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17-Year Outcome of Preterm Infants with Diverse Neonatal Morbidities: Part 1, Impact on Physical, Neurological, and Psychological Health Status

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Abstract

Purpose—The purpose of this study was to comprehensively examine physical, neurological, and psychological health in a U.S. sample of 180 infants at age 17.

Design & Methods—The World Health Organization International Classification of Functioning, Disability and Health model framed the health-related domains and contextual factors. Assessments included growth, chronic conditions, neurological status, and psychological health.

Results—Physical health, growth, and neurological outcomes were poorer in the preterm groups. Minor neurological impairment was related to integrative function. Preterm survivors reported higher rates of depression, anxiety, and inattention/hyperactivity.

Practice Implications—Complex health challenges confront preterm survivors at late adolescence suggesting the necessity of continued health surveillance.

Search Terms

Prematurity; adolescence; outcomes of high-risk infant birth; ICF model

Despite a recent slight decline, 12.3% of U.S. births are premature. Today one in eight babies, or more than 500,000 per year, are premature and there is increasing recognition of long-term health, developmental, behavioral, and vocational consequences (Behrman & Stith Butler, 2006; Martin, Osterman, & Sutton, 2010). Neonatal medical problems such as bronchopulmonary dysplasia (BPD) and necrotizing enterocolitis (NEC) have resulted in additional medical interventions as well as increased use of complex multidisciplinary post-discharge care resources (Hack & Fanaroff, 1999). Clinicians and researchers have been

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urged to broaden the evaluation of long-term outcomes of prematurity in order to fully reveal the range of sequelae (Hack, 1999; McCormick, 1997; Saigal, 2000). To date, there are no reports in U.S. cohorts of longitudinal research to late adolescence of formerly preterm infants with diverse perinatal-neonatal morbidities. In an Institute of Medicine report, long-term outcome studies were recommended into young adulthood for preterm infants to determine the extent of recovery, if any, and to monitor them for the onset of adult disorders (Behrman & Stith Butler, 2006).

Late adolescence is a time when increasing developmental expectations add a level of complexity for those who were born prematurely. In addition, this time of development is critical because adolescent health is an indicator of later adult health and social success (Jessor, Van Den Bos, Vanderryn, Costa, & Turbin, 1995). There is evidence that health may change over time such that some preterm infants may stabilize medically as toddlers while other infants experience an uneven course with periods of medical, neurological and psychological health problems through school-age and early adolescence (McGrath, Sullivan, Lester & Oh, 2000; Doyle & Casalaz, 2001). Sequelae for school-age children born prematurely include physical and/or coordination difficulties, learning/academic problems, and delays in social skills during childhood (Allin et al., 2006a; Foulder-Hughes & Cooke, 2003; Hack et al., 2005). Thus, ongoing surveillance of prematurely born infants into adolescence is important. The complete evaluation of health outcomes at late adolescence requires consideration beyond the neonatal factors of birth weight and neonatal morbidity to consider contextual factors known to influence health (Saigal & Rosenbaum 2007; Msall, Sullivan, & Park, 2010).

The first aim of Part 1 of our study was to comprehensively examine physical, neurological, and psychological health at age 17 in a sample of preterm infants grouped by diverse neonatal morbidity and a full-term infant comparison group. Second, we aimed to analyze the role of the contextual factors of socioeconomic status (SES) and gender on these outcomes. In Part 2, we will examine the functional outcomes of activities and participation in this same sample and analyze the role of contextual factors of SES, gender, and educational supports on these outcomes. The World Health Organization (WHO) International Classification of Functioning Disability and Health Model (ICF model) is the theoretical framework (World Health Organization [WHO], 2001). The ICF model incorporates multiple determinants of health and functional outcomes of survivors of prematurity (Msall & Park, 2008).

Theoretical Framework: The ICF Model

The ICF model (WHO, 2001) is a scientific basis for understanding and studying health outcomes and their determinants with application to research, clinical practice, social policy, and education. The ICF model was designed to provide a “unified and standard language and framework for physical, developmental, and psychological health as it impacts on body structure, body functioning, activities, and social participation” (WHO, 2001). It broadly conceptualizes health and illness classification descriptions to be interpretable both across healthcare disciplines and throughout the world.

In the ICF model, outcomes of Functioning and Disability include Body Functions, Body Structures, Activities and Participation, as well as Contextual Factors (see Figure 1). Body Functions are physiological and psychological functions of body systems. Body Structures are anatomical components of body systems. Activities are the execution of tasks or actions. Participation is involvement in social roles. Contextual Factors consist of environmental and personal factors. Environmental Factors include the external physical world that forms the

context of a person's life such as social structures. Personal Factors include attributes of the person such as gender.

Prematurity and Later Health

A review of clinical research studies of preterm infants to school-age and early adolescence reveals continued health problems, with the preponderance of the research focused on those born with very low birth weight (VLBW; 1,000 & < 1,500 grams) and extremely low birth weight (ELBW; < 1,000 grams). In a U.S. cohort at school-age, high rates of chronic conditions were found in children with birth weights less than 1,000 grams when compared to a normal birth weight group (Hack et al., 2005). Sixty-four percent of the formerly preterm children had functional limitations, 14% had cerebral palsy, 10% had vision problems, and 47% had poor motor skills (Hack et al., 2005). In Sweden, 45% of 11-year-old children with birth weights less than 1,000 grams had at least one medical or psychiatric condition compared to 22% of the normal control group (Farooqi, Hagglof, Sedin, Gothefors, & Serenius, 2006). In Norway, VLBW girls reported more behavioral and emotional problems at adolescence than boys, and both boys and girls reported lower behavioral problem scores than the normative group (Dahl et al., 2006). In Israel, more anxiety, depression, and aggression were reported for formerly preterm infants at early adolescence compared to a full-term comparison (Levy-Shiff et al., 1994). Thus, there is worldwide evidence that effects of prematurity extend into early adolescence.

