in 2004 accounting for 12.5% of all live births (Martin et al., 2006). This rate has been increasing yearly, with a greater than 30% increase since 1981 (Martin et al., 2005). Although some preterm children develop normally, a significant number of children will experience a variety of alterations in health. Even though research has supported that children born prematurely have later morbidity, there is little known about their health as they reach adolescence. While birth weight has been the most consistent global predictor of disease, disability, and/or injury; more recently the range and specificity of medical complications have improved understanding of outcomes (Taylor, Klein, & Hack, 2000). This study examined the impact of perinatal morbidity on children's health at age 12 and the independent and combined effects of biological, social, and physical environmental factors on health status. Health status outcomes are medical, neurological, motor, psychological, and overall health status. The study predictors are derived from the Institute of Medicine's (IOM's) conceptual framework of children's health which views health as influenced by complex interactions of biological, behavioral, social, and physical environments (Committee on Evaluation of Children's Health & National Research Council, 2004).

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Background

Conceptual Framework

The relative importance of biological, behavioral, social, and physical influences varies over time as the child moves from one developmental stage to another. Health is viewed by the IOM as “a positive resource that gives children the ability to interact with their surroundings and to respond to life’s challenges and changes” (Committee on Evaluation of Children’s Health & National Research Council, 2004, p. 33). Alterations in health include disease, physical and/or developmental disability, and injury. As development progresses, prior influences, such as the child’s past health status, are incorporated (Committee on Evaluation of Children’s Health & National Research Council). The IOM’s definition of health focuses on the intrinsic characteristics of children, their resources for interacting with the environment, while specifying a fundamental principle of development – the optimization and maintenance of function over time. This dynamic process of complex interactions is set within the broader context of policy and services which were not addressed in this study (see Figure 1). The IOM’s new conceptual model agrees with Holditch-Davis and Black’s (2003) review that children develop in a continuous, ongoing, reciprocal relationship with their environment. In this theory driven study, biological, social, and physical influences on the biological and behavioral outcomes of health status were chosen based on the IOM framework.

Biological Factors and Health Outcomes

There is evidence of a gradient effect where decreasing birth weight is associated with increased developmental sequelae, such that the smallest infants are more likely to have later health and developmental problems (Aylward, 2002; Marlow, Wolke, Bracewell, & Samara, 2005). Stein, Seigal, and Bauman (2006) found that among a national sample of children ($n = 7817$) from 0 to 12 years of age, children born with moderately low birth weight were at significantly greater risk for poor health compared with normal birth weight children (NBW; $>2500\text{gms}$) even with sociodemographic factors controlled.

Lindeke, Mills, Georgieff, Tanner, and Wrbsky (1998) followed a sample of infants (born 1987–1989) who required neonatal intensive care, classified by birth weight (low-birth-weight [LBW; $\geq 1500\text{g}$ & $< 2500\text{g}$], very-low-birth-weight [VLBW; $\geq 1000\text{g}$ and $< 1500\text{g}$], and normal birth weight). The LBW children showed considerably fewer health concerns at early school age than children in either the VLBW or NBW groups as reported by parents. However, not all extremely low birth weight children (ELBW; $< 1000\text{g}$) have alterations in health while some low birth weight children do, which suggests that it is not birth weight alone but also neonatal illness which places children at risk for future health problems.

Low birth weight is associated with increased neurodevelopmental problems (Hack & Merkatz, 1995). Additionally, children born preterm and with LBW are also at risk for motor impairment (Abernethy, Cooke, & Foulder-Hughes, 2004; Cooke, 2005; Powls, Botting, Cooke, & Marlow, 1995). Lastly, children born preterm and with low birth weight are at greater risk for behavioral and psychological health problems at school-age and adolescence (Anderson & Doyle, 2003; Bhutta, Cleves, Casey, Cradock, & Anand, 2002; Elgin, Sommerfelt, & Markestad, 2002; Grunau, Whitfield, & Fay, 2004; Hack et al., 1994; Stevenson, Blackburn, & Pharoah, 1998).

Social Factors and Health Outcomes

In studies of preterm infant outcomes, nurse researchers have examined social environment and its effect on preterm infants and children (Holditch-Davis, Bartlett, & Belyea, 2000; McGrath & Sullivan, 2003; McGrath, Sullivan, & Seifer, 1998; Medoff-Cooper, 1986; Medoff-Cooper & Schraeder, 1982; Schraeder, Heverly, & O’Brien, 1996) but these were focused on

infant/child development and not specifically child health. Magyary, Brandt, Hammond, and Barnard (1992), in a follow-up study of preterm children, concluded that diverse information about the child and family needs to be collected to effectively predict developmental competence in children.

In the present study, several social sources of influence on health (parental support and connectedness, parental perceptions of child vulnerability, maternal depression, parents' and friends' modeling of health behaviors, and socioeconomic status) are examined based on published evidence. Adolescents' perception of parental social support has been a key factor in decreasing the likelihood of depressive symptoms (Kaltiala-Heino, Rimpela, Rantanen, & Laippala, 2001; Patten et al., 1997). Family connectedness has been identified as one of the top five protective factors related to youth well-being. Analyses from the National Longitudinal Study on Adolescent Health (Add Health) found family connectedness to be protective against early initiation of sex, as well as cigarette and alcohol use (Resnick et al., 1997). In addition, family connectedness has been linked with decreased suicidal ideation and attempts, decreased extreme weight loss behaviors, and increased emotional well-being in adolescents (Resnick, Harris, & Blum, 1993).

