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Nutritional considerations in the growth and development of pre-term, low-birth-weight infants

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Nutritional considerations in the growth and development of pre-term, low-birth-weight
infants

by

Tay Seacord Kennedy

A dissertation submitted to the graduate faculty
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

Major: Nutrition

Major Professor: Mary Jane Oakland

Iowa State University

Ames, Iowa

1998

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GENERAL INTRODUCTION

Introduction

Prematurity is a medical problem, that has been resistant to medical intervention (Iams, 1998). In fact, the size of the problem is increasing because of advances in infertility treatment leading to unprecedented increases in multiple births, and improvements in neonatal care with improved survival of low birth weight, premature infants (Cloud, 1997; Ventura, Martin, Curtin & Matthews, 1998). In 1996, the latest year for which government statistics were available, the rate of prematurity, or birth before 36 weeks gestation, was 11.0%. There were 55,000 more pre-term births in 1996 than in 1981, representing a 17% increase. Preterm infants are at high risk for neurodevelopmental disorders and are seven times more likely to die in the first year of life. Since 1984, low birth weight (less than 2500 gm) has increased 10% to 7.4% of all births in 1996. Non-Hispanic blacks are most likely to have low birth weight infants because of their high rate of prematurity; 17.5% of births are preterm compared to 11.0% of births to mothers of all races. Risk of low birth weight also varies with maternal age; women less than 20 and over 40 have the highest rates, 8.5% and 7.8% respectively. As birth rates for teenagers have fallen steadily in the 1990's, the increased rate of low birth weight and prematurity was primarily the result of increased numbers of low birth weight infants born to non-Hispanic white women. Part, but not all, of this increase is attributed to increased numbers of multiple births. Since 1980, the number of twins born in one year has increased 47% and the rate for higher order multiple births has quadrupled (Ventura, et al., 1998).

While prematurity and low birth weight are not always found together, a premature infant is more likely to be low birth weight (Ventura, et al., 1998). There are significant

developmental and behavioral problems associated with low birth weight, particularly as birth weight decreases below 1500 gm. Preterm infants are more likely than term infants to exhibit negative behavior characteristics, such as alterations in temperament and Attention Deficit Disorder (Chapieski & Evankovich, 1997). Msall et al. (1991) found that 25% of infants born between 24 and 26 weeks gestation had severe handicaps. Out of over 9900 graduates of neonatal intensive care units (NICU), 21.8% required special education services in third grade, including 2.5% with severe physical impairment and 6.5% with mental retardation (Resnick et al., 1998). Of infants born at less than 750 gm, 21% had IQs of less than 70 at school age (average IQ is 100), 25% were two standard deviations below the mean in height and 45% required special education services (Hack et al., 1994). As many as 61% of premature infants may have some type of sensory, physical, cognitive or emotional disability, compared to 21% of the general population. In general, the risk of cognitive defects increase as birth weight and socioeconomic status decrease (Batshaw & Perret, 1992).

The goal of nutritional care in low birth weight preterm infants is to approximate the growth rate and development of term infants without inducing additional morbidity secondary to feeding (American Academy of Pediatrics, 1998). Not only do illness and immaturity make providing nutrition to neonates difficult, but these infants have increased, and often poorly understood, nutritional needs (American Academy of Pediatrics, 1998; Anderson & Pittard, 1997). Preterm low birth weight infants, require at least 90-120 calories and 3 to 4 grams of protein per kilogram of body weight per day and increased amounts of calcium, iron and zinc because of incomplete maternal transfer. Vitamin needs are also higher in preterm than in term infants (American Academy of Pediatrics, 1998).

Current recommendations suggest that formula designed for term infants is appropriate for preterm infants after discharge from the hospital, with some provision made for continuing to give preterm formula (designed for use in the hospital) to infants discharged at weights around 1500 gm (American Academy of Pediatrics, 1998).

Despite the attention paid to nutrition in the NICU, there are significant reductions in growth rates of low birth weight infants, with 50% of infants born at less than 1250 grams failing to grow above the 10% weight for age on National Center for Health Statistics (NCHS) growth charts. A cohort of 985 preterm infants from multiple centers across the U.S. was followed until age three. The only period in which a small amount of catch-up growth occurred was in the first four months of life. The low birth weight infants had a peak body mass index that was lower than term infants. The researchers concluded that there was no evidence of catch-up growth in the first three years of life and that the smallest infants at birth were still furthest behind at 3 years of age (Casey, Kraemer, Bernbaum, Yogman & Sells, 1991). Infants with bronchopulmonary dysplasia, have altered growth rates and body composition by one month of age (deRegnier, Guilbert, Mills & Georgieff, 1996). Hack et al (1994) found height to be less than the 5% on NCHS charts in 25% of infants with a birth weight less than 750 gm and 14% of the infants born at 1500 gm or less had low head circumferences.

Higher than expected rates of impaired growth suggest that nutrition may have a role in the neurodevelopmental sequelae seen in low birth weight infants. Some interventions have shown that improved nutrition in the first year of life leads to improved growth and developmental outcomes (Bryson et al, 1997; Lucas et al., 1996; Morley & Lucas, 1994).

Brown and Pollett (1996) attempt to explain the effects of nutrition on child development by incorporating both physical and environmental factors. One area of the model allows for the physiological adjustments made by the organism to cope with poor nutrition. Another area describes the physical environment's effects on child development, including both the effects of poverty and limited educational opportunities. The third area describes alterations in family and child interactions. The behaviors of parents change because they see their child as small and sickly. The child's interactions with the family and the environment decrease because of apathy and lethargy related to malnutrition and illness.

Because there is reason to believe that all preterm low birth weight infants are at some degree of nutritional risk, nutrition is listed as a required discipline in the early intervention education service provided under the Individuals with Disabilities Education Act (Cloud, 1997). Unfortunately, many feeding problems are not addressed in this community setting (Clark, Oakland & Brotherson, in press). The odds ratio for a referral to a nutritionist after the identification of a nutritional problem never rose to even 50%. In a survey of all children referred to a university based developmental clinic over the course of a year, only 5% were identified as NOT having a nutritional problem. (Ekvall, Ekvall & Frazier, 1993) The Nutrition Committee of the Canadian Paediatric Society (1994) states it is unacceptable not to treat undernutrition as evidenced by growth failure in children with neurodevelopmental disabilities. They feel that neurodevelopmental consequences of undernutrition only compound the pre-existing disability. Additionally, they point out that a "well-nourished child is alert while an undernourished child is miserable"(pg. 754). The movement of most children with severe disabilities out of institutions and into the community, with their families or into group homes, makes a systematic approach to

managing nutritional problems even more important. The position of the American Dietetic Association (1995) is that children, at risk for developmental delay and eligible for early intervention services, are also at high risk for nutrition related problems and should be periodically screened and treated for any nutrition problems identified.

Dissertation organization

The current work focuses on the care of NICU graduates in the first year of life. Although some information was collected on the hospital course of the infants, the focus of the research was what happened to the infants and their families after discharge from the hospital. As it is impossible to separate infants from the families who care for them (Pellagrino, 1995), the research was designed to be family centered and to look at the nutritional problems of infants not just from a physiological view, but from a family systems perspective (Brotherson, Oakland, Secrist-Mertz, Litchfield & Larson, 1995).

This research project studied the growth of infants born at less than 1750 grams in the first year of life to discover if a telephone based nutritional intervention could improve rates of growth and to see what questions or concerns families had regarding nutritional care in the first year and their perceptions of the advice they received. After a review of the literature, the balance of the dissertation is presented in three pieces of research in the form of papers that were designed to address these questions. The first is an observational study that examined outcomes from a group of NICU graduates followed by the local children's hospital's developmental clinic. The second is a report of an intervention project designed to provide nutritional information and guidance to families. Finally, the last paper is a qualitative evaluation of family interactions, and perceptions of feeding issues using the model developed by Brotherson et al (1995).

The last chapter is a summary of the findings from the three papers, including recommendations given to the NICU and developmental clinic at the referring hospital. In the process of the reading and reflecting done for this project, a model of development of a nutritional disease in children was designed that differs from the classic model of the development of nutrition related disease in adults outlined by Arroyave (Young & Scrimshaw, 1979). A presentation of the revised model and an explanation of how it encompasses the findings of the current work and a list of references cited in the General Introduction and Review of Literature and General Conclusion conclude the dissertation.

REVIEW OF THE LITERATURE

Growth, development and nutrition

Introduction

That nutrition has something to do with normal development in children seems a given (Batshaw & Perret, 1992). Food deprivation during childhood can affect physical, intellectual and social development (Brown & Pollitt, 1996; Lewit & Kerrebrock, 1997; Peterson & Chen, 1990). While there are many social, economic, physiologic, and even emotional factors that impact normal development in children, one finds no disagreement with Brown and Pollitt's (1996) belief that good nutrition, while not sufficient in and of itself for normal growth and development, is a necessary factor.

Unfortunately, research into what constitutes appropriate nutritional support for normal growth is hampered by a lack of consensus of what are the appropriate measures for determining undernutrition in the United States (Peterson & Chen, 1990). Peterson and Chen (1990) have suggested the use of National Center for Health Statistics (NCHS) growth charts to identify malnutrition. Internationally accepted indications of growth failure are - 2.0 standard deviations below the mean for weight for age, length for age and weight for length. They feel that clinical diagnostic categories such as failure to thrive and kwashiorkor are not appropriate indicators for population studies. The Center for Disease Control (CDC) chose to define undernutrition, for purposes of a pediatric population study, as: weight for length or height below the third percentile, hemoglobin less than 8 gm/100 ml, hematocrit less than 25%, a specific diagnosis of clinical malnutrition, or a child with a documented weight loss of 10% or greater of body weight (Trowbridge & Wong, 1990).

Determination of the prevalence of pediatric undernutrition is also complicated by concerns with the reference standard, the NCHS growth charts. The reference population of infants less than 24 months old, used in designing the growth charts, is thought to be unrepresentative of ethnic differences and taller than average (Lewit & Kerrebrock, 1997). They were measured every three months, not the ideal every month (an important consideration in this period of fast growth) and almost all were bottle fed (World Health Organization Working Group on Infant Growth, 1995). The WHO (1995) examined the NCHS growth charts to see if they overstate the degree of growth retardation in healthy breast fed infants by pooling growth data from seven data sets with growth measures of breastfed infants. Five of the chosen studies excluded preterm or low birth weight infants, and three also excluded large for gestational age infants. At two months, the breast fed infants were slightly larger than the NCHS standard, with a length for age z-score of + 0.2, weight for age z-score of + 0.5 and weight for length z-score of + 0.6. But by 12 months of age, the weight for age z-score had fallen to - 0.6 and length for age and weight for length z-scores had fallen to - 0.3. When the new distributions were applied to data sets from developing countries, the pooled breast fed growth data classified slightly more infants as growth retarded in the first six months of life, but only half as many were classified as growth retarded in the second six months of life. All the breastfed infant data sets were predominately Caucasian, and there were concerns over lack of ethnic diversity. As there is also limited ethnic diversity in the current reference population, this concern may not be warranted. The infants measured were from families who complied with health recommendations, i.e., to breastfeed, which may be a more valid non-representative characteristic. However, the most telling objection to the development of new growth charts

based on these standards was the division in the working group on the role of growth in development. They concluded that the recommendation to breastfeed exclusively does not promote the degree of growth that bottle-feeding does, but they were unable to make a judgment on which feeding practice promoted "normal" growth and was best for infant development.