Long-term effects of neonatal morbidities have not been consistently examined in studies of prematurity outcomes since most researchers use the variables of birth weight or gestational age as primary predictors. However, there is evidence that neonatal morbidities affect health beyond infancy and toddlerhood. For example, bronchopulmonary dysplasia (BPD), which continues to be a leading cause of neonatal illness, has been shown to have a continued effect on cognitive, motor, and language outcomes from toddlerhood to age 8 with more severe BPD associated with poorer outcomes (Short et al., 2007; Singer, Yamashita, Lilien, Collin, & Baley, 1997). In these two studies, BPD had an independent effect after accounting for other neonatal morbidities. In another cohort, infants with birth weight less than 1,500 grams had poorer neurological exams at ages 4 and 15 than a control group, boys did poorer than girls, and a significant neonatal predictor at age 4 was use of mechanical ventilation while intraventricular hemorrhage (IVH) was the major predictor at age 15 (Gäddlin, Finström, Wang, & Leijon, 2008). Farooqi and colleagues (2006) found that small for gestational age (SGA) status and gender predicted internalizing and externalizing behaviors and social competence outcomes at age 11. With the exception of two studies that used a neonatal risk index in estimating long-term outcomes, most studies used a single predictor such as birth weight in the analysis (Taylor, Klein, Schatschneider, & Hack, 1998; Taylor, Klein, Drotar, Schluchter, & Hack, 2006). However, preterm infants in addition to having low birth weight often experience neonatal illness during a long Neonatal Intensive Care Unit (NICU) stay. Clearly, further examination of long-term effects of neonatal morbidity is warranted.

Social and economic disadvantage has long been known to affect infants and children. Since socially disadvantaged women are more likely to deliver a premature infant, there is a double risk of prematurity and socioeconomic challenges. In the Dutch longitudinal study of 1,338 infants with birth weight less than 1,500 grams, 5-year-old children from low SES backgrounds were 5 times more likely to require special education services than those from higher SES (Hille et al., 1994). And at age 19, impairments in neurosensory and cognitive functioning were greater for those teens whose parents had a lower education level (Hille et al., 2007). Given the evidence that social and environmental factors may moderate health trajectories, it is critical to include their measurement in long-term study (Msall et al., 2010).

Boys born prematurely have higher risk for neonatal death and neonatal morbidity. In the National Institute of Child Health and Development Network study of more than 7,000 preterm infants, males were less likely to survive, more likely to need intubation, and had higher rates of BPD and IVH (Stevenson et al., 2000). Similarly, in a Swedish cohort of 250 preterm infants less than 29 weeks gestation, males required more mechanical ventilation, more inotropic support with dopamine, and had higher rates of chronic lung disease (Elsmen, Hansen Pupp, & Hellstrom-Westas, 2004). Gender effects appear to continue into school age with ELBW infants, where males have lower cognition scores than girls at 6 years (Marlow, Wolke, Bracewell, & Samara, 2005). In another study, the negative effect of male gender persisted for VLBW infants even when neonatal morbidities were statistically controlled in cognition and reading scores at school age (Vohr et al., 2003). Gäddlin and colleagues (2008) reported poorer neurological and developmental scores for boys at age 15 compared to girls born with VLBW. Medical, psychological, and educational services are needed into early adolescence for teens born prematurely and their families. Thus, long-term effects of prematurity become both a public health and economic issue (Farooqi et al., 2006; Hack et al., 2005).

In summary, there are limited long-term studies into late adolescence in U.S. samples. Reports of VLBW and ELBW infant samples indicate physical, neurological, and psychological health sequelae, especially for males. Neonatal morbidity and contextual factors are variably incorporated in estimating outcomes. In this study, we use the ICF model to organize health outcomes as body functions and structures (Part 1) and activities and participation (Part 2) and include contextual factors of SES and gender.

Methods

Design

This was a prospective, longitudinal study of a northeastern U.S. sample of 213 infants born from 1985–89 with preterm birth weights less than 1,850 grams grouped by neonatal morbidity with a full-term comparison group. In Part I, we report on health outcomes of this sample using the birth and age 17-years time points.

Sample and Participant Selection

The a priori sample criteria for preterm infant recruitment were neonatal diagnoses and birth weight less than 1,850 grams (the only exclusion being those critically ill and not likely to survive and those with major congenital anomalies). There were four neonatal preterm groups: healthy preterm infants (HPT) without medical or neurological illness; medical preterm infants (MPT) with clinical illness such as BPD (defined as oxygen requirement at 28 days of life), NEC (Bell's criteria; Bell et al., 1978), or sepsis (high clinical suspicion with administration of antepartum antibiotics, plus all culture-positive episodes) but without neurological abnormality; neurological preterm infants (NPT) with severe neurological illness such as IVH grade III/IV (classified according to the highest Papile grade; Papile, Burstein, Burstein, & Koffler, 1978), seizures, or meningitis; and SGA preterm infants, defined as birth weight less than the 10th percentile of expected weight for gestational age (Lubchenco, Hansman, & Boyd, 1966) with or without medical problems. A neonatal group of full-term infants (FT) was recruited in the same timeframe and at the same regional center as the preterm infants. Criteria for full-term infant recruitment were absence of neonatal health issues (no medical or neurological problems) and gestational age of 37 weeks or more. The maternal criteria for infant recruitment were absence of maternal mental illness or intellectual disability, maternal age of 16 years or older, and English as a primary language. Fewer than 10% of parents who were approached to participate in the study declined. Socioeconomic status (Hollingshead, 1975) was calculated and stratified so that there were

equivalent levels of SES strata across the five neonatal groups. The sample represented 8% of the hospital's NICU population during the years of recruitment and reflected the demographic profile and range of neonatal morbidity of the regional tertiary neonatal center. At each time point, the studies were approved by hospital and university institutional review boards. Adolescent subjects and their parent(s) were fully informed. Adolescents signed assent if they were 17 years old or younger. Parents and adolescents 18 years or older signed consent.