Parental perceptions of increased vulnerability in their children have been linked to parental reports of developmental lags, immaturity, and behavioral disorders (Levy, 1980; Thomasgard, Shonkoff, Metz, & Edelbrock, 1995). McGrath (1993) found that perceptions of vulnerability have been linked to various childhood psychological problems. Maternal depression is associated with many adverse outcomes in children including language, cognitive, attachment, social, and behavioral problems (Petterson & Albers, 2001). Wong (2006) found that lower functional health in one to five-year-old African American and Latino children was significantly related to increased parental depressive symptoms. While no studies were found examining parents' psychological distress and its effect on early adolescents' health outcomes, Lyons-Ruth, Zoll, Connell, and Grunebaum (1986) reported increased levels of maternal depression were related to poorer infant motor development at age one. Cornish and colleagues (2005) also found that chronic maternal depression, lasting throughout the first 12 months postpartum, was associated with lower infant motor development at 15 months of age.

Jessor, Turbin, and Costa (1998; Turbin et al., 2006) have investigated the impact of protective factors of parents' and friends' modeling of health behavior and the health-enhancing behaviors of adolescents which can directly affect health outcomes. Health-enhancing behaviors constitute protection since they "provide opportunities to learn how to engage in the behaviors, provide social support for engaging in the behaviors, and indicate that the behaviors are characteristic of the social group to which the adolescent belongs" (Jessor et al., 1998).

Physical Environment Factors and Health Outcomes

McGrath and Sullivan (1999) found that motor outcomes at age 4 were best predicted by combined effects of biological and ecological factors using regression models. Mortality and morbidity rates differ for almost every disease and condition due to socioeconomic status (SES); (Antonovsky, 1967; Karpati, Bassett, & McCord, 2007; Winkleby, Cubbin, & Ahn, 2006). Socioeconomic status is associated with poorer nutrition, crowded and unsanitary living conditions, and inadequate medical care (Adler et al., 1994). In one study, the lowest income group had a high hazard rate ratio of mortality of 3.22. Lantz et al. (1998) concluded that despite reducing the prevalence of health risk behaviors in low-income populations, socioeconomic differences in mortality are due to an assortment of factors and would persist even with improved health behaviors among the disadvantaged. Due to its strong association with health, SES is considered a sound factor in the conceptualization for this study. Thus, we view multidimensional health in agreement with IOM models from a developmental perspective

influenced by the ongoing reciprocal relationship of biological, behavioral, social, and physical factors.

Purpose

The first aim of this study was to examine the effect of infant perinatal morbidity in health status at age 12. Health outcomes are medical, neurological, motor, psychological, and overall health status. We hypothesized that compared to a full term group, children in the preterm groups would have poorer overall health status with more medical, neurological, motor, and psychological health problems at age 12. The second aim was to examine the independent and combined effects of biological, social, and physical environmental factors on health status at age 12. Biological factors were birthweight, gestational age, total days hospitalized, neonatal risk, and neonatal illnesses. Social factors were parenting skills and attitudes, home environment, family connectedness, parents' perception of adolescent health, parents' health behavior modeling, and peer health behavior modeling. The physical environmental factor was socioeconomic status. We hypothesized that biological, social, and physical environmental factors would each affect health status of preterm children at age 12.

Method

Sample

This was a prospective, longitudinal study of 213 infants, grouped by perinatal morbidity, and followed to age 12 years. The sample was recruited by medical chart screening followed by enrollment with maternal consent during the postpartum stay or during the infant's neonatal intensive care unit (NICU) stay. The level III, 60-bed NICU employed the latest neonatal technologies and was a federal site for all clinical trials in neonatology, thus these infants benefited from cutting edge NICU technology. The percentage of neonatal deaths from 1985 to 1989 for those born at the hospital was 0.5 to 0.75%. This regional NICU has consistently reported survival rates for very low birth weight infants that are well above national averages. For example, in 2004, 89.5% of infants born between 750 and 1000 grams survived, and more than 98% of those infants born weighing 1000–1250 grams survived (CNE, n.d.).

The sample inclusion and exclusion criteria were determined a priori. The criteria for preterm infant recruitment were neonatal diagnoses (with the only exclusion being those critically ill and not likely to survive and/or major congenital anomalies) and birth weight <1850g. A group of full term infants were recruited in the same timeframe (1985–89) and at the same hospital as the preterm infants. Criteria for full-term infant recruitment were infant health (no medical or neurological problems) and gestational age 38 weeks or more. The maternal criteria were maternal health (no mental retardation or history of mental illness), maternal age ≥ 16 years, and English as a primary language. Fewer than 10% of the parent(s) declined participation. The study was approved by hospital and university IRB at the two time points. Parents gave informed consent each time while children signed assent at age 12 years.

There were four preterm perinatal morbidity groups and a healthy full term comparison group (Table 1). The infants in the healthy full term group were born via an uncomplicated pregnancy, labor, and delivery. The four preterm groups were: a group of healthy preterm infants without medical or neurological illness; a group of medical preterm infants with clinical illness (bronchopulmonary dysplasia, respiratory distress syndrome, necrotizing enterocolitis, sepsis, anemia, intraventricular hemorrhage [IVH] grade 1 and 2) but without neurological abnormality; a group of neurological preterm infants with severe neurological illness (meningitis, seizures, hydrocephalus, grade 3 or 4 intraventricular hemorrhage); and a group of small-for-gestational-age preterm infants (SGA), defined as birthweight less than the 10th percentile of expected weight for gestational age (Lubchenco, Hansman, & Boyd, 1966), with

or without medical problems. Socioeconomic status (SES) was calculated using the Hollingshead Index (Hollingshead, 1977) and perinatal morbidity groups were stratified so there were no differences in SES across the five groups. All infants, both full term and preterm, received the standard of care at the time.