Despite disagreements on definitions, research has shown that pediatric undernutrition exists in the United States. Lewit and Kerrebrock (1997) looked at population level growth data collected through the CDC's Pediatric Nutrition Surveillance System, which collects data from children enrolled in government sponsored health programs. There was an 8.3% incidence of stunting or length less than the 5th percentile, on NCHS growth charts in these predominately poor children in 1995. This is a decrease from a level of 11.4 % in 1978 that was consistent with the finding that over 12% of children living in poverty were stunted from National Health and Examination Survey Data: 1976-1980.

The entire inpatient population of a tertiary care hospital for children in Boston was assessed for undernutrition using growth criteria modified from Waterlow (Hendricks, et al., 1995). Based on their decreased weight for height, 24.5% of the children had some degree of acute malnutrition. Chronic malnutrition, evidenced by decreased height for age, was found in 27.2% of the children. A similar survey in 1976, in the same institution, found that one third of all patients exhibited acute malnutrition and one half had chronic malnutrition. While the prevalence of malnutrition has decreased, the authors concluded that the current observed rates were too high and indicated a need for improved nutritional care of chronically ill children (Hendricks et al., 1995).

Ekvall et al. (1993) supports the finding that children with chronic medical conditions have increased nutritional needs. In a survey of 100 children referred to a medical center serving children with developmental disorders, only 5 did not have a nutritional problem. Feeding problems were identified in 23 children and 13 had a nutritional deficiency. In another survey at the University of Iowa, 15 to 25% of the children, who referred to the clinic, had evidence of acute malnutrition, with weight for height less than the 5th percentile. With the movement of children with neurodevelopmental disabilities into the community, the need for systematic nutritional care of children with special needs becomes even more critical (Nutrition Committee, Canadian Paediatric Association, 1994). The passage of the Individuals with Disabilities Education Act included nutrition as a covered service and should be a vehicle for delivering nutritional care in family settings to chronically ill children with special health care needs (Cloud, 1997). However, work in Iowa, by Clark et al (in press), has shown that children with identified nutritional needs are unlikely to receive a referral to nutritional care. The identification of a nutritional problem on a screening form did not generate a referral to the nutritionist for one half of the patients. If a child was identified as overweight a referral was made 45% of the time, and referrals for more serious nutritional problems, with developmental consequences, were made even less often. A referral was made to the nutritionist if a child was tube feed only 24% of the time. Of the children identified with poor appetite 12% received a referral and 7.5% of the children with parental concerns about nutrition received a referral.

Nutrition and growth

Although there is controversy about the degree of growth retardation that constitutes undernutrition; there is a general agreement that growth measures are the most sensitive

measures of nutritional status (Allen, 1990; Mascarenhas, Zemel & Stallings, 1998; Scott, Artman & St. Joer, 1992; Smith, 1993). While growth charts are useful for assessment in groups of children, for the individual child the most appropriate measure is longitudinal growth or growth over time, particularly growth velocity (Allen, 1990). Clinical examinations for nutritional status are often unreliable and unspecific in the United States (Allen, 1990; Mascarenhas, et al., 1998), but they have been useful in developing countries (Van den Broeck, Meulemans & Eeckels, 1993). Good biochemical tests do not exist for measuring marginal states of many nutrients, such as protein, zinc and calcium, that are of interest in children's diets. For example, the best test for zinc deficiency in children is to give a supplement and monitor for a growth response (Allen, 1994).

The rate and pattern of growth in an individual is influenced primarily by genetics, but nutrition is a powerful modulator of both growth rates and patterns (Scott et al., 1992). For example, in the change of height, there is the distance one grows, or how tall one gets which is genetically determined, but nutrition effects the velocity of growth. If provided with adequate nutrients, each child has a standard plot of growth velocity, or how much they grow in a period of time. One of the first adaptations to inadequate nutrition is the slowing of growth velocity. The child still grows, but at a slower rate (Neumann & Harrison, 1994; Tanner, 1990; Zeitlin, Ghassemi & Mansour, 1990). First there are delays in weight gain and then, if the nutritional deficit continues decreases in height for age (Scott et al., 1992). Growth stunting presents as a flattening of the normal growth curve due to a decreased velocity, and it is more a result of environmental factors such as poor nutrition, illness and infection than genetics. Genetic variation between ethnic groups is only on the order of one-half of a standard deviation, so variability between ethnic groups cannot explain stunting

(Allen & Uauy, 1994; Ulijaszek, 1994). Normal growth patterns can resume with the provision of adequate nutrition, but the reversibility of stunting may depend on the timing of the treatment (Martorell, Kahn & Schroeder, 1994). The child will 'catch-up' by increasing the velocity of growth above the baseline and return to his or her natural growth curve (Tanner, 1990). Generally, this catch-up growth occurs first in weight, then in height with growth velocities as much as three times the normal rates of growth (Waterlow, 1994).

A type of cellular clock seems to govern cell division. If there is a period of severe undernutrition when cells are dividing, cell division slows or may even stop. If the undernutrition occurs when cells are already formed, but are increasing in size, the cells can 'catch-up' later when nutritional status is improved (Tanner, 1990). The extent to which cells may 'catch-up' in growth if the nutritional insult occurs during the phase of cell division is currently an active area of inquiry. The case of folic acid illustrates one extreme of the argument. A deficiency of folate during a few days very early in the gestation of a fetus causes a defect in the development of the neural tube, leading to permanent central nervous system damage (Selub & Rosenberg, 1996). Cell division does not go back and catch-up. The persistent changes in bone structure due to vitamin D deficiency in rickets is another example of a persistent structural change from nutritional deficiency in a critical growth period (Barker, 1997). There have been indications that alterations in fetal growth rates may lead to insulin resistance or increased cholesterol levels, because of permanent damage done by nutritional deficiency to pancreatic or liver cells in the fetal period (Barker, 1997).

Many nutrients have been implicated in the development of growth delays. Allen (1994) and Loveridge & Nobel (1994) have written excellent reviews on the topic. In

general terms, appropriate energy and protein are both required. A deficiency in either will slow growth. Calcium and phosphorus are necessary for bone growth, as is vitamin D. Zinc is required for cellular proliferation and appropriate immune function. Copper, molybdenum, and manganese also affect bone growth (Allen, 1994; Loveridge & Nobel, 1994). While supplementation of a single nutrient is effective in treating a specific deficiency, single nutrient supplementation, whether it is a macronutrient like protein, or a micronutrient like zinc, has had uncertain results in promoting improved growth. In some studies, any of the mentioned nutrients had significant growth results, but in other studies supplementation was relatively ineffective. The supplement studies, in addition to recent observational work, suggest that growth delays are not caused by single nutrient deficiencies but are the result of interactions among a variety of nutrients (Allen, 1994).

Finally, there is the complex interaction between infection, poor nutrition and growth. Diarrheal infections are associated with no increase in height/length for up to several months (Keller, 1988). Stunted children were found to have more days of illness than non-stunted children. Apathy, fever, anorexia, coughing, and diarrhea had significant effects on weight gain with the greatest reductions in growth occurring with apathy and fever (Walker, Grantham-McGregor, Powell, Himes & Simeon, 1992). A possible mechanism that would explain this interrelationship is the redirection of nutrients to the immune system from growth caused by activation of the immune response. Acute phase response proteins, such as interleukin-1, tumor necrosis factor and interleukin-6, partition dietary nutrients away from growth in favor of metabolic processes that support the immune response and disease resistance (Solomons, Mazariegos, Brown & Klasing, 1993). Additionally, minerals like iron and zinc are either removed from circulation and

sequestered or excreted and lost as part of the immune response. When the increased metabolic needs of infection are included, the reasons for growth retardation are clearer (Kuvibidila, Yu, Ode & Warriar, 1993).

It is suggested that between 25 to 50% of child deaths worldwide are associated with malnutrition, as defined by alterations in growth rates. The cause of death listed on the death certificate may be an illness, but malnutrition is seen as a major contributing factor. When considering the relative proportion of mild to moderate malnutrition versus severe malnutrition, up to 80% of the deaths can be attributed to the milder forms (Pelletier, 1994). In infants, decreased arm circumference for age, reflecting decreased muscle mass, is the best predictor of mortality, but decreased length for age is the best predictor for children after the first year (Pelletier, Low, Johnson & Muskwa, 1994).

Nutrition and development

As previously pointed out, cell division proceeds on an orderly timetable. In humans some cells, such as gut, liver, skin and blood, retain their ability to divide over a lifetime. Other cell lines, such as brain, fat and muscle have a more limited developmental window (Strauss, 1997). The maximum rate of increase in the cells of the central nervous system takes place between 25 and 40 weeks gestation and extends into the first months after birth. The cerebellum and the neocerebellum have their maximum growth at the time of birth and in the first months of the first year. The rate of growth indicates those areas which may be most easily damaged (Cesear, 1993). So the question of when (or if), there is a sensitive period of development during which nutrition can affect cell division is an important one. For example, given growth rates, Cesear (1993) cerebral palsy could be expected to develop from a delay in nerve cell division in mid gestation and in to the early third trimester.

Levitsky and Strupp (1995) reviewed recent research on protein-energy malnutrition and brain development based on animal models. While acknowledging the difficulties of extrapolation from animal work to humans, they draw several interesting conclusions. Primarily, there is not a 'sensitive period' that leads to irreversible damage. The structural changes in the brain seen in some studies seem to be reversed with refeeding. However, there are persistent alterations in neurotransmitter function. The findings indicate that the behaviors and cognitive functions damaged by malnutrition are related to emotional responses and coping under stress and are not among the cognitive areas measured by intelligence tests.

A similar review by Morley and Lucas (1997) concluded that animal studies have demonstrated changes in performance after nutritional deprivation. In rats that were undernourished in a stage of brain growth similar to that seen in humans in the third trimester of pregnancy, cortical cell numbers were stable, but cerebellar and glial cell numbers were reduced, as well as, the complexity of dendritic branching. They also noted that early malnutrition produced down-regulation of beta-adrenergic receptors, which could be expected to impair the animal's ability to react to stress. Peeling and Smart (1994) also reviewed and reanalyzed the literature and concluded that malnutrition affects all areas of brain development equally. Undernutrition clearly affects the brain but an understanding of the extent of the effect is frustrated by the variability in experimental results (Peeling & Smart, 1994).