Neonatal Measures—The neonatal medical record was the source for birth and neonatal data. Data included length of stay, neonatal diagnoses and treatment, and calculation of the Hobel Risk score (Hobel, Hyvarien, Okada, & Oh, 1973). The Hobel, the preferred high risk screening measure of the time, was designed to assess the importance of perinatal factors on the neonate. There are 51 prenatal items, 40 intrapartum items, and 46 neonatal items, each weighted according to assumed risk. Items are totaled to yield three subscores and a total risk score. Construct and predictive validity were established in a series of studies (Hobel et al., 1973; Hobel, Youkeles, & Forsythe, 1979). Hobel Neonatal Risk scores were calculated by a neonatal clinical nurse specialist at the time of infant discharge. Clinical questions were brought to the two consulting neonatologists, one of whom authored the scale.

Body Function and Structure – Age 17 Years

Health status: The health status was determined by a physical examination of the adolescent preceded by a health history interview with the parent(s). The exam included height, weight, head circumference, body mass index (BMI), 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 adolescent self-assessment using the Pubertal Development Scale (Peterson, Crockett, & Richards, 1988). General health status data were classified as normal (no physical abnormalities), suspect (e.g., recurrent sinusitis/bronchitis, cardiac auscultation abnormalities, concerns about vision and hearing, mild scoliosis), or abnormal (e.g., asthma, obesity, and/or seizure disorder).

Chronic conditions: Persistent conditions requiring ongoing care for more than 6 months were defined as chronic conditions and classified by body systems. Chronic conditions were identified via health history interview items of illnesses, medication use, and a comprehensive review of systems. The parent-reported health history was verified with medical records obtained with consent from the adolescent's primary care provider. All adolescent data were classified as normal (healthy; no chronic conditions), suspect (current conditions that may need monitoring, suspected chronic conditions, or managed conditions not interfering with daily activities), or abnormal (diagnosed chronic conditions). These data were classified in keeping with the Niswander and Gordon (1972) and Prechtl and Beitema (1967) guidelines and were expanded with the assistance from a senior developmental pediatrician who consulted on the project.

Neurological status: The Quick Neurological Screening Test, Second Edition (QNST-II) (Mutti, Sterling, Martin, & Spalding, 1998) was used to detect neurological soft signs and to assess areas of neurological integration as they relate to learning. Neurological soft signs are a common term in health assessment to indicate minor neurological results associated with non-specific cerebral dysfunction. The QNST-II scoring yields three groups: neurologically normal, moderate discrepancy (one or more symptoms having either developmental or neurological etiology), and severe discrepancy (combination of symptoms). There are 15 subtests: hand skill, figure recognition and production, palm form recognition, eye tracking, sound patterns, finger-to-nose, thumb and finger circle, double simultaneous stimulation of hand and cheek, rapidly reversing repetitive hand movements, arm and leg extension,

tandem walk, standing on one leg, skipping, left-right discrimination, and behavioral irregularities. Test-retest reliability at a 1-month interval yielded a coefficient of .81 (Yamahara, 1972). Interrater reliability, also at a 1-month interval, had a coefficient of .71 (Geisler, 1976). Construct, content, criterion-related, and concurrent validity were supported (Mutti et al., 1998).

Psychological health: The Youth Self-Report (YSR) of the Achenbach System of Empirically Based Assessment (ASEBA) was used to assess problem behaviors, internalizing and externalizing behaviors as reported by the adolescent (Achenbach & Rescorla, 2001). A T score greater than 65 indicates an at-risk psychological status. The national normative sample was diverse and demonstrated excellent reliability and validity for the YSR (Achenbach & Rescorla, 2001). Reliability coefficients of .95 on behavior problems and .99 on social competence have been reported. Test-retest reliability is demonstrated by a strong positive relationship with a mean of .90. Content, criterion-related, and construct validity have been supported in multiple ways (Achenbach & Rescorla, 2001).

Contextual Factors

Environment - Socioeconomic status: The Hollingshead Four Factor Index of Social Status includes both parents' education attainment as well as current occupational status (Hollingshead, 1975). The four factors are maternal education, maternal occupation, paternal education, and paternal occupation. The Hollingshead Four Factor score is regarded as a highly reliable measure of social position. The social status scores are a valid measure of socioeconomic status differentiation. Strong criterion validity has been reported between the Hollingshead Four Factor score and other known measures of socioeconomic status (Gottfried, 1985).

Personal – Neonatal morbidity & gender: The 5-group research design was the indicator of neonatal morbidity as described in the inclusion/exclusion criteria. Gender (male/female) was identified at birth.

Procedure

At infancy recruitment, data from the NICU hospitalization were collected from medical records, and the Hobel Neonatal Risk and Hollingshead Four Factor scores were calculated. At age 17, the adolescents and their parents were seen in the hospital research laboratory as part of a research protocol. In the research laboratory, the health history interview was conducted privately with the parent(s) while physical assessment and standardized testing (QNST-II, YSR) with the adolescent were completed by MS- or PhD-prepared nurses. Adolescent health information was verified with the medical record obtained from the primary healthcare provider. The Hollingshead Four Factor score was again calculated. Nurses and research assistants were trained on the protocols and standardized testing to attain greater than 90% agreement with the project director and principal investigator. The inter-rater reliability among study staff for all protocols and standardized testing was maintained at or above 90% agreement throughout the study.

Analyses

Descriptive statistics and frequency distributions of all variables were initially reviewed to assure that statistical assumptions were met before analyses were conducted. Univariate and multivariate statistics were used to address the study aims of the effects of neonatal morbidity (5 neonatal groups) and contextual factors (SES, gender) on health outcomes. Chi-Square was used to examine the association of neonatal group, SES and gender with categorical variables of health status, chronic conditions, and neurological status at age 17.

Multivariate ANOVA models were used to test the effects of neonatal group, SES, gender, and their interactions on age 17 psychological health outcomes. Significant multivariate models were followed with univariate analysis. Duncan's Multiple Range Test was used post hoc to test pairwise differences. Overall power was more than sufficient for the models using Chi-square ($\beta = .99$) with $\alpha = 0.05$. For the model testing psychological health, power was also sufficient ($\beta = .90$ – 1.0) with $\alpha = 0.05$. Only the power for gender was slightly lower ($\beta = .70$).