At age twelve, 186 children were seen (87% retention from birth). The children were followed through infancy, at preschool, and school-age for developmental assessments which are not part of this study. A multi-pronged retention strategy was used over the last 20 years including regular contact with families by follow-up letters, greeting cards when appropriate, annual holiday cards, and bi-annual study newsletters. Subjects were periodically asked to return stamped post cards with updated contact information to keep the sample database current. Other successful retention strategies included: creating a project identity, prudent budgeting for participant tracking and travel, creating a welcoming environment for study families, providing small incentives, providing referral information if requested, and encouraging altruism. Reasons for attrition were family relocation, child and parent unavailability due to family schedules and child extra-curricular activities, family illness or death, and/or child hospitalizations.

There were no differences [$p < .05$] between those who participated at age 12 and those who did not in perinatal morbidity, SES, race, birth weight, gestational age, Hobel neonatal risk score, total days hospitalized, occurrence of neonatal illnesses, parents' marital status, maternal age, paternal age, maternal or paternal level of education. There was a significant difference between genders for attrition where more male children ($n = 20$) than female ($n = 7$) dropped from the study at age 12 ($\chi^2 (1, 213) = 6.756, p = .009$).

Measures

This was a theory driven study where variables were chosen based on the IOM framework. Predictor variables (biological, social, and physical environmental factors) are conceptualized as proximal to distal sources of influence.

Biological Factors

At the time of enrollment, neonatal data including birth history, birth weight, gestational age, total days hospitalized, neonatal risk score, and neonatal illness were gathered from medical chart review. Neonatal risk was calculated using the Hobel neonatal scale (Hobel, Hyvarien, Okada, & Oh, 1973) which evaluates the presence of neonatal illness related to the systems of the body (i.e., respiratory, circulatory, hematological and metabolic). Each item is given a weighted score with the resulting total score representing the total risk for the infant with higher scores indicating higher risk.

Social Factors

Social factors at age 12 were parenting skills and attitudes; social, emotional, and cognitive support; family connectedness; parent perception of adolescent health; parent current psychological distress, parents' health behavior modeling, and peer health behavior modeling.

Parent-Child Relationship Inventory (PCRI)—The PCRI was developed by Gerard (1994) to assess parents' attitudes toward parenting and toward their children. It is a 78-item, parent-report questionnaire with a Likert-type 4-point response format of strongly agree, agree, disagree, and strongly disagree. This instrument has been used in child custody evaluation, family therapy, parent training, child abuse assessment, and research. To the authors' knowledge, this instrument has not been used extensively in the preterm population. Overall, internal consistency is considered to be good with a median value of .82 (see Table 2). Test-retest reliability for a one-week interval had a mean of .81 (Gerard, 1994). Content, construct,

and predictive validity have been supported. The seven content scales of parental support, satisfaction with parenting, involvement, communication, limit setting, autonomy, and role orientation describe the parent-child relationship and evaluate the quality of their relationship. In addition, two validity scales within the instrument alerts one to the possibility that the parent is responding inconsistently or portraying the parent-child relationship in an unrealistically positive light. T scores for each of the seven content scales were used.

Early Adolescent Home Observation for Measurement of the Environment (EA-HOME)—The widely used HOME Inventory has had many applications including identification of “at-risk” families, evaluation of parent education programs, planning for family intervention, and research in child development (Caldwell & Bradley, 2003). The HOME Inventory has been used in research studies involving infants and toddlers. The EA-HOME (Bradley, Caldwell, Brisby, Magee, & Whiteside, 1992) extends the HOME to measure social, emotional, and cognitive support in early adolescence (10–15 year olds). The semi-structured observation/interview has six scales which measure the quantity and quality of stimulation, support, and structure available to teenagers in the home. Internal consistency was reported to be between .68 and .85 for the subscales, .94–.95 for the total score. Interobserver agreement has been reported by Bradley and colleagues (2000) as .90 and above. Validity was supported by correlations of the EA-HOME with measures of family context and child development (Bradley et al., 2000). The subscales and total EA-HOME score were used in the analysis.

Family Connectedness Inventory (FCI)—The FCI, developed and refined within the National Longitudinal Study on Adolescent Health (Add Health);(Resnick et al., 1997), measures family caring and connectedness. The FCI has been used mostly in examining high risk behaviors within the adolescent population, however no studies were found that included adolescents born preterm. Family connectedness was measured in this study by the 13-item scale which asked adolescents about their closeness to mother and/or father, perceived caring by mother and/or father, satisfaction with relationships to mother and/or father, and feeling loved and wanted by family members on a five-point Likert-type scale (Resnick et al., 1997). The total score was used in the analyses.

The Perception of Adolescent Health (POAH) questionnaire was revised from the Perception of Child Health Questionnaire (POCH) by changing the wording to be more developmentally appropriate for adolescents and dropping certain items that were not age appropriate. The POAH assesses parent perception of child vulnerability (McGrath, 1989). There are 14 Likert-type items to which a parent indicates their perception of concern regarding topics such as appearance, eating habits, accident proneness, and child fragility and strength. Higher scores represent greater concern about the child’s health. An alpha coefficient for the POCH was .87. Content and construct validity was supported (McGrath, 1995). The total score of the POAH was used in the analyses.