In a study by Fleagle, Samonds and Hegstead (1975) monkeys from two to six months of age nutritionally were deprived of either protein or energy. In the monkeys fed a restricted calorie diet (and adequate protein), there was slowed growth, but there still were

increases in weight and height. There was no weight gain in the protein malnourished group in spite of allowing them to eat ad libitum. After six months of rehabilitation, the energy deprived group had returned to normal growth patterns, but the protein deficient group still showed growth delays. In the development of the same groups of monkeys, the effects of poor nutrition and social deprivation were not interactive but additive, with the group deprived of both interaction and nutrition having the poorest growth and slowest development (Elias & Samonds, 1977). There also were differences in development related to the type of nutritional insult. Those animals with the caloric deficit had the most direct effect of nutrition on development, while the group with protein deficiency seemed to have an interaction with environmental conditions. After six months of rehabilitation, recovery in development was complete in the low calorie group, but not in the protein-restricted group. Clearly, while there are short-term effects from poor nutrition, it appears that the recovery capacity is essentially complete, especially if developmental circumstances are favorable.

Gunnar and Barr (1998) approach the development of the brain from a neuroendocrine perspective. They point out that modern neuroscience goes beyond genetic programming to suggest that many activities of brain development are dependent on experience. The brain retains the synaptic connections that are used and discards those dendrites that are not activated indicating that the structure of the brain depends on how it is used. Examining the development of the stress response in the central nervous system suggests that exposure to stress modifies the functioning of the hypothalamic-pituitary axis and the body's response to glucocorticoids. Prolonged exposure to stress has been shown to decrease the number of glucocorticoid receptors in the pituitary and hypothalamus reducing the brain's ability to turn off the stress response. Gunnar and Barr (1998) suggest that

insecure childhood attachment, which increases levels of cortisol and is associated with the development of behavioral and emotional disorders in later childhood, might be an example of a conditioned abnormal stress response. They also express concern with the extensive use of steroids in pediatric medical practice, because of the long-term alterations in cortisol response seen in these patients. The intersection of this developmental neuroendocrine research and the current topic of childhood malnutrition, comes through the fact the cortisol plays an important part in the adaptation of children to malnutrition (Zeitlin et al., 1990). Cortisol levels are high in children with marasmus. Zeitlin et al. (1990) suggests that increases in cortisol levels are a critical adaptation that allows children with poor nutrition to successfully adapt to the decreased nutrient supply.

Gunnar and Barr (1998) suggest that the effects of stress on the brain are difficult to detect because they are subtle. The effects of stress early in life may not show up until old age. When looking for nutritional effects on development and function, cause and effect may be as far apart as infancy and old age. Grantham-McGregor (1993) studied malnourished hospitalized children and well nourished sick controls. The malnourished children were apathetic, less active and did not play with as many toys as the control group. The control children were irritable and unhappy. After refeeding the apathy disappeared, and activity approached the control level, but there were developmental differences years later. She stressed the importance of not seeing the disappearance of a temporary symptom, like apathy, as evidence for full recovery.

Additional factors that influence development

There are many additional factors other than nutrition that affect normal growth and development. Any research into this area needs to collect information that allows one to

account for at least some of these confounding effects. Zeitlin et al. (1990) suggested a wide range of variables for consideration when looking at the effects of nutrition on development.

These variables are:

1. Parent and household characteristics: mother's age, maternal anthropometry, maternal medical history, household food consumption, parents' education, social support, family stress, household size and structure, occupation of parents.
2. Parental attitudes and behaviors: parents' nutrition knowledge, use of health and nutrition services, breast/bottle feeding (duration and type), parent-child interaction, parental attitude toward child.
3. Child characteristics: birth weight, gestational age, sex, birth order.
4. Child nutritional and health status: anthropometry, dietary intake, medical history, developmental screening, activity level. (p. 89-92)

Zeitlin et al. (1990) recommends collecting variables in each category and suggests that including as many variables as possible may give more information when regression analysis is planned.

Smith (1993) also developed a list of variables to consider when assessing nutritional status. Variables suggested include anthropometric measures, indications of activity level, biochemical assessments, behavioral assessments including eating skills, cognitive or developmental assessments, evaluations of dietary intake, social environment and a review of drug and diet interactions.

In a review of variables related to malnutrition, Allen (1990) discussed the use of functional tests to determine outcomes related to malnutrition. Tests measuring the cognitive function in children with malnutrition are more likely to find alterations related to

arousal or the ability to pay attention than changes in conceptual learning ability or IQ measures. When one considers that a child needs to be able to pay attention in order to learn, the importance of this alteration is obvious. However, these findings seem to be similar to those of Grantham-McGregor (1993) in that they are temporary and are reversed with refeeding. Cognitive performance on common childhood tests, like the Bayley Motor and Mental Exam (Bayley), are correlated with many confounding factors not related to nutritional status including parenting styles, education levels of parents, and personality traits like motivation. However, Bayley scores are also positively correlated with height and weight for age, even in the United States. As a measure of the apathy, common in children with malnutrition, it is possible to conduct observations of children's activity patterns to assess differences in their activity levels. In Mexico, mothers reported that their children became more of a nuisance after nutritional supplementation. Activity measures can be both complex and technical using portable heart rate monitors, or they can simply be measures of fidgeting over a period of time while a child is left in a chair. While functional tests can lack some of the specificity of biochemical measures, they have the benefit of demonstrating to policy makers the harm done to children by malnutrition (Allen, 1990).

Research into the relationship of nutrition, growth and development

Skuse, Pickles, Wolke, and Reilly (1994) developed a model that suggested mental development is adversely affected by a growth delay in the early postnatal period. These results were found after studying a group of full term infants who were later treated for growth delay. The model predicted a 10 point loss in Bayley development scores if the weight loss began in the immediate postnatal period, but only three points if the delay did not start until four months of age. The relationship disappeared if the growth delay started

after eight months of age. In addition to the growth data, the model also includes the mother's education and minor congenital anomalies in the child as less important variables. The researchers postulate that there is a sensitive period for the interaction of nutrition and development in the first three months post-partum. Carmona da Mota and Antonio (1990) discussed the transient effects of malnutrition due to diarrhea. They looked at the outcome of infants who suffered severe weight loss secondary to illness at less than six months. At school age, there was a significant negative correlation between the duration of weight and length at less than the fifth percentile and IQ.

Grantham-McGregor, Powell, Walker and Himes (1991) found there was a significant beneficial effect of supplementation on stunted infants (9 to 24 months of age) in Jamaica. The researchers studied four groups:

1. stimulation and supplementation (formula, cornmeal and skim milk powder),
2. supplementation only
3. stimulation only
4. a control group with a short home visit.

There were slightly greater increases in developmental scores after two years in the supplemented only than in the stimulated only group. The effect was additive with the best outcomes found in the supplemented and stimulated group. This finding was similar to the work reported by Elias and Samonds (1977) in monkeys. The supplement effect was gradual and continued throughout the study period (Grantham-McGregor et al., 1991). In an additional report, growth rates in the same study groups were examined. Stimulation was found to have no effect on growth. The supplemented group, however, had significant increases in length, weight and head circumference. The growth gains came in the first six

months of supplementation, but the developmental gains from supplementation came gradually and were continuing when the study ended. The authors speculate that the children would have continued to improve if supplementation were continued. They contrasted this to the effects of stimulation which were early and tended to lessen with time (Walker, Powell, Grantham-McGregor, Himes & Chang, 1991).

In 1997, Grantham-McGregor, Walker, Chang and Powell published work that looked again at the children studied in 1991, now 7-8 years of age. They found that many of the earlier gains had evaporated, but there were small gains in the total developmental scores for all three intervention groups. Children in the stimulation groups showed improvements in perceptual motor scores. In the supplemented group, the children with mothers with higher verbal scores showed improvements. As one of the major factors in the development of intelligence is maternal education, this finding suggests that the supplementation allowed the children to better take advantage of the positive factors in their environment. The most powerful predictor of IQ at the time of the seven year follow-up was length and head circumference at entry into the study at 9 months of age.

The Nutrition Collaborative Research Support Program is a longitudinal study of the effects of nutrition on development (Allen, 1993). Families in villages in Mexico, Egypt and Kenya, were studied to determine nutrient intake and adequacy, pregnancy outcome, maternal health and infant development. There were approximately 300 households in each country and participants were followed for one year. Neurodevelopmental behavior of the newborn was found to relate to maternal diet. A low maternal level of vitamin B-6 was the strongest predictor of neonatal behavior. Maternal micronutrient levels were a factor in infant and child development in all three countries. Growth faltering began by three months

post-partum, and affected both weight and length, contrary to the prevalent view that weight fails first (Allen, 1993). Allen (1994) explained the early growth faltering by suboptimal transfer of nutrients during the fetal period and low intakes in early post natal life. These infants did not have adequate nutrient stores to support growth. In pre-schoolers, gains in weight and height were positively correlated only if the diet was of good quality. If the children ate poor quality diets, gains in weight were inversely correlated with gains in length. Stunting occurred by 18 months and after that time growth velocities followed the NCHS reference rates (Allen, 1993).

The Institute of Nutrition of Central America and Panama carried out an intervention designed to study the effects of improved energy and nutrient intake on women and children. The study took place in four villages in eastern Guatemala from 1966 to 1977. Two villages were provided with a high energy supplement and two were given a high protein supplement. The vitamin and mineral content varied by type of supplement. In the initial analysis, it was discovered that birthweights increased irrespective of the supplement, i.e. that increased energy alone was responsible for the observed effect. In the villages which were protein supplemented, children were significantly taller with a decrease in stunting from approximately 45% to less than 20% (Martorell, 1995). In a follow up study, done from 1988 to 1989, children from the original study, now 13 to 19 years old, were retested. Subjects from the protein supplemented group scored higher on subject knowledge tests than subjects given the energy supplement. Also the socioeconomic effect was erased in the villages which received the protein supplement. The researchers felt the protein supplement acted as a social equalizer (Pollitt, Groman, Engle, Rivera & Martorell, 1995).

Research Models

Research on child development and nutrition has looked at the nutritional status of children as a continuum, from children who are well nourished to those who are poorly nourished. The research has sought to identify factors that are associated with those children who do less well in order to eliminate those factors and hopefully improve the outcome of all children. An alternative approach is to look at those children who do well in a high-risk situation and to discover those factors that are associated with thriving. This positive deviance approach is predicated on the assumption that the factors that allow a child to thrive in difficult circumstances, are not necessarily the same factors associated with poor outcomes (Shekar, Habicht & Latham, 1991; Zeitlin, 1991; Zeitlin et al., 1990). Because the approach looks for successful strategies within the high risk population, there is a greater chance of designing acceptable interventions as the intervention arises out of modifications of behavior or diet already successfully applied by families in the population of interest (Zeitlin, 1991; Zeitlin, et al., 1990). Renal dietitians have applied this approach in order to identify factors that are associated with successful management of end stage renal disease (Kelly, Kight & Migliore, 1995).