Results

At age 17 years ($M=17.1$, $SD = .4$, range 16.3–18.8), 180 adolescents completed assessments. This represented a sample retention rate of 85% from birth. There were no differences between the infancy and adolescent sample in neonatal illness, SES, race, birth weight, gestational age, Hobel Neonatal Risk score, and length of NICU stay. Only gender differed between the two time points as more male ($n = 25$) than female ($n = 8$) adolescents dropped at age 17 [$\chi^2(1, 213) = 9.8$, $p = .002$; Table 1].

Eighteen adolescents (13%) who were born preterm had severe impairments that precluded complete participation in the assessments. Eleven had cerebral palsy (3 MPT, 5 NPT, 3 SGA), one MPT male was blind, and one NPT male was deaf. Five developmentally challenged adolescents who were preterm were unable to complete the QNST-II and YSR (1 MPT, 3 NPT, 1 SGA). Three adolescents chose to complete questionnaires and the parental interview only.

Body Function & Structure

Health status & chronic conditions—Neonatal morbidity and gender were associated with health status at age 17 [$\chi^2(1, 8) = 15.8$, $p = .04$]; SES was not. As shown in Table 2, 98% of the FT group had normal or suspect health status, while the preterm groups had more suspect and abnormal health status. This effect was significant for males born preterm ($t = 2.24$, $p = .02$) but not for females.

Neonatal morbidity, gender, and SES were not associated with chronic conditions at age 17. The NPT and SGA groups who had the most perinatal morbidity had the highest levels of chronic illnesses with 49% and 55% respectively reporting suspect or confirmed conditions (Table 2). At age 17, chronic health conditions in the FT group included vision requiring correction (38%); special healthcare needs such as occupational therapy, physical therapy, speech therapy, and/or orthopedic devices (10%); and respiratory problems requiring a healthcare visit (25%). For the HPT group the most frequent health conditions were vision requiring correction (54%), allergies (45%), and special healthcare needs (17%). There was a similar distribution in the MPT group in vision problems (50%) and special healthcare needs (14%). The majority of the MPT group had BPD as infants, and 20% reported respiratory conditions at age 17. As expected, the NPT group had large percentages of adolescents with neurological conditions (50%) and was comparable to the other preterm groups in vision problems (45%). The SGA group had the highest occurrence in vision problems (64%) and allergies (55%) compared to the other groups. Asthma diagnosis was variable among groups though not statistically different (FT 23%; HPT 13%; MPT 23%; NPT 17%; SGA 27%). Allergy (medicine, environmental, food) diagnoses were also variable with a range across groups of 41–55%.

Somatic growth—Height and weight were found to differ at age 17 due to neonatal morbidity but not gender (Table 3). SGA preterm females and males were significantly smaller than those in the other groups [height: $F(4, 176) = 3.64$, $p = .007$; weight: $F(4, 177) = 2.44$, $p = .04$]. BMI did not differ across groups. Almost 1 in 3 adolescents born at term

were obese (Centers for Disease Control definition of BMI for age percentile) compared to 1 in 6 among adolescents who were preterm. Rates of obesity were highest in adolescents born full term (31%) compared with those born preterm ranging from 14–23%. There were no gender- or neonatal-group differences in Tanner's Stages at age 17. Most adolescents reported themselves as Tanner's Stage 5 (females 84%; males 79%).

Neurological health—There were no associations between the three Quick Neurological Screening Test (QNST-II) categories of normal, moderate discrepancy, and severe discrepancy with neonatal group, gender, or SES. In the QNST-II subtests, neonatal group was related to three of 15 tests at age 17: figure recognition and production [$\chi^2(1, 8) = 19.9, p = .01$], arm and leg extension [$\chi^2(1, 8) = 18.1, p = .02$], and tandem walk [$\chi^2(1, 8) = 16.5, p = .03$]. Forty-seven percent of the MPT group was categorized as having moderate discrepancy in figure recognition and production, while 49% were categorized that way in arm and leg extension. The HPT group was categorized with moderate or severe discrepancy in arm and leg extension (40%) and tandem walk (36%). Fifty-three percent of the NPT group had moderate or severe discrepancy in figure recognition and production, 32% in arm and leg extension, and 39% in tandem walk. See Table 4.

Psychological health—Using Wilk's criterion, the combined outcomes of problem behaviors, internalizing behavior, and externalizing behavior YSR T scores were not significant for neonatal group [$F(12, 341) = 1.7, p = .06$], gender [$F(3, 129) = 2.1, p = .10$], SES [$F(12, 341) = 1.4, p = .32$] or their interactions. We also examined at-risk clinical T scores across neonatal groups. No adolescent in the NPT group had internalizing, externalizing, or total problems T scores above 65; however, the FT group had 14% and the HPT group had 17% with clinical T scores indicating at-risk psychological status (see Table 4). By health history, the most frequently self-reported psychological health problem was depression (17 confirmed, 14 suspect) followed by anxiety (14 with diagnosis, 17 suspect). Eighteen teens had a confirmed diagnosis of ADHD (3 FT, 4 HPT, 7 MPT, 1 NPT, 3 SGA). Though rates of depression, anxiety, and ADHD were higher for those in the preterm groups with neonatal morbidity and may be clinically significant, they were not statistically significant.

Discussion

There is growing recognition that outcomes of prematurity are not singularly determined by birth weight or gestational age. Rather, multiple interacting components of health and context best capture the complex pathways of development. The ICF framework is one model whereby multiple indicators of physical, neurological, and psychological health frame outcomes in terms of body structure and body function. Context, defined as environment and personal factors, also impact health. The ICF model provides a meaningful, interrelated structure encompassing health of all persons that is easily usable by clinicians and researchers. As a clinical tool, it can be used to direct needs assessment, alignment of treatment with condition, and outcome evaluation. In the present study, the ICF model has been used as a research tool to organize the complexity of health outcomes assessed at late adolescence in an at-risk population. Msall and Park (2008) employed the ICF model to frame clinical scenarios of the regulatory, behavioral, and social challenges of children ages 3–5 years who were VLBW and ELBW. They concluded that a better understanding of the complexities of prematurity outcomes can lead clinicians, parents, and communities toward pathways of risk and resiliency. In a long-term view on prematurity outcomes at adolescence and young adulthood, Saigal and Rosenbaum (2007) noted that the ICF model provides a “much richer and more positive framework with which to consider health and outcomes of conditions such as prematurity” (p. 419). The ICF components of body functions and structures and the four sub-components as described for this study illustrate the utility of the

model. Importantly, the ICF components of activities and participation outcomes of prematurity, reported in Part 2, provide a dynamic view into how body functions and structures affect activities and participation in the context of environment and personal factors.