Brief Symptom Inventory (BSI) developed by Derogatis and Melisaratos (1983) assesses parent (usually mother) current psychological distress. The 53 items comprise nine symptom dimensions of somatization, obsessive-compulsive, interpersonal sensitivity, depression, anxiety, hostility, phobic anxiety, paranoid ideation, and psychoticism (Derogatis, 1993). Typical items on the BSI are “feeling lonely,” “difficulty making decisions,” and “feelings of worthlessness” with responses on a five point scale which ranged from “not at all” to “extremely.” This instrument has had wide use, in cancer populations, pain assessment/management, as an adjunct to screen psychiatric disorders, comparing efficacy of treatment interventions for various health conditions, and multiple other research studies. The test-retest reliability over two weeks for the global score = .90. Convergent, discriminant, construct, and predictive validity have been supported (Derogatis, 1993). In this study maternal

psychological distress was measured at the time of child assessment. Therefore, the total score was used in the analyses.

Parents' modeling of health behaviors—A subscale from Jessor, Donovan, & Costa's (1992) "Health Orientation Questionnaire" was a child-report measure that assessed paternal and maternal models for health behaviors. Model behaviors included paying attention to eating a healthy diet, getting enough exercise, getting enough sleep, and using seat belts when in a car were rated on a scale of 1 to 3 (1 = almost no attention, 2 = some attention, 3 = a lot of attention). The parents' modeling of health behavior score was used extensively by Jessor, Donovan, and Costa as a protective factor in examining adolescent health, health behaviors, problem drinking behavior, and problem behaviors. Validity has not been published. The paternal and maternal score was combined for a total parent modeling of health behaviors score in the analyses. *Friend's modeling of health behaviors*, a subscale from Jessor, et al. (1992) "Health Orientation Questionnaire," is a child-report measure of their best friend's health behaviors of eating a healthy diet, getting enough exercise, getting enough sleep, and using seat belts when in a car. It was rated on a scale of 1 to 3 (1 = almost no attention, 2 = some attention, 3 = a lot of attention). As with the parents' modeling of health behavior score, the friend's score was used as a protective factor in examining adolescent health, health behaviors, problem drinking behavior, and problem behaviors. Validity has not been published. The total score was used in analyses.

Physical Environmental Factor

The physical environmental factor used was socioeconomic status. *Socioeconomic status* was identified by using the Hollingshead Four-Factor Index of Social Status (Hollingshead, 1977), a composite index of SES using maternal and paternal education and occupation that is regarded as a highly reliable measure of social position. Hollingshead raw score was used in analyses.

Biological and Behavioral Factors - Child Health Status at age 12 (Dependent Variables)

In keeping with a comprehensive definition of health, child health variables at age 12 were theoretically distinct individual components of medical, neurological, motor, and psychological status, and a summary variable of the child's overall health status. All health data obtained by research nurses during the research assessments were verified with pediatric health records. Due to the comprehensiveness of the health history interview, details of perinatal history may have emerged revealing full term or preterm status. Therefore, it was difficult to keep research nurses fully blinded as to the child's full-term/preterm status. However, the neonatal illness detail was usually insufficient to identify preterm group membership. Two research nurses were familiar with the families and children because of their long association with the study and were not blinded to perinatal group status. At age 12, these nurses conducted the health interview but did very few child assessments.

All child health status data were classified as normal (healthy; no abnormalities), suspect (current conditions that may need monitoring or suspected chronic conditions), or abnormal (diagnosed chronic conditions). These data were classified in keeping with the Niswander & Gordon (1972) and Prechtel & Beitema (1967) guidelines and were expanded to age 12 with the assistance from a senior developmental pediatrician who consulted on the project. Interrater reliability was assessed by reviewing all physical exams and health histories with at least one additional research nurse. Interrater reliability was maintained at or above 95% agreement.

Medical status—Medical status was obtained from a health history interview with the parent (s) and a physical exam. The exam included height, weight, head circumference, blood pressure, general health data, exposed skin examination, head and neck exam, lung and heart

sounds, screening for scoliosis, and Tanner's Staging. Tanner's staging was measured by self-assessment using the Pubertal Development Scale (Petersen, Crockett, Richards, & Boxer, 1988). All medical status data were classified as Normal (no physical abnormalities), Suspect (continued chronic respiratory, cardiac murmurs, referral for hearing, orthopedic), or Abnormal (e.g. asthma, allergies, diabetes, and/or autoimmune deficiencies).

Neurological Status—The neurological status was obtained from a health history interview with the parent(s) and a physical examination. The research nurse classified findings as Normal (no neurological abnormality), Suspect (deviation that warrants watchful observation, i.e. fine motor weakness; unilateral sensorineural hearing loss; and atypical neurologic findings in tone, posture, gait, cranial nerves, reflexes, movement, or head growth for which no specific diagnosis was available) and Abnormal (cerebral palsy, blindness, deafness, shunted hydrocephalus, uncontrolled seizures, attention deficit hyperactivity disorder [ADHD], or attention deficit disorder [ADD]; Niswander & Gordon, 1972; Prechtel & Beitema, 1967). The diagnosis of ADHD and ADD were first identified by maternal report during the health history. Medical records and neuropsychological evaluations were obtained with parental consent to verify diagnosis.

Motor Status—The Bruininks-Oseretsky Test of Motor Proficiency-Short Form, normed on 765 representative U. S. children aged 4.6 to 14.5, was used to assess fine and gross motor skills using a comprehensive battery of test items (Bruininks, 1978). There are eight subtests including: running speed and agility, balance, bilateral coordination, strength, upper limb coordination, response speed, visual-motor control, and upper limb speed and dexterity. This assessment has been used by educators, clinicians, and researchers in evaluating children for educational placement, gross and fine motor skills, motor training programs, screening, and research (Bruininks, 1978). This assessment has been frequently used in preterm populations, though specific reliability statistics were not found for this population. Test-retest reliability coefficients range from .58 to .89. Construct validity is strongly supported (Bruininks, 1978). The standard score was used in the analyses. A binary variable was developed using standard scores < 30 and ≥30 as abnormal and normal status for the logistic regression models.