Arroyave's classic model of the sequence of events leading to nutritional disease in adults (Figure 1) was developed to describe the maintenance of a biochemical marker of nutrition status, albumin (Young & Scrimshaw, 1979). Since this is a biochemical determination, it makes sense that the initial step in the development of a nutritional disease is a change in a biochemical marker. Young and Scrimshaw (1979) pointed out that if the marker of nutritional status to be maintained was different, the model would be different. They specifically listed the achievement of normal growth as a biological function that

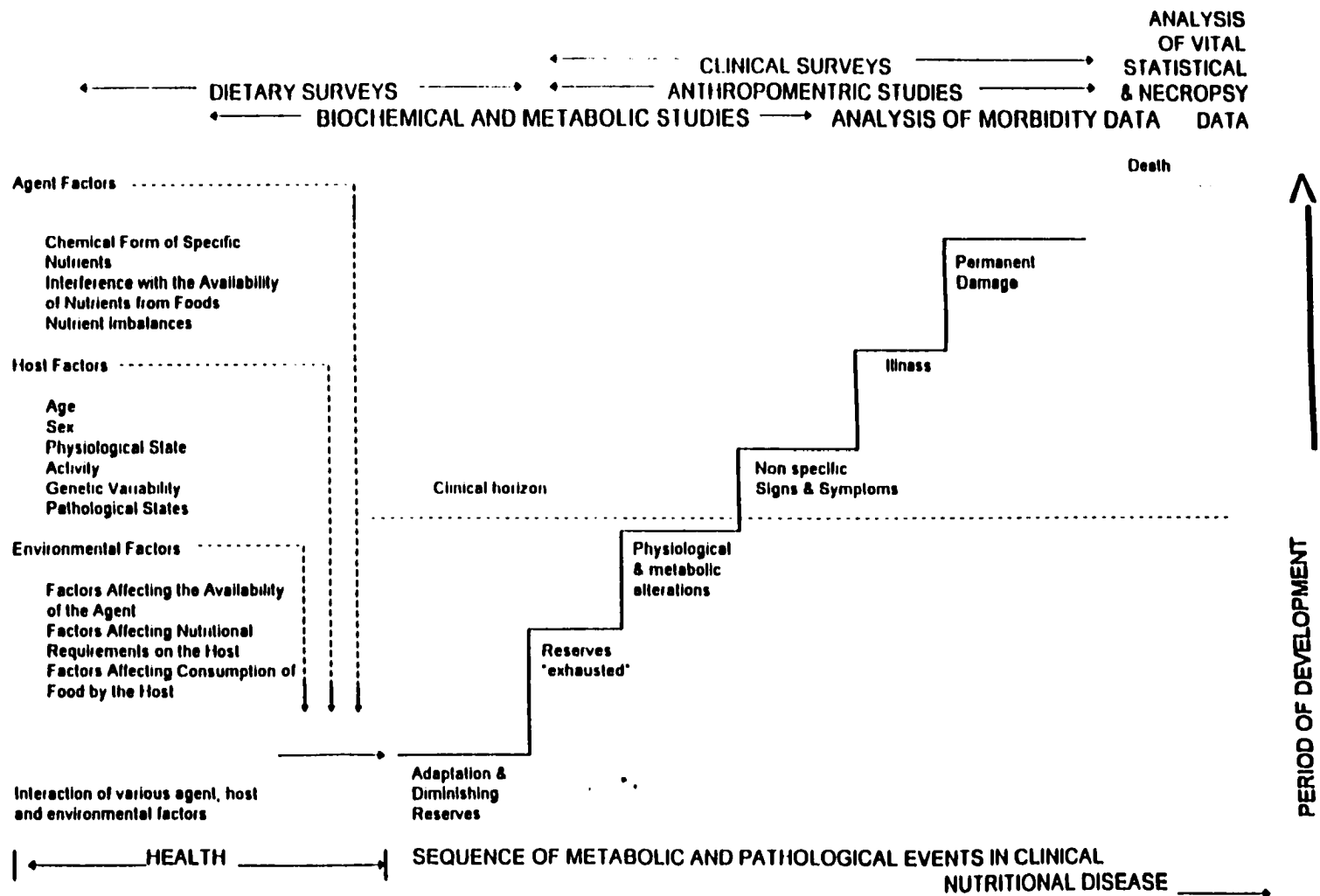


Figure 1: Sequence of metabolic and pathologic events in clinical nutrition disease (Young & Scrimshaw, 1979).

would generate a different looking model. The use of a model that focuses on biochemical measures of normalcy makes the early diagnosis of a nutritional related growth deficiency difficult. For example, a child with marasmus can have a normal albumin and may not be identified as malnourished using the model (Zeitlin et al. 1990).

Brown and Pollitt (1996) have recently proposed a three-pronged model of the effects of nutrition on development (Figure 2). The first prong describes physical brain development, which may or may not be permanently damaged based on the extent and duration of the nutritional insult. The third stream includes the socioeconomic effects of poverty, that limit dietary quality (Philip, James, Nelson, Ralph & Leather, 1997) decrease educational and social stimulation (Grantham-McGregor, 1995) and contribute to lack of medical care (Brown and Pollitt, 1996). The center stream is the interaction of the child with the environment. Poor nutrition causes lethargy and withdrawal, while growth delays lead parents to perceive their child as sickly and to expect less of him or her (Grantham-McGregor, 1993; Zeitlin, et al., 1990). Children learn through their interactions with life. If they withdraw, even for a short time, their development will be retarded. Perhaps this accounts for the difficulty in separating the effects of social deprivation and malnutrition. In the first case, the environment presents limited opportunities for the child to learn, in the second the child withdraws from the learning opportunities available.

Brown and Pollitt (1996) developed their model after working with children in the developing world and with those living in poverty in the United States. Children born preterm, with low birth weights, often live in poverty and may share other characteristics with children from the developing world. Both groups have poor nutritional resources for

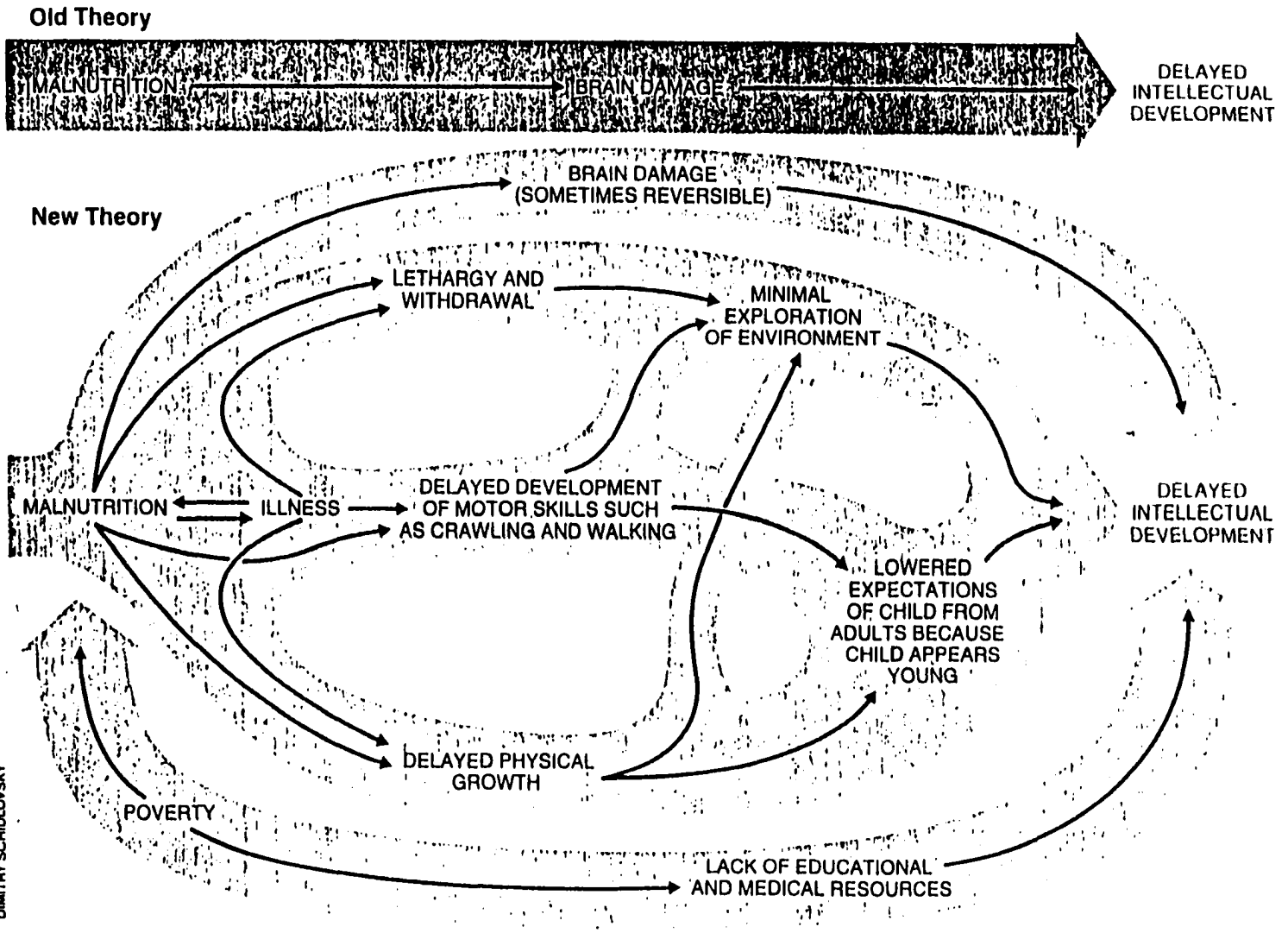


Figure 2: Malnutrition's effect on cognitive abilities from Brown & Pollitt (1996)

growth, are stressed by illness, often come from socioeconomically deprived environments and have neurodevelopmental delays that may respond to nutritional intervention.

Prematurity's effects on growth, development and nutrition

Introduction

In the United States in 1996, the average birth weight for an infant born at term was 3,350 grams or 7 lb. 7 oz and 80.3% of all babies were born at term or 37 to 40 weeks gestation. Infants born post term or with a gestational period of over 42 weeks were 8.7% of all births and 11% were preterm or less than 37 weeks gestation. The preterm total could be further partitioned into infants born between 28 and 36 weeks gestation, 10.3% of all infants and those born before 28 weeks who were 0.7% of all infants (Ventura et al., 1998).

Birth weights are classified into low birth weight less than 2500 grams and very low birth weight, less than 1500 grams. New terms for classifying birth weights are extremely low birth weight for infants born at less than 1000 grams, and micro-preemie for ones born at less than 750 grams. Prematurity and low birth weight generally occur together (Batshaw & Perrett, 1992; Ventura et al., 1998).