The findings in the present study contrast with those reported for VLBW and ELBW survivors. Our results demonstrate that long-term neonatal morbidity effects are not confined to infants with VLBW or ELBW. Abnormal and suspect health conditions were more frequent in all four preterm groups compared to the full-term group. For the HPT group there was a 26% increase in suspect and abnormal health conditions including acute and chronic illnesses compared to the full-term group. For the groups with neonatal morbidity (MPT, NPT, SGA) the 18–29% increase in suspect and abnormal conditions included more vision problems and special healthcare needs. Similar to our U.S. findings, in the United Kingdom, an ELBW cohort without major neurodevelopmental disabilities were found to have lower physical functioning in late adolescence and into early adulthood compared to a term control group at 19–22 years (Cooke, 2004).

Males had more suspect and abnormal health than females at age 17 years. More males than females were lost to follow-up at age 17. Attrition in longitudinal studies of preterm infants has not been related to neonatal complications, but more likely due to low SES, specifically low maternal education, and those children with developmental delay or disability (Wolke, Söhne, Ohrt, & Riegel, 1995; Hack et al., 2002). Because those who are lost to follow-up are likely to be more vulnerable for non-optimal outcomes, our findings may represent better outcomes than those found in clinical practice. In particular, our findings for males may be better than that found for preterm infants at late adolescence. McCormick and colleagues (2006) acknowledged this issue in a discussion of the mixed results at late adolescence of a large multi-site early intervention trial for VLBW infants. The variation among survivors of prematurity, including attrition from follow-up, raises challenges and complexities in determining the nature of intervention content and approaches.

Despite poorer physical health, the number of chronic conditions did not statistically differ across the neonatal groups, between males and females, or by SES levels. Vision problems requiring correction, special healthcare needs, asthma, and allergies were equally reported across groups. In one U.S. study of VLBW survivors at age 20, one in three were reported to have a chronic health disorder with one in four reporting one chronic condition contrasted to one in six of full-term controls (Hack et al., 2002). For adolescents born ELBW in Ontario, Canada, 27% self-reported chronic health conditions compared to 2% of controls (Saigal et al., 2007). The larger birth weights for our sample may partially explain the reported differences in chronic conditions.

In an earlier report of our sample, the mean height and weight for the SGA group was the lowest of all the preterm groups at each follow-up assessment at 18 months, 30 months, 4 years, 8 years, and 12 years (Sullivan, McGrath, Hawes, & Lester, 2008). This difference appears to have continued to age 17 years. Pubertal development was not affected by prematurity status and did not appear to be a factor in adolescent growth outcomes. Smaller physical growth status has been reported for VLBW preterm infants at adolescence and early adulthood, but it is not clear whether SGA infants were included (Cooke, 2004; Hack et al., 2002).

We have reported that neurological status fluctuates over time for the MPT, NPT, and SGA groups in sequential assessments of this sample at hospital discharge, 18 months, 30 months, 4 years, and 8 years (McGrath et al., 2000). The children with abnormal or suspect neurological status at age 8 had lower cognitive, reading, and math scores than children with

normal neurological status. It appears that this fluctuation in neurological status continues for the males at age 17 as shown by the increase of suspect and abnormal health status, which includes neurological conditions. Doyle and Casalaz (2001) reported that the severity of neurosensory impairments changed between ages 2 and 14 with more children previously found to have normal health later classified as suspect. The rates of neurological abnormality continued to be high for preterm groups as demonstrated in European studies (Foulder-Hughes & Cooke, 2003; Hille et al., 2007). Although these neurological problems can often be described as minor neuromotor dysfunction, they continue to impact physical and psychological health in young adulthood (Aylward, 2003; Vohr et al., 2000).

In a comprehensive neurological examination at age 17–18 of preterm infants less than 33 weeks gestation, Allin and colleagues (2006a) reported worse general neurological status, poorer integrative functions of sensory and motor systems, and confusion during sequencing tasks. These impairments are comparable to our findings using the QNST-II. Discrepancies in figure recognition and production as well as tandem walking are related to cerebellar-vestibular dysfunction (Frank & Levinson, 1973). Assessment of arm and leg extension from the QNST-II allows one to see potential discrepancies in gross- and fine-motor control of the right and left sides of the body (Mutti et al., 1998). Preterm infants are known to have a high incidence of white matter injury. Since the QNST-II tasks are integrative functions and require processing of more than one neural network as well as interhemispheric pathways, we speculate that our finding might be related to thinning of the corpus collosum (Stewart et al., 1999). This neuroabnormality has been seen in neuroimaging studies of formerly preterm infants in mid and late adolescence (Nosarti et al., 2004; Santhouse et al., 2002). More recently, Gäddlin and colleagues (2008) reported more abnormal neurological exams at age 15 for preterm VLBW males without severe neurological disability compared to full-term male controls. In the study, 25% of the VLBW group had abnormal MRI findings, primarily cerebral white matter damage, but this was not uniformly related to neurological status. However, our study outcomes did not include neuroimaging. According to the QNST-II manual, adolescents with the discrepancies that we found have difficulty in reading. Research evidence concurs that even mild neurological dysfunction is associated with poorer academic performance (Allin et al., 2006a).