Psychological Status—Psychological status was determined by the Child Behavior Checklist (CBCL) – parent report (Achenbach, 1991). The CBCL identifies the symptoms of problem behaviors on a 118-item questionnaire which make up eight subscales: withdrawn, somatic complaints, anxious/depressed, social problems, thought problems, attention problems, delinquent behavior, and aggressive behavior. The CBCL has been used in a variety of settings including mental health intake, educational, medical, child and family service, and in research. This assessment has been used in preterm populations, though specific reliability statistics were not found for this population. Evidence has been reported for content, criterion-related, and construct validity of the CBCL (Achenbach & Rescorla, 2001). The CBCL in this study was also validated by our health history questions concerning friends/peers, siblings, or family situations; coping mechanisms; accepting responsibility; and any psychological problems diagnosed or suspected. The Total Problems scale, which is the sum of scores on all the problem items on the form, converted to the CBCL total problems *t* score was used in the analyses.

Overall Health Status—An overall health status score was categorized from the child's medical, neurological, motor, and psychological status by research nurses as Normal (healthy), Suspect (current conditions that may need monitoring or suspected chronic conditions), or Abnormal (diagnosed chronic conditions).

Procedure

After recruitment, data from the NICU hospitalization were collected by chart review. Two NICU advanced practice nurses extracted the data and calculated the Hobel score. They maintained an interrater reliability agreement of 97 percent. At age 12, children were seen in the hospital research laboratory and at home after informed consents and assents were obtained. The Health Orientation Questionnaire was completed by the participant at home prior to lab and home visits. During the lab visit, the mother and/or father were interviewed in a private room where demographics, health history, CBCL, PCRI, POAH, and BSI were obtained. The child was assessed with the Bruininks-Oseretsky Test of Motor Proficiency and a standardized physical assessment performed by the research nurse. A home visit was scheduled within 2 weeks of the lab visit where the EA-HOME Inventory and FCI were obtained. The procedures took 2 hours and 15 minutes to complete. Health information was verified by the child's medical records from the primary health care provider. Research personnel for each assessment were a research assistant trained in psychometry and a master's prepared or doctorally prepared nurse. The interrater reliability of protocols was maintained at or above 90% agreement throughout the course of the age 12 assessments.

Data Analysis

Descriptive demographic and neonatal variables were examined by perinatal morbidity group to characterize the sample at age 12. Descriptive statistics were reviewed to characterize all variables of interest in the study, and to check that data met assumptions for ANOVA, as well as regression analyses (i.e., that data were parametric, and that a minimum of 10% of cases had a "positive" health status outcome for logistic regression modeling).

To answer the first aim of the study, to examine perinatal group differences on health status in preterm children at age 12, the categories of "suspect" and "abnormal" were collapsed into one category to sharply contrast the normal classification. Chi-square (2×5) analyses were then used to determine distributional differences in overall health status with components of medical, neurological, motor, and psychological status (normal health versus any alteration in health) by perinatal morbidity group.

To answer the second aim of the study, to examine the independent and combined effects of biological, social, and physical environmental factors on health status, regression models were built. Three outcomes of interest were binary coded (normal and abnormal) for logistic regression: neurological status, motor status, and overall health status. The predictor variables, following a proximal to distal order, were biological, social, and physical environmental factors at age 12.

Results

Demographics

There were no differences among perinatal morbidity groups at age 12 for socioeconomic status ($F(4, 177) = .796, p = .529$). The racial distribution (Caucasian 88.2%, Black 8.1%, Hispanic 3.2%, and other 0.5%) reflected families living in Southeastern New England with no group differences by perinatal morbidity group ($\chi^2(12, 186) = 11.075, p = .523$). There was no difference in the distribution of females and males by perinatal morbidity group with a total of 98 females and 88 males ($\chi^2(4, 186) = 8.49, p = .075$). As expected by study design, mean values of birthweight, gestational age, Hobel score, and days hospitalized differed significantly among the perinatal groups, with the neuropreterm group having the lowest birthweight followed by SGA, medical preterm, healthy preterm, and then full term infants (see Table 1). For gestational age, the neuropreterm group had the youngest gestational age followed by the medical preterm, healthy preterm, SGA preterm, and full term groups. The neuropreterm group

also had the highest Hobel risk score followed by the medical preterm, SGA preterm, healthy preterm and full term groups. The neuropreterm group was hospitalized the longest followed by the medical preterm, healthy preterm, and full term groups. The SGA preterm group was also hospitalized longer than the healthy preterm and full term groups.

The Effect of Perinatal Morbidity in Health Status at Age 12

For aim 1, significant perinatal group differences were found for neurological status, motor status, and overall health status at age 12 (see Table 3). In neurological status, there were higher rates of abnormal status for the four preterm groups than the full-term group. In motor scores, the SGA preterm, medical preterm, and neuropreterm groups had lower motor scores than the full-term group. For overall health, the four groups of children born prematurely had a higher percentage of abnormal health status at age 12 than children born full-term.

Though no differences among the perinatal morbidity groups were found for the child's overall medical status at age 12, the SGA preterm and neuropreterm groups had higher rates for chronic health conditions, surgeries, placement of a shunt, allergies, and parental concern about child's growth compared to the full-term group. There were no group differences in psychological status (CBCL) at age 12.

The Effects of Biological, Social, and Physical Environmental Factors on Child Health

For the second aim, logistic regression models tested the effects of biological, social, and physical environmental factors on child health outcomes of neurological status, motor status, as well as overall health status at age 12 (see Table 4). As there were no differences among the perinatal groups in medical or psychological health status in the univariate analyses, these were not included as dependent variables in the modeling.