Preterm infants are very different physically from term infants. Their skin is ruddy because of the closeness of the capillaries to the body's surface, which makes heat loss from the capillary beds a problem. In addition to problems maintaining body temperature, they lack the suckle reflex before 32-34 weeks gestation and have poor gastric motility. Common medical problems include respiratory distress, intracranial hemorrhage, hypoglycemia, slow heart rates, problems with the neurological control of breathing and poor growth rates (Batshaw & Perrett, 1992; Neal, 1995). Before preterm infants are able to leave the hospital, they must be able to show a sustained pattern of weight gain, have

physiologic stability characterized by the ability to maintain their temperature in an open environment and the ability to suckle. They should also have stable cardiorespiratory function and have had a nutritional risk assessment. Historically, infants were kept in the hospital until 37 to 40 weeks gestation or their weight was over 2500 grams, but currently infants are beginning to be discharged at weights as low as 1500 grams (Committee on Fetus and Newborn, 1998).

Nutrition and prematurity

Nutrition is a critical factor in the care of low birth weight infants. Common nutrition problems include: low energy reserves, higher metabolic rates due to higher proportions of metabolically active tissue, higher protein turnover, higher glucose needs for brain metabolism, high lipid needs to match rate of fat deposition in utero, low rates of peristalsis with limited production of gut enzymes and growth factors, a high incidence of metabolically stressful events, and abnormal neurological outcomes possibly related to feeding (Hay, 1996). The caloric needs for growth are difficult to measure as they must be estimated based on population standards. As much as 36% of the caloric needs of a normal one month old infant and over 50% of the caloric needs of a preterm infant can be attributed to growth (Porter & Cohen, 1996). The 1998 edition of the Pediatric Nutrition Handbook of the American Academy of Pediatrics includes four sets of recommendations for macro and micro nutrient intakes.

The practical effect of the difficulties of determining nutritional needs in the period after birth is that preterm infants are underfed during the immediate postnatal period. Most infants born at less than 1500 grams show delays from fetal growth rates in length, weight and head circumference for as much as three weeks (Hay, 1996). Because there are

significant concerns about the ability of preterm infants to tolerate early feeding (Anderson & Pittard, 1997; Battaglia & Thureen, 1997), infants initially receive less nourishment than later when they are growing well and certainly less than when they were in utero. In practice, infants are eased into feeding, starting at one half to one quarter of estimated protein needs and one third to two thirds of estimated energy needs sometime in the first three days of life (Anderson & Pittard, 1997).

It is still controversial to suggest that one apply fetal tissue accretion rates to infants under 1500 grams or especially less than 1000 grams. However, when infants at less than 1000 grams are given protein up to 3 to 4 gm/kg/day, their growth rates approach those of an in utero fetus of the same age. For older infants, 34 to 40 weeks gestation, only 1.5 to 2.5 gm/kg/day of protein are needed to achieve fetal growth rates. With early feeding of adequate protein, infants can achieve positive protein balance in the first few days of life. The first feedings of protein are parenteral amino acid solutions and the use of a product formulated to mimic the plasma amino acid profile of term infants has been shown to provide improved growth rates over a parenteral product formulated for adults (Hay, 1996; Battaglia & Thureen, 1997). The pediatric product has increased levels of the branched chain amino acids (leucine, isoleucine and valine), tyrosine, taurine, glutamine and glutamate (Battaglia & Thureen, 1997). It is not always used, however, because of the cost (Anderson & Pittard, 1997).

Research concerning the relative amounts of specific amino acids in cow's milk based formulas and human milk suggests possible alterations in neurotransmitter production and function related to diet. High plasma concentrations of tyrosine have been observed in preterm infants receiving cow's milk based formula. As tyrosine is a precursor of

dopamine. this imbalance may lead to increases in the amount of dopamine in the brain. Also tyrosine is transported into the brain competitively with other neutral amino acids, such as tryptophan. Tryptophan is the second limiting amino acid in milk based formulas, and is a precursor to serotonin. The effect of competitive inhibition on the transport of tryptophan into the brain and its effect on serotonin production is not known, but alterations in neurotransmitter production may be a possible explanation for the differences seen in breast fed and bottle fed infants (Wharton & Scott, 1996).

Since up to 70% of energy utilized by a preterm infant is devoted to brain growth and function, glucose metabolism is of critical importance. Glucose is the predominant energy source for the brain, and the production of the alternate energy source, keto acids, is limited by the lack of lipid stores. Hay (1996) reports that many researchers assume that repeated incidents of hypoglycemia are related to neurodevelopmental handicaps, but as these are clinical observations, he cautions that causality is suspect. Hyperglycemia is particularly common in smaller infants when under stress which increases cortisol secretions (Hay, 1996). The possible effects of cortisol on brain development were previously discussed in the review of Gunnar and Barr's work (1998). Battaglia and Thureen (1997) report some evidence, based on analysis of cord blood, that the fetus in utero is exposed to glucose concentrations considerably higher than is currently considered normal.

Lipid needs of both preterm and term infants are a particularly active area of research. The brain is 60% lipid and its need for very long chain polyunsaturated fatty acids for structural purposes is already known. Docosahexaenoic acid (DHA), which is derived from the essential fatty acid linolenic acid, concentrates in neural tissue, the brain and the retina and comprises 90% of the structural fatty acids derived from linolenic acid in the

brain (Salem & Ward, 1993). That linolenic acid is essential has been well known and infant formula is fortified with this essential nutrient. But recent research has suggested that preterm infants, and perhaps even term infants, are not able to convert enough linolenic acid to DHA to meet the structural needs of the growing brain. Crawford, et al. (1993) found that maternal intake of linolenic acid at conception was correlated to the birth weight of their infants, with higher intakes correlated to higher birth weights. Analysis of cord blood showed that infants who were growth retarded in utero had lower than normal levels of arachidonic acid, while premature infants had lower levels of DHA. Fetal blood concentrations of both of these fatty acids are higher than maternal levels. In preterm infants, blood levels of both of these fatty acids fall rapidly in the first few hours after birth and do not recover (Crawford, 1992; Crawford et al. 1993). Because of the critical role structural lipids play in membrane function, deficiency of these metabolites may be related to a variety of complications found in preterm infants, such as retinopathy, hemorrhage, and respiratory distress (Crawford, 1992).

Breast milk is the recommended feeding for preterm as well as term infants (American Academy of Pediatrics, 1998). Breast milk concentrates the metabolites of essential fatty acids above maternal plasma, while infant formula in the United States has only the essential fatty acids themselves. Breastfed infants have higher blood levels of DHA and arachidonic acid than either preterm or term formula fed infants. In Europe, both DHA and arachidonic acid are added to infant formula (Anderson & Pittard, 1997; van Beek, Carnielli & Sauer, 1995). Because breast milk does not meet the recommendations for vitamin and mineral intake in preterm infants, use of a human milk fortifier is recommended (American Academy of Pediatrics, 1998; Anderson & Pittard, 1977). However, a

randomized trial of fortified and unfortified breast milk, did not show any significant difference between treatment groups for growth or in development at 18 months of age. The group receiving more than 50% of their intake as fortified breast milk had a higher weight gain than the infants receiving a similar amount of unfortified breast milk (Lucas et al. 1996).

Nutrition after hospital discharge

Hay (1996) admits that the growth delay seen in hospitalized preterm infants requires increased feeding later to prevent unspecified, but "not good" developmental consequences. However, he confines his recommendations to the acute period of hospitalization. The Academy of Pediatrics (1998) states that although term formula has been used at discharge, this may not be appropriate practice for infants discharged at less than 1500 grams. They also point out the availability of higher calorie formulas designed for preterm growing infants and remark that use of these products has been associated with improved growth. They make no specific formula recommendations, or recommendations on the use of human milk fortifiers after discharge.

Isaacs et al. (1997) suggests 120 cal/kg as a goal for preterm infants until they weigh 2.5 kg, and 100 cal/kg after that. The Recommended Dietary Allowance for term infants is 108 cal/kg from birth to six months (Food and Nutrition Board, 1989). Nursing guidelines for primary care follow up of preterm infants, suggest that healthy preterm infants may require 110-130 cal/kg while chronically ill preterm infants may need as much as 200 cal/kg. Miller (1993) suggests the use of corrected age (chronological age - weeks of prematurity = corrected or adjusted age) in monitoring growth rates and in making recommendations for introduction of solids or whole milk. She points out the need for monitoring for feeding

disorders, which are more common in preterm infants. Dusick (1997) makes many of the same recommendations to physicians. She recommends that feeding guidance be adjusted for prematurity and not be based on chronological age. She cautions that preterm infants need closer monitoring for feeding disorders, and growth delays and suggests families may need more anticipatory guidance to cope with developmental issues related to nutrition and growth.

Lucas, King and Bishop (1992) calculated the formula consumption of healthy growing preterm infants until nine months adjusted age. In the preterm infants, formula intake was 230 g/kg body weight at 4 weeks post term compared to 170 g/kg/body weight in term infants. At six months, intakes were 150 g/kg/body weight in preterm infants compared to 60 g/kg/body weight in term infants. Over 50% of the infants consumed more than the maximum 165 cal/kg recommended by the European Society for Paediatric Gastroenterology and Nutrition suggesting that the nutritional needs of preterm infants remain high long after the period of hospitalization.

Prematurity and developmental delays

Interpreting developmental results requires an understanding of social factors influencing developmental testing, and an understanding of what different tests measure. Tests like the Bayley and the Denver Developmental screening, focus on early motor development, while tests given later in childhood, focus on more 'intellectual skills' (Hack, Klein & Taylor, 1995). Part of the problem is that one cannot observe a delay in a skill until it is past the time for its developmental expression. For example, a one year old may or may not walk, but a two year old should. Testing for walking at 6 months will not be very useful in predicting adult walking behavior.

Preterm infants are not a homogenous group. They differ in medical complications, both at birth and after. The great majority develop within normal limits, but as a group preterm infants have increased rates of poor growth, illness and neurodevelopmental problems. The frequency of problems escalates as birth weight decreases (Chapieski & Evankovich, 1997; Hack et al., 1995). The most significant abnormalities are the expression of negative temperament characteristics, symptoms of Attention-Deficit Disorder, and lower levels of social competence (Chapieski & Evankovich, 1997). Hack et al. (1995) describe the delays as mild problems in cognition, attention and neuromotor function. Both references are excellent reviews of the confusing state of the literature.

Breslau, Chilcoat, DelDotto, Anreski and Brown (1996) studied over 700 children at 6 years of age with birth weights from less than 1500 grams to normal. All the children were given a battery of developmental tests. Low birth weight infants scored lower than normal birth children, when controlling for race and maternal education. In general, the lower the birth weight, the less well the child did. Interestingly, performance continued to improve with increasing birth weight well into the normal ranges. The relationship between birth weight and performance does not seem to be bounded by the arbitrary limits we have set on normal birth weight.