The NPT group differed from the FT and other preterm groups in their self-report of psychological conditions, but their at-risk T scores were lower indicating no symptoms indicative of clinical concern. Compared to U.S. statistics, we found higher percentages of psychological problems: 11% had ADHD compared to 4.1% (National Institute of Mental Health, 2010), 12.1% were diagnosed with depression compared to 5–8% (Mental Health: A Report of the Surgeon General, 2010), and 9.8% were diagnosed with anxiety disorders compared to 3.1% (Anxiety Disorders Association of America, 2010). There have been variable estimates of the extent of psychological sequelae in formerly preterm infants calling into question whether there is an effect of prematurity (Hille et al., 2001). In the United Kingdom, high rates of self-reported psychological problems, especially for women ages 19–22, were reported, but there were no statistical differences between preterm and full-term groups in depression and anxiety (Cooke, 2004). In Canada, no differences were found in teen self-report of psychopathology between ELBW and full-term groups at ages 12–16 (Saigal, Pinelli, Hoult, Kim, & Boyle, 2003). Preterm studies to adulthood in the United Kingdom and Canada indicate that psychological health bears monitoring. Researchers report that as adults, preterm infants are shy and introverted, which puts them at risk for later psychiatric problems (Allin et al., 2006b; Schmidt, Miskovic, Boyle, & Saigal, 2008).

Parents and teens have been found to differ in their report of the teens' behavior. Parents rated their adolescents who were ELBW higher on ADHD and depression than parents of adolescents in the control group (Saigal et al., 2003). Dahl and colleagues (2006) also

reported discrepancies between scores of parents and teens born with VLBW at age 19 on the CBCL and YSR measures, the same measures we used. Whereas parents reported more social and attention problems and less school competence, the teens reported fewer problems and higher competence than their peers. Girls reported more externalizing problems that were unrecognized by their parents. One interpretation we propose is that the use of teen self-report in the present study allowed for reporting of internal state and symptoms; however, it may be an underestimate of actual diagnosis. Although the teens completed the YSR privately with assurances of confidentiality, it is possible that they were not fully attentive to their behaviors and feelings. Also, it is possible that they were not fully comfortable disclosing the extent of their feelings or behavior. Thus, a possible under-reporting of behaviors by the teens born prematurely may put them at risk resulting in scores that only partially meet diagnostic DSM IV-TR criteria. Alternately, the externalizing and internalizing behaviors that they report are sub-clinical as shown by the group mean YSR scores of the present study. Nonetheless, sub-clinical internalizing and externalizing behaviors can be problematic in the teen's daily life as these behaviors may affect interaction and behavior in daily living and social activities with peers in school, clubs, and sports.

Our sample differs from many that have focused solely on birth weight (e.g., VLBW, ELBW). We have a larger birth weight range and a clear categorization of neonatal morbidity. There has been excellent sample retention from birth to age 17 years. Our sample also had the advantage of SES stratification across the five neonatal groups. As a measure of social and economic resources, the Hollingshead Four Factor Score adequately captured SES and is easy to use for repeated calculation. With high prematurity rates and a new focus on the 75% of preterm infants born between 32 and 37 weeks gestation, our findings may be more applicable to a wider group of NICU survivors (Davidoff et al., 2006; Martin et al., 2010). The infants in the present study were all born in a regional neonatal center where research trials of pulmonary and pharmacological treatments were occurring. Accordingly, the infants may have benefitted from new neonatal technology that later became standard practice. Our study findings may differ from other settings due to variation in NICU practices.

A limitation we noted was difficulty keeping research nurses fully blinded to the teen's full-term/preterm status. Since the health history interview was comprehensive, the neonatal history may have emerged revealing prematurity status. However, the detail was usually insufficient to identify neonatal group membership. Health assessment and interview procedures have inherent weaknesses due to clinical interpretation. We balanced this limitation by rigorous training and reliability checks of the nurses throughout the duration of the study.

Data collection forms were developed from multiple sources including clinical and research evidence on preterm outcomes and with the consulting developmental pediatrician. Health histories were validated with medical records from the adolescents' primary care providers. The QNST-II offered a fine-grained, but easily administered, approach to assess neurological subtleties. As such, it could be incorporated into clinical assessment of children and teens when findings of traditional neurological examination are concerning. The YSR-ASCEBA data collection system has had broad use in preterm follow-up research enabling comparison across studies. It is widely used in diagnostic neuropsychological and special education appraisal and may be the next level of clinical follow-up.

How Might This Information Affect Nursing Practice?

Consistent with the view of nursing and other healthcare professionals, we defined and examined health as a multidimensional concept and an integral component to functioning in many domains of adolescent development. The ICF model offered a frame of four subcomponents of health. Clinicians may find these sub-components to be a helpful way to organize assessment and evaluation of adolescent strengths and challenges. Our findings provide longitudinal evidence from an intact sample of preterm infants across diverse neonatal morbidities surviving intensive care and a healthy, full-term group recruited at the same time as the preterm groups. The effects of prematurity on health at age 17 indicate the need to identify the extent of preterm status and neonatal illness even at late adolescence. This would require nurses and healthcare providers in settings such as primary care, school, and community centers to include questions about prematurity status, neonatal illnesses, length of hospital (NICU) stay after birth, post-discharge course including medical specialty care, and duration of additional therapy (occupational, physical, speech, and language).

Also, we would suggest that careful assessment for subtle/soft/minor neurological signs and suspect conditions is worthwhile as these may fluctuate over time and re-appear affecting academic, social, and health outcomes. Neurological soft signs are minor neurological findings indicating non-specific cerebral dysfunction. They include poor motor coordination, sensory perceptual difficulties, and difficulties in sequencing of complex motor tasks, and they may result from specific or diffuse brain structural abnormalities. Thus, early identification of soft signs may reduce difficulties in other areas of function.

Our use of the ICF model highlights the importance of the adolescents' social-economic environment and gender. While we have used SES as a marker variable, it has a wider connotation including access and provision of health services. Male gender, identified in neonatal studies, is a second marker variable to consider in adolescent health appraisal.