Neurological Status Outcomes

The logistic regression model for predicting neurological status showed the odds ratio for the variable "full-term" is 0.096 with a 95% confidence interval of .022, .414, $p = .002$. This suggests that infants born full-term are 90% less likely to have neurological abnormalities at age 12 than infants born preterm. On the other hand, a child born preterm was 3.5 times more likely to have an abnormal neurological status at age 12 if he or she had the neonatal diagnosis of BPD (odds ratio of 3.551 with a 95% confidence interval of 1.489, 8.466, $p = .004$). With the diagnosis of NEC in the newborn period, a child was three times as likely to have an abnormal neurological status at age 12 compared to one who was not diagnosed with NEC (odds ratio of 2.976 with a 95% confidence interval of 1.050, 8.435, $p = .040$).

In a second stage of logistic regression, full-term status, BPD, NEC, and child gender were entered in pairs to ascertain their combined effect on neurological status at age 12. Only one combined model adequately differentiated between normal and abnormal outcomes. BPD and NEC together classified 42.9% of the abnormal cases. None of the infants in the sample had both BPD and NEC. Social and physical environmental factors were not significant.

Motor Status Outcomes

SGA preterm status, parent perception of adolescent health (POAH), and parent current psychological distress (BSI) was the best logistic regression model for differentiating between normal and abnormal motor outcomes at age 12, classifying 28% of the abnormal motor status cases. Infants that were born SGA preterm were four times more likely to have an abnormal motor status at age 12 than those born full-term or preterm and appropriate-for-gestational-age. POAH alone accounted for classifying 12% of the abnormal motor outcome cases while BSI alone classified 7.7%.

Overall Health Status Outcomes

The logistic regression model for predicting overall health status showed that a child being classified at birth in the neuropreterm group was 3.4 times more likely to have an abnormal overall health status at age 12, classifying 31.5% of the abnormal cases. On the other hand, a child diagnosed with BPD was 4.5 times more likely to have an abnormal overall health status at age 12 compared with those infants who never developed BPD, classifying 27.8% of the abnormal cases. In another finding, the neonatal diagnosis of IVH placed a child at 1.5 times as likely to have an abnormal overall health status at age 12 compared to a child who was not diagnosed with IVH, classifying 13% of the abnormal overall health status cases.

In a second stage of logistic regression, BPD, IVH, and POAH were entered in pairs to ascertain the combined effect on overall health status at age 12 outcomes. Only one combined model adequately differentiated between normal and abnormal outcomes. BPD and parent perception of adolescent health together classified 34% of the abnormal cases and in this combined model.

Discussion

Preterm infants are at risk for increased health problems, but the long-term effects of prematurity and perinatal morbidity have been untested. This study examined the effects of prematurity, birthweight, and perinatal morbidity on health status across four preterm groups and a full term comparison group followed longitudinally to age 12. Using the Institute of Medicine's (IOM's) conceptual framework of children's health as a guide, this study examined the influences of biological, social, and physical environments on age 12 health.

Biological Factors on Health Outcomes

One of the more powerful findings in this study is the influence of the diagnosis of bronchopulmonary dysplasia on neurological and overall health status at age 12. BPD was defined in this study as oxygen requirement at 28 days of life (Avery, Tooley, & Keller, 1987). Although there are different definitions of BPD, this definition was the predominant one in use when these adolescents were infants. In a regional cohort comparison study of premature infants < 32 weeks gestation, rates of BPD increased from 6 to 19% between 1983 and 1996–1997 (Stoelhorst et al., 2005). Smith and colleagues (2005) reported that the rates of BPD have not declined in the post-surfactant era but severe BPD has. Variations in the definitions of BPD make it difficult to compare actual BPD rates and their long-term effects.

In predicting motor outcome at age 3, Singer, Yamashita, Lilien, Collin, and Baley (1997) found that with very low birthweight (VLBW) infants, BPD predicts poorer motor outcome even after controlling for other risks (such as neurological risk and SES). Cohorts of infants with BPD also had higher rates of mental retardation. Lower IQ at age 8 was also found in children diagnosed with BPD as infants (Robertson, Etches, Goldson, & Kyle, 1992). Lewis, et al. (2002) compared VLBW and term children and found that the BPD group demonstrated significant deficits at age 8. After controlling for birthweight and neurological problems, BPD and/or duration on oxygen predicted lower performance IQ, perceptual organization, full-scale IQ, motor and attentional skills, and increased special education placement. In addition, the BPD group demonstrated reduced oral articulation and receptive language skills. The pathophysiology that leads infants with BPD to having greater developmental delay is probably multifactorial and may include chronic, intermittent hypoxia in the neonatal period, and altered environmental stimulation. In our sample, only 4.6% of the children had a lower IQ consistent with mental retardation (IQ <70) at age 8.

Necrotizing enterocolitis, a disorder primarily seen in preterm infants, increased the risk for abnormal neurological status at age 12. NEC is associated with inflammatory processes

accompanied by hypoxia and ischemia that may affect the neurodevelopmental outcomes of infants (Hintz et al., 2005; Rees, Pierro, & Eaton, 2007, September 19, 2006; Soraisham, Amin, Al-Hindi, Singhal, & Sauve, 2006). Mortality rates due to necrotizing enterocolitis have decreased in the past two decades (Holman, Stoll, & Glass, 1997), however the rates of NEC are increasing possibly due to infants surviving at increasingly lower weights.