There is a fair amount of evidence to suspect that nutrition has altered brain function in low birth weight infants. Levitsky and Strupp (1995) described malnourished and re-fed rats as having impulse control and temperament problems, which sounded similar to the attention and temperament findings in Hack et al. (1995) and Chapieski and Evankovich (1997). The effects increase with decreasing birth weight in relation to the increasing difficulties in providing adequate nutrition to smaller infants. If, as Gunnar and Barr (1998)

suspect, developmental disturbances are related to brain programming early in life. fluctuations in hormones caused by nutritional manipulations or even normal feeding may contribute to the observed outcomes. Finally, there is Brown & Pollitt's (1996) contention that nutrition may be a protective factor.

Prematurity and growth delays

Hay (1996) points out that growth delays begin very early in the life of preterm infants. In general, the infants discussed previously have been appropriately sized for their gestational age at birth, i.e., they are born too early but not too small. There are nutritional differences and growth rate differences between infants that are appropriately sized for gestational age and those who are too small for their gestation age or are growth retarded in utero (Crawford et al., 1993). Unless specifically stated, preterm infants will continue to refer to those who are appropriately sized for their gestational age.

In the course of their hospitalization, 90 preterm infants fell from a weight for age z-score of -0.25 at week one to -1.22 at discharge ($p < 0.0001$). Breastfed infants were significantly smaller than formula fed infants at discharge with a weight z-score of -1.53. Protein and energy intakes were lower in infants receiving breastmilk instead of formula probably accounting for the poor growth results (Simmer, Metcalf & Daniels, 1997).

deRegnier, Guilbert, Mills and Georgieff (1996) studied alterations in body composition in very low birth weight infants (less than 1500 grams) who developed bronchopulmonary dysplasia (BPD). Both the control and BPD groups showed significant reductions in growth in the immediate postnatal period, with length falling to one standard deviation below the mean. In the group that developed BPD, the lengths of the infants continued to fall to two standard deviations below the mean by the end of the study period.

The subjects in the control group, however, showed no catch-up growth. At the end of the study period, the average weight of the controls was still one standard deviation below the mean. Johnson (1995) followed infants with BPD, until one year of age and concluded that growth delays continued in the first six months after hospital discharge with significant decreases in weight for age z-scores. Developmental delays were seen in 68% of the infants with weight or length less than the 5th percentile on NCHS growth charts, but only in 26% of those with more acceptable growth measures ($p = 0.006$).

Follow up studies of growth, during the first three years, suggest that catch-up growth does not occur after the baby goes home. Casey et al. (1991) have shown that in the first three years, growth remains parallel to, but below that of normal birth weight infants. There was limited catch-up growth in the first six months of life, but at the end of the study period the smallest infants at birth were still the smallest at three years of age. Ovigstad et al. (1993) studied children born at less than 1500 grams in the Netherlands and found catch-up growth was still continuing at 5 years of age: with only 40% of the children less than the 30th percentile at age five as opposed to over 60% at less than the 30th percentile at 6 months of age. But 19% of the population remained below the 10th percentile at age 5. Regression analysis showed that length at one year, length percentile at one year, height at two years and weight at two years, were significant predictive variables of height at age five. Additional predictive variables of height at age five were parental education, total parent height, gender of the child and hypertension during pregnancy. Hirata and Bosque (1998) followed infants born at less than 1000 grams until ages 12 to 18, and found that all of the children measured met their growth potential. However, less than one third of the original sample was measured in the follow up study and none of the children had neurologic or

health problems so the representative nature of the sample is suspect. However, the results certainly indicated that catch-up growth was possible for at least some children.

Small for gestational age (SGA) infants born at less than 1500 grams were compared with two groups of appropriate for gestational age (AGA) infants. One AGA group was matched with the SGA group on basis of weight and the other was matched on the basis of similar gestational age. After three years, the SGA infants were smaller than both of the control groups ($p < 0.5$), showing that these children also have poor catch-up growth. The development of SGA infants was significantly delayed at 3 years of age when compared to the gestation matched controls but was similar to the children matched on birth weight. In all the infants, there was a strong correlation between head circumference at one year of age and performance on the McCarthy General Cognitive Test at age 3 (Sung, Vohr & Oh, 1993).

Ross, Krauss and Auld (1983) found that preterm infants born at less than 1500 grams who had normal Bayley Motor and Mental Exam scores (>85) were significantly larger than those infants who had lower scores at one year of age. Hack and Breslau (1986) followed very low birth weight infants (<1500 gm) until age 3 and studied their Stanford Binet IQ results as a function of catch-up growth. Head circumference at 8 months adjusted age was the growth variable most significant in predicting IQ at age three, explaining 6% of the variance. If the infants had normal head circumference (+ 5th %ile) at both 8 and 20 months adjusted age, mean IQ was 94.9 (average IQ = 100). If the head circumference was normal at 8 months and fell below normal at 20 months, IQ was 97.4, with no significant difference between groups. However, if head circumference was below normal at 8 months and there was catch-up growth by 20 months, IQ was only 79.2. If head circumference was

below normal at both measurement points. IQ was 79.3 (four factor analysis of variance $p < 0.005$). When one adds Johnson's (1995) previously discussed work, to that of Ross et al. (1983) and Hack and Breslau (1986), the circumstantial case for a relationship between early catch-up growth and normal development seems strong.

Intervention based research

A large multi-center trial of early intervention educational services tried to affect the developmental delays seen in premature infants. In-home education services were provided for the first year of life and two additional years of services at a day care center were also provided. At eight years of age, developmental gains were seen only in the intervention group with birth weights over 2000 gm: the group our previous discussion has shown to be least at risk (McCarton et al., 1997).

Two reports of a long-term longitudinal study (Lucas et al. (1990), Lucas, Morley, Cole, Lister, & Lesson-Payne, 1992) specifically examined nutritional affects on the development of preterm infants. The first study looked at the effects of feeding an enriched preterm formula to infants weighing less than 1850 gm. The formula was fed for a median of four weeks before discharge from the hospital. At 18 months, there was a 15 point increase in motor development scores for appropriate for gestational age infants, and a 23 point increase in small for gestational age infants (Lucas et al., 1990). Lucas' work indicates a very early sensitive period for nutrition intervention. In the second study, Lucas et al. (1992) looked at the IQ scores of 7 1/2 to 8 year olds who were pre-term infants fed breast milk by nasal-gastric tube. There was a significant advantage for feeding breast milk even when the scores were corrected for social class. There also was a dose response to the breast milk with higher scores associated with greater quantities fed. The researchers

speculated that the effects are related to the very long chain fatty acids in breast milk. Breast milk was also related to decreased incidence of allergy development in children with a family history of allergy (Lucas, Brooke, Morley, Cole & Bamford, 1990), and normal bone mineralization at age 5 despite of concerns with the adequacy of calcium and phosphorous in human milk (Bishop, Dahlenburg, Fewtrell, Morley & Lucas, 1996).

The randomized and prospective nature of Lucas' work has transformed thinking in neonatal nutrition in the 90's. It is the basis of much of the research into the importance of very long chain fatty acids and is the reason breast milk is now the preferred feeding in neonatal intensive care units (American Academy of Pediatrics, 1998; Anderson and Pittard, 1997; Simmer et al, 1997). However, the weight gain results in Lucas et al. (1990) were 15.8 gm per day (SD \pm 0.3), which was higher than the 14.0 gram per day weight gain (SD \pm 2.0) seen in Simmer et al. (1997). Variations in growth rates were seen when De Klerk et al. (1997) varied energy and protein intakes in infants in the NICU. The 'slow growers' gained 16.0 gm per day (SD \pm 1.9), similar to the gains reported by Lucas et al. (1990), but the 'fast growers' gained 21.9 gm per day (SD \pm 2.3) and had higher protein and energy intakes. In addition to the difference in weight gain, the rapid growers were female, had higher heart, respiratory and metabolic rates and spent more time in active sleep. De Klerk et al. (1997) speculates that higher protein levels lead to alterations in neurotransmitter synthesis with fast growers having lower serotonin levels than slow growers. They also speculated that the hormonal flux associated with eating might have developmental effects. Whatever the nutrient effects, the difference in weight gain in the three studies seems worth noting. There are so many variables to consider in the feeding of these very fragile infants that a rush to judgment on the "best" feeding practice is still premature.

The previous interventions were based in the acute care period of hospitalization. Bryson et al. (1997) compared growth data in the first year of life between children cared for in a major medical center's general pediatric clinic with those attending the same center's multidisciplinary comprehensive care clinic that included a nutritionist. All of the infants studied had birth weights less than 1500 grams. They found improved growth rates, at one year adjusted age, in the comprehensive care group, with 90% of the infants achieving greater than the 5th percentile in head circumference compared to 52% in the general pediatric clinic.

Summary

Recent research seems to indicate a critical period for an interaction between nutrition and development in the third trimester of pregnancy and the first three months of life. The severity of problems faced by very low birth weight infants certainly indicates the need for a positive proactive approach to nutrition in this early period (Anderson & Pittard, 1997; Batshaw & Perret, 1992; Casey et al., 1991; Hay, 1996). Even a small reduction in the disability rates would provide significant improvements in the quality of life for these children and their families and savings in the cost of their education and care to society as a whole.

Jackson (1992) articulates a philosophy for dealing with children at risk. Some premature infants may do well, but all of them are at risk for delayed developmental and for nutritional deficits. The goal for community care providers should be to identify and initiate treatment in what Young and Scrimshaw (1979) describe as the pre-clinical period. (Figure 1) Achievement of this goal requires anticipation so that intervention starts when there are indications of delays in development but before gross manifestations are evident.

Family centered care for premature infants

Why family centered care?

The Individuals with Disabilities Education Act provides multidisciplinary early intervention services from birth to age three to children at risk for developing educational problems. The definition of at risk is broad and encompasses children who would be classified as low birth weight. The covered services extend well beyond education and include nutrition, physical therapy, occupational therapy and speech therapy among others (Cloud, 1997; Schultz-Krohn, 1997).

Integral to the entire program's design is the concept of family centered practice: the importance of focusing interventions on fostering the parent child bond, not just on isolated skill development or individualized needs of the infant. The goal is to shift to a focus on family's skills and strengths, instead of a narrow view of only the infant's problems. Family centered practice recognizes that infants are cared for in a family context and separating the two is not practical (Schultz-Krohn, 1997).

The position of the American Dietetic Association (1995) is that nutritional care provided for these children should be preventative, and family centered. They define family centered care as that "in which the pivotal role of family in the lives of children is recognized and respected" (pg. 810). The Association recognizes the importance of supporting families in their care-giving role and encourages interventions that promote normal patterns of living through collaboration with families.

The traditional model of caregiving used in medicine has a tendency to develop dependency in patients. Medical caregivers, including nutritionists, are trained to identify problems and implement solutions, suggesting that if families can do this for themselves.

there is no need for the caregiver. Thus, the caregiver tends to foster a sense of dependency, to support the caregiver's own sense of competence. Unfortunately, a sense of dependency leads to either alienation with the caregiving process or a sense of hopelessness (Dunst, Trivette, Davis, Cornwell, 1988).