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Study Measures According to Components and Sub-components of the International Classification of Functioning Model

ICF Components	Sub-components	Measures
Body Functions & Structures	health status	Physical assessment, health history
	chronic illnesses	Health history
	neurological status	QNST-II
	psychological health	YSR-ASEBA internalizing, externalizing, total problems T scores
Activities & Participation	cognition & learning	K-BIT vocabulary, matrices, composite standard scores
	decision making	WCST-64 perseverative responses, perseverative errors, and conceptual level response standard scores
	self-care & personal living	SIB-R motor skills, social interaction, personal living, community living, and broad independence standard scores
	involvement with academics	K-TEA reading, math & composite standard scores
	involvement with friends, groups, recreation	YSR-ASEBA activities, social, total competence T scores
Environment	socioeconomic status	Hollingshead Index
	educational supports	School records
Personal	gender	Male or female

Figure 1. Study Measures According to Components and Sub-components of the International Classification of Functioning Model

Note. Information from World Health Organization, 2001. The ICF components are coded by color. The yellow and green shading comprise the Functioning and Disability outcomes, the White section comprises Contextual Factors. Outcomes represented in the yellow shading are reported in Part 1. Outcome and Educational Supports represented in the green shading are reported in Part 2.

QNSTII = Quick Neurological Screening Test II; YSR = ASEBA-Youth Self Report-Achenbach System of Empirically Based Assessment; K-BIT = Kaufman Brief Intelligence Test; WCST-64 = Wisconsin Card Sorting Test; SIB-R = Scales of Independent Behavior-Revised; K-TEA= Kaufman Test of Educational Achievement; Hollingshead Index = Hollingshead Four Factor Index of Social Status

Figure 2a

Figure 2b

Figure 2.

Figure 2a. Neonatal Group Health Status at Age 17

Figure 2b. Neonatal Group Health Status at Age 17

Table 1

Neonatal Characteristics of the Sample at Birth ($N=213$) & Age 17 ($N=180$)

Recruitment Sample at Birth ($N = 213$)						
Birth	FT $n = 53$	HPT $n = 33$	MPT $n = 60$	NPT $n = 36$	SGA $n = 31$	Analyses
% male	53	48	52	67	29	$\chi^2(4,213) = 9.6, p < .05$
Birth weight in grams $M(SD)$	3419.8 (402.3)	1518.3 (216.3)	1268.0 (312.4)	1148.7 (277.6)	1151.3 (371.8)	$F(4,212) = 431.7, p < .0001^a$
Sample at Age 17 Years ($N = 180$)						
Age 17	FT $n = 45$	HPT $n = 26$	MPT $n = 48$	NPT $n = 31$	SGA $n = 30$	
% male	51	38	48	61	27	$\chi^2(4,180) = 8.5, p < .07$
Birth weight in grams $M(SD)$	3392.7 (401.3)	1478.6 (224.6)	1277.1 (320.4)	1139.8 (281.0)	1162.3 (373.0)	$F(4,179) = 347.8, p < .0001^a$
Gest. Age in weeks $M(SD)$	39.80 (.8)	31.3 (1.7)	29.4 (2.3)	28.3 (2.2)	32.2 (2.7)	$F(4,179) = 216.4, p < .0001^b$
Hobel Risk $^* M(SD)$	1.1 (3.2)	56.2 (23.2)	89.4 (26.0)	114.2 (21.9)	77.4 (34.3)	$F(4,179) = 136.4, p < .0001^c$
Length of Stay (days) $M(SD)$	3.0 (.4)	32.6 (9.9)	52.7 (24.8)	69.3 (23.2)	57.8 (50.7)	$F(4,179) = 38.0, p < .0001^d$
SES $^* M(SD)$	38.3 (14.2)	37.7 (16.5)	42.9 (14.4)	43.6 (14.2)	40.9 (14.6)	$F(4,174) = 1.1, p < .357$
IVH (III/IV) $n(\%)$	0	0	0	10(32)	3(10)	$\chi^2(16,180) = 1.01, p < .0001$
BPD $n(\%)$	0	0	11(23)	12(39)	3(10)	$\chi^2(4,180) = 30.02, p < .0001$
NEC $n(\%)$	0	0	8(17)	4(13)	3(10)	$\chi^2(4,180) = 11.77, p = .01$
Sepsis $n(\%)$	0	0	4(8)	8(26)	4(13)	$\chi^2(4,180) = 18.63, p = .001$
Meningitis $n(\%)$	0	0	0	2(6)	1(3)	$\chi^2(4,180) = 6.8, p = .14$

Note. FT = Full term; HPT = Healthy preterm; MPT = Medical preterm; NPT = Neurological preterm; SGA = Small-for-gestational age preterm; IVH = intraventricular hemorrhage; BPD = bronchopulmonary dysplasia; NEC = necrotizing enterocolitis; SES = Socioeconomic Status.

Duncan Post-hoc tests:

^aFT>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, $p < .0001$.

BPD was defined as oxygen requirement at 28 days of life. NEC was classified using Bell's criteria (Bell et al., 1978). Sepsis was defined as high clinical suspicion with administration of antepartum antibiotics, plus all culture-positive episodes. IVH was classified according to the highest Papile grade (Papile, Burstein, Burstein, & Koffler, 1978).

* Hobel Risk Score (Hobel, Hyvarien, Okada, & Oh, 1973); SES (Hollingshead, 1975).