Even though BPD had the largest effect on overall health status, IVH cannot be overlooked. Preterm infants are at risk for intraventricular hemorrhage; that is, hemorrhage into the germinal matrix tissues of the developing brain (Vohr & Ment, 1996). Despite the increase in preterm birth and the increase in survival of very-low-birthweight and extremely-low-birthweight infants, the incidence of IVH is decreasing. However, according to Sheth (1998), despite the dramatic declines in IVH rates, in 1995 there were significant numbers of infants who are affected, with 12% of infants with birth weights <1500gms and 21% of infants with birth weights <1000gms.

Biological and Social Factors on Health Outcomes

SGA preterm status, parent's perception of adolescent health (POAH), and the parent's current psychological distress (BSI) had an effect on motor outcomes at age 12. Approximately one-half of the SGA preterm infants also had medical and/or neurological morbidity which would suggest later poor motor performance. Perception of child health or child vulnerability has been shown to be associated with poorer developmental outcome in premature infants (Allen et al., 2004; De Ocampo, Macias, Saylor, & Katikaneni, 2003). Parents' psychological distress, such as depression, also has been shown to have an impact on children's health. Mothers who are depressed may not engage in interaction and child activities, which can greatly impact the child.

Prior research with this longitudinal study sample suggests that preschool and school-age outcomes are influenced by complex interactions labeled by the Institute of Medicine as biological, behavioral, social, and physical environments (McGrath & Sullivan, 1999, 2002, 2003). This is supported by these results showing perinatal morbidity, parent perception of child health, and the presence of the parent psychological distress combined to explain motor health of the child. The findings correspond with the developmental science perspective where children develop in a continuous, ongoing, reciprocal relationship with their environment (Holditch-Davis & Black, 2003).

Implications for Nursing Practice

Health is key to optimal development and adolescent functioning. Outcomes of children born prematurely with various perinatal complications are not only costly in terms of health care, but also in terms of human services and educational services. Obtaining comprehensive health histories and assessments of children should include gestational age and neonatal illnesses, especially BPD, IVH, and NEC. This fuller understanding of health to include perinatal factors will inform nurses in planning interventions in school, community, and other health settings.

Social factors have also shown to have an influence on child health, particularly motor status. How the primary caregiver perceives their child's health and how he or she feels psychologically has long term impact on the motor status of the child 12 years after birth. This research provides understanding of family influences which can inform interventions to minimize adolescent risk.

Strengths and Limitations

Even with these strong results, this type of longitudinal design cannot control for all variables that may impact the growth and development of children. However, this research was able to

examine the multidimensional factors of biological, social, and physical environmental influences on health outcomes. There is some ambiguity in extant research regarding the exact cut-off values that are acceptable for alpha coefficients. However, it is generally agreed that scales on psychological tests should have internal consistency estimates of about .70 or higher (Nunnally & Bernstein, 1978). Reliability coefficients for Perception of Adolescent Health (POAH) and Paternal Modeling of Health Behaviors scales were in this acceptable range.

Prior research with preterm infants and children have had weaknesses in the lack of prospective longitudinal data, lack of full-term control groups recruited at birth, and a lack of an appreciation of the heterogeneous nature of infant morbidity in the LBW population (Vohr et al., 1989). The strengths of this longitudinal study are adequate sample size and high retention to age 12. The full term group, recruited at birth, allows for a cohort specific comparison and strengthens the study design and findings.

Conclusion

In summary, this study examined the long-term effects of perinatal morbidity and the independent and combined effects of biological, social, and physical environmental factors on health status at age 12. Perinatal morbidity predicted neurological status, motor status, and overall health at age 12. Full-term status reduced the risk of later abnormal health by 90%. Infants diagnosed with bronchopulmonary dysplasia were three and a half times more likely to have an abnormal neurological status at age 12 and four and a half times more likely to have an abnormal overall health status at age 12. Small-for-gestational age preterm status, parental perception of child health, and parental psychological distress affected motor status. While advanced neonatal technology has resulted in the survival of smaller birth weight infants, the incidence of some neonatal illnesses, especially BPD, have remained steady. While this sample was born in the late 1980s and NICU therapies have changed, studies such as this are the only evidence to suggest how the fragile preterm infants who are born today will do as they enter adolescence.

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FIGURE 1. A New Model of Children's Health and Its Influences¹

¹From "Children's health, the Nation's wealth: Assessing and improving child health," by the Committee on Evaluation of Children's Health, & National Research Council, p. 42. Copyright 2004 by The National Academies.

Table 1

Neonatal Characteristics of the Sample

	Full Sample N = 186	FT N = 43	HPT N = 27	MPT N = 52	NPT N = 34	SGA N = 30	Analyses
Birthweight							
M (SD)	1758 (966)	3412 (350)	1481 (219)	1279 (301)	1146 (283)	1162 (374)	$F(4,185) = 396.723, p < .0001^a$
range	640–4130	2720–4130	900–1690	710–1800	660–1670	640–1915	
Gest. Age							
M (SD)	32.3 (4.81)	39.9 (.78)	31.3 (1.68)	29.4 (2.24)	28.2 (2.26)	32.1 (2.81)	$F(4,185) = 211.555, p < .0001^b$
Range	24–43	38–43	28–34	25–33	24–33	26–36	
Hobel Risk							
M (SD)	66.8 (45.81)	1.40 (3.51)	57.4 (22.3)	88.8 (25.3)	114.3 (20.9)	77.4 (34.3)	$F(4,185) = 139.440, p < .0001^c$
range	0–160	0–15	20–110	30–129	48–160	8–136	
Days Hosp.							
M (SD)	42.3 (35.5)	3.02 (.41)	31.8 (9.9)	52.0 (23.7)	69.5 (23.1)	59.2 (51.2)	$F(4,185) = 39.175, p < .0001^d$
range	2–274	2–5	17–60	17–103	23–130	9–274	