An alternative model of caregiving is one that supports and empowers families. By providing learning experiences, or information that supports the family's sense of competence, the caregiver can enable the family to meet its own needs and the needs of the child. In this enabling and empowering model, the caregiver does not identify problems or provide explicit solutions, but assists the family in identifying problems and supports problem solving efforts by providing information, access to services or even just encouragement and emotional support (Dunst et al., 1988). Research suggests that interventionists are able to provide both factual and social support to increase families' sense of competence and that when self identified needs are met families have a greater ability to implement interventions recommended by early intervention education programs (Dunst, Leet & Trivette, 1988; Dunst, Trivette, Hamby & Pollock, 1990).

Baroni and Sondel (1995) developed a model for delivering nutritional care in which acceptable outcomes for interventions included providing reassurance, or anticipatory guidance in response to parental concerns. They felt that improved communication was as important as improved physical outcomes, e.g. growth. Brotherson et al. (1995) developed a modification of the family systems model that addresses feeding issues in families with children with a disability. There are five areas that interact to describe family functions: *family characteristics*, objective descriptors that define the family; *family interactions*, including family member roles, extended family support and the use of other support

systems; *family perceptions*, the meaning the family places on events or how they interpret information, and *family quality of life*, or how the family feels about their ability to meet family members' needs for happiness and satisfaction. As change is inevitable for families with children, the effects of time and growth surround the other factors and are represented by the *life cycle* area. The model assumes families make decisions that maximize the quality of life for the entire family, rather than just a single family member.

Professional and parental perceptions

Family centered care requires that family needs be met, but research suggests that professionals are not very good at identifying family needs. In studying maternal recall of the NICU experience, researchers discovered that interactions with NICU staff were a significant source of stress for the mothers, while information and emotional support decreased stress (Wereszczak, Miles & Holditch-Davis, 1997). Warzak, Majors, Ayllon, Milan and Delcher (1993), found that professionals identified medical complications and monitoring procedures as problems to be overcome in delivering pediatric diabetic care, while parents were concerned about how the disease affected their interaction with their child and the child's interactions with others. Epps and Kroeker (1995) provided family practice physicians with case studies in which parents expressed concern about their child's development and reported symptoms of developmental delay, but the physicians were reluctant to diagnosis mild delays in the younger children. Although these were hypothetical case studies, "parents" reported problems that were dismissed by the physician. Michaelis, Warzak, Stanek and Van Riper (1992) found that parents of children who had received long term tube feedings at home were more likely to identify social support issues as problems than health professionals, who tended to identify technical care issues as

problems. Families were concerned with decreased social support evidenced by problems finding baby-sitters, and having their child viewed negatively by the larger community. Brotherson et al. (1995) also identified poor information from professionals as a problem families had to confront when making nutritional care decisions. This lack of information influenced the family's perceptions of the nutritional adequacy of their child's diet and their understanding of the need for a feeding tube. Only one of eight families were given information about contacting another family who had made a decision to use a feeding tube: seven families wished they had the information (Brotherson et al., 1995). Families focus on the need for support and the effect of the intervention on the child's interactions within the family and the community, while health professionals focus on issues of technical care and compliance.

Family interaction

There is evidence that the birth of a high-risk child transforms the interactions within the family, both interactions between the parents, and those between the parents and the child. The theory of transformed parenting (Seideman & Klein, 1995) suggests that after the initial shock and adjustment, there is a series of continuing adjustments between the expectations of normal parenting and the reality of parenting a high-risk child. These adjustments are often stepwise as the realities of their child's disability reaches the parent's awareness. A critical part of the process of successfully parenting a high risk child is the ability of the parent to make these adjustments, and to see their child as valuable while acknowledging the realities of the disability (Seideman & Klein, 1995).

Parents of preterm infants had lower interaction scores when teaching their child a standardized task, than a matched group of parents of term infants. This difference was not

explained by parent stress as measured by the long form of the Parenting Stress Index (PSI), or by infant behavior or by socioeconomic factors. The researchers speculate that this finding may be related to development of the vulnerable child syndrome, in which parents' perceiving their child as weak or sickly, alter their behavior (Harrison, Magil-Evans, 1996).

Robson (1997) found that five years after the birth of their infants with low birth weight, mothers with high stress as measured by the long form PSI (equal to or greater than the 85thtile on any of the 3 scales) had children with significantly lower scores on the McCarthy Scale of Children's Abilities. The total PSI score was negatively correlated with development during both infancy and childhood.

Affleck, Tennen, Rowe, Roscher and Walker, (1989) discovered that mothers of preterm high risk infants with post-discharge medical problems, who had high needs for support, responded with increased competence to a support program of monthly visits by a nurse to discuss issues of growth and development. In contrast, mothers with low social support needs and a relatively healthy infant responded to the support visits with decreased parenting competence scores. The results are consistent with the premise of family centered care. If the mother perceived a need for support, she benefited from the additional support provided by the program, suggesting that if the mother did not require support, the intervention upset the mothers system of coping. Bradley, et al. (1994) found that low birth weight premature children living in poverty had better developmental outcomes at age 3 if they had at least three protective factors in their environment. These included less than one person per room in the dwelling, a safe play area, a variety of learning materials and parental acceptance.

Miles and Holditch-Davis (1997) extensively reviewed the literature and concluded that the lingering emotional impact of the NICU experience and the difficulties of caring for a preterm infant negatively affected parenting in the first year by adding a sense of disappointment and sadness to the process. Mothers of preterm infants need to work harder to obtain reactions from their infant and the infant returns fewer positive responses than term infants. It is not known whether this is a result of the altered interaction or is inherent in the differential development of preterm infants. But the researchers found that changes in parental behavior persisted as the children grew. Although it is not clear exactly how parenting is changed, Miles and Holditch-Davis (1997) suggest that altering their perception of the child, to be seen as weak or vulnerable, leads the parent to initially stimulate the child less, and then to be overprotective in the preschool period. Mothers may also deny health or behavioral problems, in an effort to view their child as more normal. This explanation for the observed developmental differences in preterm infants is remarkably similar to the alteration in parental behavior described in Brown and Pollitt's (1996) model of the interaction between growth, development and nutrition

Family centered interventions

Focus group research into nutritional service needs for children with special health care needs suggests that parents are concerned about their child's feeding, nutrition and growth whether or not these concerns are shared by a health care provider. Nutrition information is strongly identified as a need. The families prefer to have an ongoing relationship with the provider, rather than one time visits (Bonam, Gale & Zrueger, 1993). Cross-McClintic, Oakland, Brotherson, Secrist-Mertz and Linder (1994) also identified nutrition information as an unmet need in families. Baroni and Sondel (1995) found that

failure to respond to parental concerns was secondary to a lack of communication between caregivers. Part of the problem with delivering this needed service is the lack of dietitians trained in developmental issues, and part is the difficulty in paying for nutritional services (Baroni & Sondel, Ekvall et al., 1993; and Cloud, 1997). Because paying for nutritional intervention is a long standing problem, innovative techniques for delivering nutritional information need to be developed if we are to meet the need for nutrition information identified by families.

**GROWTH PATTERNS AND NUTRITIONAL FACTORS ASSOCIATED WITH
INCREASED HEAD CIRCUMFERENCE AT 18 MONTHS IN NORMALLY
DEVELOPING LOW BIRTH WEIGHT INFANTS**

A paper submitted to the Journal of the American Dietetic Association

Tay Seacord Kennedy, Mary Jane Oakland, Robert D. Shaw

Abstract

Objective

To identify patterns of growth, nutritional practices and/or feeding behaviors associated with normal Denver II developmental screening results at 18 months of age.

Design

A retrospective chart review was conducted on hospital medical records to collect discharge diagnosis and dietary data. Developmental clinic charts were reviewed to collect growth, diet, Denver II results, and medical data from 4, 9 and 18 month visits.

Subjects/Setting

Twenty-eight children were identified from a review of developmental clinic records in a mid-western children's hospital. Criteria were single or twin birth < 2000 gm. initially admitted to the hospital, and three screening visits.

Statistical analyses performed

Z-scores were calculated using national standards. Patterns of growth were analyzed using analysis of variance accounting for random subject effects associated with serial measurement. Stepwise forward linear regression was done to construct a model for predicting head circumference at 18 months.

Results

Catch-up growth occurred in length ($p = .0006$) and weight ($p < .0001$). A model was developed that explained 99.5% ($r^2 < .000$) of the variability in head circumference at 18 months. Nutrition and growth variables included 9 month head circumference, type of parenteral amino acids, z-score of weight at 4 months adjusted age, and time of first enteral feeding.

Applications

Interventions designed to support breastfeeding in the hospital and at home are indicated with increased emphasis on growth monitoring. Growth delays need to be treated aggressively, with nutritional interventions beginning by 4 months if weight gains are not appropriate

Introduction

With advances in neonatal medicine, the number of very low birth weight infants who survive is increasing. These children are at increased risk for growth abnormalities, developmental delays and chronic illness (1, 2, 3). There is good reason to believe that pre-term infants are at nutritional risk because of the difficulties associated with feeding in the neonatal period (4, 5, 6). Unfortunately, interventions to decrease the number of premature births have been disappointing (7) and randomized experiments using early intervention educational services to improve developmental outcomes have had disappointing results (8, 9). But those low birth weight, premature infants who also grow well seem to have better developmental outcomes (10, 11).

In contrast to the poor results seen with education interventions, nutritional intervention in the first year of life has been associated with improved growth and better

developmental outcomes in low birth weight infants (12, 13, 14). Studies in developing nations show that early growth faltering, similar to that seen in premature infants, responds best to supplementation before 18 months of age (8, 15). While there are many factors that influence the growth and development of a child at risk, good nutrition is necessary for an optimal outcome.

The study of successfully growing members of a high-risk population, or the study of positive deviants, is based on the assumption that the determinants of successful growth are not necessarily the reverse of determinants of growth failure. By studying "successful" infants, it may be possible to identify nutritional or growth factors that may be used to tailor treatments, target interventions or design educational programs helpful to the general population of high risk infants (16, 17). Positive deviance studies have been done in child development to identify social factors associated with positive outcomes (18, 19, 20) and in clinical nutrition to identify factors associated with nutritional wellness (21). The infants described in this report had a classic pattern of catch-up growth with weight increasing first and then length accompanied by increased caloric intakes early in life (22). They demonstrated significant catch-up growth and good developmental outcomes at 18 months, in spite of the fact that they are part of a group at increased risk for growth and developmental delays.