Table 2

Frequency of Health Status and Chronic Conditions at Age 17

	FT n/total (%)	HPT n/total (%)	MPT n/total (%)	NPT n/total (%)	SGA n/total (%)	Analyses
Health status*						
Normal	26/45 (58)	8/25 (32)	14/48 (29)	12/30 (40)	11/29 (38)	$\chi^2(1, 8) = 15.8, p = .04$
Suspect	18/45 (40)	12/25 (48)	25/48 (52)	9/30 (30)	12/29 (41)	
Abnormal	1/45 (2)	5/25 (20)	9/48 (19)	9/30 (30)	6/29 (21)	
Chronic Conditions						
Normal	26/39 (67)	16/24 (67)	30/44 (68)	15/29 (52)	13/29 (45)	$\chi^2(1, 8) = 12.07, p = .14$
Suspect	9/39 (23)	2/24 (8)	9/44 (20)	8/29 (28)	6/29 (21)	
Abnormal	4/39 (10)	6/24 (25)	5/44 (11)	6/29 (21)	10/29 (34)	
Asthma						
Normal	30/39 (77)	20/23 (87)	34/44 (77)	24/29 (83)	21/29 (72)	$\chi^2(1, 8) = 6.98, p = .53$
Suspect	9/39 (23)	2/23 (9)	10/44 (23)	5/29 (17)	7/29 (24)	
Abnormal	0 (0)	1/23 (4)	0 (0)	0 (0)	1/29 (3)	
Allergies						
Normal	19/39 (49)	13/24 (54)	26/44 (59)	15/29 (52)	13/29 (45)	$\chi^2(1, 8) = 10.32, p = .24$
Suspect	19/39 (49)	9/24 (37)	14/44 (32)	13/29 (45)	10/29 (34)	
Abnormal	1/39 (2)	2/24 (8)	4/44 (9)	1/29 (3)	6/29 (21)	
Special Health Care Needs						
Normal	35/39 (90)	20/24 (83)	38/44 (86)	23/29 (79)	25/29 (86)	$\chi^2(1, 8) = 7.60, p = .47$
Suspect	4/39 (10)	3/24 (12)	3/44 (7)	2/29 (7)	1/29 (3)	
Abnormal	0 (0)	1/24 (4)	3/44 (7)	4/29 (14)	3/29 (10)	
Vision						
Normal	24/39 (62)	11/24 (46)	22/44 (50)	16/29 (55)	10/29 (34)	$\chi^2(1, 8) = 8.3, p = .40$
Correction	15/39 (38)	12/24 (50)	18/44 (41)	11/29 (38)	17/29 (59)	
Abnormal	0 (0)	1/24 (4)	4/44 (9)	2/29 (7)	2/29 (7)	

Note. FT = Full term, HPT = Healthy preterm; MPT = Medical preterm; NPT = Neurological preterm; SGA = Small-for-Gestational Age preterm.

Table 3**Growth & Obesity at Age 17**

	FT M(SD)	HPT M(SD)	MPT M(SD)	NPT M(SD)	SGA M(SD)	Analyses
Height percentile	47.46(30.6) ^a	40.89(30.9) ^a	35.88 (28.9) ^a	36.45(33.1) ^a	21.44(22.7) ^b	$F(4, 176) = 3.64, p = .007$
Weight percentile	60.35(32.4) ^a	54.95(31.4) ^a	50.88(32.1) ^{a,b}	49.21(33.4) ^{a,b}	37.23(31.2) ^b	$F(4, 177) = 2.44, p = .04$
BMI	25.04(7.2)	25.62(8.6)	23.86(6.2)	26.09(19.2)	23.22(5.7)	$F(4, 176) = .45, p = .77$
	<i>n</i> /total (%)	<i>n</i> /total (%)	<i>n</i> /total (%)	<i>n</i> /total (%)	<i>n</i> /total (%)	
Boys Obese* (BMI>26)	7/23 (30)	1/10 (10)	4/22 (18)	2/17 (12)	2/8 (25)	$\chi^2(1, 4) = 3.90, p = .41$
Girls Obese* (BMI>26.8)	7/22 (32)	5/15 (33)	4/25 (16)	2/11 (18)	2/22 (9)	$\chi^2(1, 4) = 4.90, p = .29$
Total Obese	14/45 (31)	6/25 (24)	8/47 (17)	4/28 (14)	4/30 (13)	$\chi^2(1, 4) = 2.88, p = .57$

Note. FT = Full term, HPT = Healthy preterm; MPT = Medical preterm; NPT = Neurological preterm; SGA = Small-for-Gestational Age preterm; BMI = body mass index.

Letters in the table indicate a > b.

* CDC definition: BMI > 26 for boys at age 17 and BMI > 26.8 for girls at age 17.

Table 4

Frequency of Neurological and Psychological Health at Age 17

	FT n/total (%)	HPT n/total (%)	MPT n/total (%)	NPT n/total (%)	SGA n/total (%)	Analysis
Neurological						
Figure Recognition⁺						
Normal	36/44 (82)	18/25 (72)	25/47 (53)	13/28 (46)	20/29 (69)	$\chi^2(1, 8) = 19.9; p = .01$
Moderate Discrepancy	8/44 (18)	6/25 (24)	22/47 (47)	13/28 (46)	9/29 (31)	
Severe Discrepancy	0/44 (0)	1/25 (4)	0 (0)	2/28 (7)	0 (0)	
Arm & Leg^{^^}						
Normal	36/44 (82)	15/25 (60)	24/47 (51)	10/28 (68)	19/29 (65)	$\chi^2(1, 8) = 18.1; p = .02$
Moderate Discrepancy	8/44 (18)	9/25 (36)	23/47 (49)	7/28 (25)	10/29 (34)	
Severe Discrepancy	0/44 (0)	1/25 (4)	0 (0)	2/28 (7)	0 (0)	
Tandem Walk[§]						
Normal	37/44 (84)	16/25 (64)	36/47 (77)	17/28 (61)	23/29 (79)	$\chi^2(1, 8) = 16.5; p = .03$
Moderate Discrepancy	6/44 (14)	8/25 (32)	5/47 (11)	6/28 (21)	6/29 (21)	
Severe Discrepancy	1/44 (2)	1/25 (4)	6/47 (13)	5/28 (18)	0 (0)	
Psychological						
Internalizing						
Normal	37/43 (86)	17/23 (74)	44/47 (94)	25/28 (89)	23/30 (77)	$\chi^2(1, 4) = 7.16; p = .12$
At-Risk	6/43 (14)	6/23 (26)	3/47 (6)	3/28 (11)	7/30 (23)	
Externalizing						
Normal	39/43 (91)	21/23 (91)	44/47 (94)	25/28 (89)	30/30 (100)	$\chi^2(1, 4) = 3.32; p = .50$
At-Risk	4/43 (9)	2/23 (9)	3/47 (6)	3/28 (11)	0 (0)	
Total Problems						
Normal	37/43 (86)	19/23 (83)	44/47 (94)	27/28 (96)	28/30 (93)	$\chi^2(1, 4) = 4.67; p = .32$
At-Risk	6/43 (14)	4/23 (17)	3/47 (6)	1/28 (4)	2/30 (7)	

Note. FT = Full term, HPT = Healthy preterm; MPT = Medical preterm; NPT = Neurological preterm; SGA = Small-for-Gestational Age preterm.