FT = Full term, HPT = Healthy preterm; MPT = Medical preterm; NPT = Neuropreterm; SGA = Small-for-gestational age; IVH = intraventricular hemorrhage; BPD = bronchopulmonary dysplasia; NEC = necrotizing enterocolitis;

^aDuncan Post-hoc tests: FT>HPT> MPT, SGA, NPT, $p < .0001$;

^bFT>SGA, HPT> MPT>NPT, $p < .0001$;

^cNPT> MPT>SGA >HPT>FT, $p < .0001$;

^dNPT>MPT> HPT>FT; SGA> HPT > FT, $p < .0001$;

Instrument Psychometrics

Table 2

Assessment		N	Range Poss	Range Obs	Reference Mean	Study Mean	Reference SD	Study SD	Reference Alpha	Study Alpha
Biological Factors	Please see Table 1									
	PCRI (t scores)	166	n/a	n/a	n/a	n/a	n/a	n/a	n/a	.91
	Parental support	166	19–78	27–78	n/a	55.30	n/a	9.40	.70	.74
	Parental satisfaction	166	18–66	24–66	n/a	53.17	n/a	9.36	.85	.87
	Parental involvement	166	18–72	23–72	n/a	51.32	n/a	10.68	.76	.85
	Parental communication	166	18–68	25–68	n/a	47.65	n/a	9.22	.82	.77
	Parental limit	166	22–80	36–77	n/a	55.92	n/a	9.28	.88	.80
	Parental autonomy	166	18–77	37–72	n/a	50.67	n/a	8.06	.80	.59
	Parental gender role	166	18–77	29–73	n/a	53.43	n/a	10.08	.75	.78
	EA-HOME	178	0–60	4–60	43.66	47.96	9.46	9.55	.90	.91
Social Factors	Physical environment	179	0–7	0–7	n/a	6.25	n/a	1.42	n/a	.70
	Learning materials	178	0–10	0–10	n/a	7.61	n/a	2.35	n/a	.75
	Modeling	178	0–10	0–10	n/a	6.85	n/a	2.20	n/a	.65
	Instruction activities	178	0–6	0–6	n/a	4.84	n/a	1.25	n/a	.48
	Regulatory activities	178	0–10	0–10	n/a	8.84	n/a	1.56	n/a	.57
	Variety of experience	178	0–8	0–8	n/a	5.79	n/a	1.99	n/a	.69
	Accept and responsiveness	178	0–9	0–9	n/a	7.77	n/a	2.18	.76	.86
	Family Connectedness	172	13–65	17–35	n/a	31.64	n/a	3.65	.83	.90
	Perception Adol Health	173	14–70	17–57	n/a	30.46	n/a	6.29	n/a	.64
	Brief Symptom Inventory	172	0–212	0–114	Raw score	15.66	Raw score	15.77	.83	.94
Physical Environment Factors	Paternal modeling of health	165	4–12	4–12	n/a	9.30	n/a	1.89	.80	.61
	Friends' modeling of health	166	4–12	4–12	n/a	8.32	n/a	2.22	.63	.75
	Socioeconomic status									
	Adolescent Health History	185	1–2	1–2	n/a	n/a	n/a	n/a	n/a	.60
	Physical Exam	180	1–3	1–3	n/a	n/a	n/a	n/a	n/a	.90
	Bruininks-Osteretsky	171	23–78	23–75	50	44.09	10	13.12	.83	.75
	CBCL Total Problems t score	173	0–100	23–83	n/a	50.02	n/a	11.50	.95	.92

n/a = non-applicable or not available

Table 3

Child Health Factors: Medical, Neurological, Motor, Psychological, and Overall Health Status at Age 12

	<i>df</i>	n	χ^2 or <i>F</i>	<i>p</i>
Medical Status	4	179	5.088	.278
Neurological Status	4	179	15.748	.003 ^a
Motor Status	4	170	3.893	.005 ^b
Psychological Status	4	173	5.793	.215
Overall Health Status	4	180	12.368	.015 ^a

^aFT > HPT, MPT, NPT, SGA^bFT > MPT, NPT, SGA

Table 4
Predicting Neurological, Motor, and Overall Health Status at Age 12 from Perinatal Health Characteristics

Variable	<i>B</i> (<i>SE</i>)	<i>exp b</i> (<i>odds ratio</i>)	95% CI for <i>exp b</i>	
			Lower	Upper
Neurological Status (0 = normal, 1 = suspect/abnormal)				
Constant	−1.368 (.212)	.255		
BPD (0 = no, 1 = yes)	1.448 (.453)	4.256**	1.752	10.338
NEC (0 = no, 1 = yes)	1.368 (.543)	3.929*	1.355	11.387
Motor Status (0 = normal, 1 = suspect/abnormal)				
Constant	−5.560 (1.226)	.004		
SGA (0 = not SGA, 1 = SGA)	1.404 (.535)	4.072*	1.428	11.614
POAH (raw score, continuous variable)	.093 (.037)	1.097**	1.021	1.179
BSI (raw score, continuous variable)	.032 (.014)	1.032	1.003	1.062
Overall Health Status (0 = normal, 1 = suspect/abnormal)				
Constant	−4.723 (1.016)	.009		
BPD (0 = no, 1 = yes)	1.301 (.479)	3.671**	1.435	9.392
POAH (raw score, continuous variable)	.116 (.031)	1.123±	1.056	1.194

Note The odds ratios reflect one-unit change in the independent variable

* $p < .05$.

** $p < .01$.

[±] $p < .001$.

BPD = bronchopulmonary dysplasia; NEC = necrotizing enterocolitis; SGA = Small-for-gestational age; BSI = Brief Symptom Inventory; POAH = Perception of Adolescent Health.