Methods

Data were collected from a retrospective chart review of 28 infants born between January and December 1994 who were followed by the developmental clinic of a mid western children's hospital. The infants completed the normal 18 month follow up at the developmental clinic and were graduates of the level III neonatal intensive care unit (NICU)

at the hospital. All single or twin births, with a birth weight of 2000 gm or less, which completed the developmental follow-up were included. All of the infants were premature although this was not a specific selection criterion. One hundred five infants meeting the birth criteria were referred to the developmental clinic during the study period.

Discharge diagnosis data were collected from the medical records of the NICU hospitalization. Physician notes and orders were reviewed to determine nutritional care during the hospital stay. Data were collected on growth, diet, Denver II developmental screening results, and recent medical history from the developmental clinic at the 4, 9 and 18 month screenings. The developmental clinic is staffed by a pediatric nurse practitioner, who collected all the post hospitalization data. She provided information to families at the developmental screening visit on normal developmental milestones, infant nutrition and growth parameters. All the children received regular medical care in addition to the developmental follow up.

To standardize growth data and to allow comparisons over time, z-scores were calculated by EPI Info, version 6.03 (Division of Surveillance and Epidemiology, Centers for Disease Control, 1995, Atlanta GA). A length or weight observation is converted into a z-score by subtracting the mean weight/length for a specific age of the reference population from the observed growth measurement and then dividing the result by the reference population's standard deviation.

Three way analysis of variance was done to account for the serial nature of the growth data using SAS, version 6.12 (SAS Institute, 1989, Cary NC). Stepwise forward linear regression was done using growth, hospital and developmental screening data to predict head circumference at the 18 month screening. Variables were included at the $p \leq$

0.05 significance levels and dropped at a subsequent step if the variable's significance dropped below the $p \leq 0.10$ level. Missing data were replaced by the variable mean. To examine the relative importance of the variables selected for the regression model, coefficients for a standardized regression were computed where the response variable and all explanatory variables were standardized by subtracting the mean and dividing by the standard deviation of the respective variables. The standardized regression coefficients directly reflect the size of the partial correlation (the correlation adjusted for other variables in the model) between head circumference at 18 months and each of the variables selected for the model. Frequencies and regression calculations were done using SPSS for Windows (Statistical Package for the Social Sciences, version 7.5, 1996, SPSS, Inc., Chicago IL.)

Results

Twenty eight infants were included in the study; 18 singleton births and 5 sets of twins. All but two infants were Caucasian, reflecting the local population. Clinical characteristics of the group are summarized in Table 1. Two infants weighed less than 1000 gm at birth (928 gm and 810 gm). The only infant identified as small for gestational age also had the smallest discharge weight. One infant was discharged home in a cast, so discharge weight and weight gain was not reported.

High risk problems identified from discharge diagnosis are listed in Table 2. Most of the infants had more than one of the identified problems. None had necrotizing enterocolitis. The summary category, 'maternal medical problems,' includes medical conditions not related to delivery or preeclampsia.

Eight of the infants received no total parenteral nutrition (TPN). Of the 20 who did receive TPN, one started on the first day of life; two on day 2; fifteen on day 3; and the last

two on day 4. Eight received a standard adult formulation as an amino acid source and 12 received a pediatric amino acid product. Because of cost considerations, infants were given the pediatric parenteral amino acid solution only if they were less than 1250 gm at birth or less than 30 weeks gestation or were thought to need TPN for more than 2 weeks.

Essentially the sickest infants received the pediatric amino acid solution.

Enteral feedings started for seven infants on day one of life. All infants had some type of enteral feeding by day 8. Fourteen infants (50%) started on expressed breast milk, 7 on breast milk mixed with premature formula and 5 (18%) on formula alone. After one week of age, human milk fortifier was added to the breast milk given to infants with a gestational age of less than 34 weeks. In two cases, where the initial feeding order was unclear, one infant was discharged on breast milk, the other on formula. Twenty-one infants received some breast milk initially and 16 were still receiving some breast milk at discharge.

Six infants were still at least partially breast fed at the four month developmental screening and 2 at nine months. Three quarters of the infants had some exposure to breast milk, which has been shown to have a positive developmental effect on low birth weight preterm infants (14). This finding should encourage increased efforts to support mothers of preterm infants to follow the breastfeeding guidelines for the general population.

At the 4 month screening, the mean caloric intake of the bottle fed infants ($n = 23$) was 116 kcal/kg ($SD \pm 25$), 7% higher than the recommended dietary allowance (RDA) for age. Ad libitum intake at home ranged from 75 kcal/kg to 204 kcal/kg. More than half (61%) of the infants took more than the RDA level of 108 kcal/kg (23). As the RDA's may overstate the calories needed for normal growth rates (23), the increased intake of this group

is more remarkable, and certainly consistent with the increased energy and nutrient needs of catch-up growth.

Z-scores of discharge weights were computed assuming that discharge weight was comparable to term birth weight. Seventeen out of 28 infants were over 37 weeks gestation at discharge and only three were less than 36 weeks gestation when discharged. At discharge from the NICU, the infants' mean weight was $-2.97 \pm .53$ standard deviations *below* the mean birth weight of term infants. Z-scores for weight and length for age, and weight for length were individually computed for each infant using the length and weight at screening and adjusted age (chronological age - weeks premature = adjusted age, ex. 2 months chronological age - 4 weeks premature = 1 month adjusted age). There was rapid weight gain in the first few months, with the mean weight for adjusted age rising to a z-score of + 0.64 and weight for length rising to a z-score of + 1.75. By the 18 month developmental screening visit, all the mean growth parameters had normalized for adjusted age, signifying that the infants had significantly caught up in growth with their adjusted age peers (Table 3). All the infants had Denver II developmental screening within normal limits at the 18 month screening, although one infant had questionable results at 4 and 9 months and 9 had questionable results at the 9 month screening.

Discussion

The premature infants studied had a degree of growth retardation from their hospitalization as evidenced by the very low z-score at hospital discharge (- 2.97), but they also had increased intakes that lead to accelerated growth rates in the first nine months of life (Table 3). The temporal relationship of the observed growth and intake changes is similar to the catch-up growth seen in re-fed malnourished children. In both cases, the

infant's weight increases first, and then head circumference increases, with catch-up growth in length lagging by several months (22). Early repletion leads to better catch-up growth as growth velocity is already high in first six months of life, and there has been less time for a growth deficit to develop (24, 25). In this study, catch-up growth was first demonstrated by the high weight for length z-scores at the 4 month screen (Table 3). This might be of concern but for the fact that weight for length normalized by 18 months. One might suspect that a higher early weight for length relationship might have lead to greater catch-up growth in length. The positive developmental outcomes seen in the study group and in other studies of premature infants with good growth rates may reflect that cell division in the neurological system is still active and the possibility of repair of defects still exists (26, 27).

A regression model was developed that explains 99.5% (r square: $p < .000$) of the variability in the population. Regression coefficients are also listed as standardized coefficients to give some indication of the relative importance of each variable to the outcome. Sixty-four variables were included in the regression modeling, including birth and diagnosis data, information on feeding in the hospital and after discharge and growth data from the developmental screening visits. In the initial step of the modeling process, birth weight, gestational age, respiratory distress, ventricular hemorrhage and invitro fertilization were significantly correlated with 18 month head circumference, but they were not included in the model as their significance decreased as other terms were added. Calories/kg at four months, use of special formulas, or z-score of growth parameters other than 4 month weight were never close to significance in the modeling process.

Discharge weight, nine month head circumference and nine month length measurements are actual measurements: not age adjusted (Table 4). The 4 month z-score for

weight is the screening measurement standardized to the infant's adjusted age at the time of the screening. Other infant problems, is a summary category of low incidence diagnoses. The results ranged from 0 to 3 and may reflect the severity of the infant's other problems. Females had a better outcome. Age at discharge in days and increased length of stay reflect both lower gestational age and increased severity of the infant's clinical course.

In the standardized coefficients, the pediatric parenteral amino acid variable is second in importance behind 9 month head circumference. In spite of the preferential use of pediatric parenteral amino acid for the sickest infants, there was a significant positive increase in head circumference at 18 months over the use of an adult amino acid formulation. There is concern that the relative effectiveness of the two solutions is not different enough to justify the difference in cost (6, 28). Further investigation of the comparative effects of the two products on developmental outcomes may be indicated.

There was a slight negative correlation with the 9 month length and the early start of enteral feeds. If feeding was started on day one of life, there was a small decrease in head circumference at 18 months, but a delay in starting enteral feeds until day 5 had a 5 times greater negative effect (5 times the negative regression coefficient). The results suggest that beginning enteral feedings early is beneficial (6, 28).

Many of the variables identified are associated with or influenced by nutrition. Growth variables, like discharge weight, length, weight and head circumference are standard measures of nutritional risk in infants, and are highly responsive to nutritional intervention. The choice of the source of protein in parenteral solutions is a direct nutrition intervention, as is the timing of the introduction of enteral feeds. Only gender, hyponatremia, jaundice and the catch all category, "other problems," are not directly affected by nutrition.

Application

Nutrition may be a major contributing factor to developmental delays observed in premature low birth weight infants as evidenced by the results of this study. The use of a positive deviance design suggests that the choice of a pediatric parenteral amino acid in the hospital, the liberal use of breast milk and early catch-up growth are protective and that interventions designed around these factors may improve outcomes. Information on the importance of catch-up growth to normal development and education on nutritional strategies to support increased growth rates should be incorporated into discharge planning and follow up pediatric care protocols. Out patient growth monitoring should start at discharge from the NICU and nutritional interventions begun if growth delays persist to four months of age. As educational intervention has not been effective (9) and nutritional intervention has produced positive results (8, 12, 13, 14), further investigation into strategies to improve the nutritional status of low birth weight infants very early in life may be indicated.

Increased emphasis on early nutrition and growth may be facilitated by improving access to nutrition services provided by early intervention programs under the Individuals with Disabilities Education Act (1).

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TABLE 1: Clinical characteristics of infants (n = 28)

	Range	Mean	Standard deviation
Birth weight. gm	810-2000	1534	371
Gestational age. wk	26-34	31	2.6
Age at discharge. day	19-105	49	25
Discharge weight. gm	1590-3170	2430	354
Weight gain. gm	255-1995	886	512

TABLE 2: Frequency of high risk discharge diagnosis (n = 28)

	n	%
Feeding problems	21	71
Respiratory problems	17	60
Apnea	10	52
Maternal medical problems	7	25
Broncho-pulmonary dysplasia	4	14
Bradycardia	4	14
Ventricular hemorrhage	2	7
High risk social situation	2	7

* each infant could have more than one problem

TABLE 3: Growth statistics: mean z-score for adjusted age and standard deviation

(n = 28)

	4 month developmental screening visit	9 month developmental screening visit	18 month developmental screening visit	ANOVA between groups
Z-score weight for adjusted age	0.64 ± 0.98	0.03 ± 0.99	- 0.27 ± 0.79	p < .0001
Z-score length for adjusted age	- 0.87 ± 0.88	- 0.67 ± 0.76	- 0.45 ± 0.77	p = .0006
Z-score weight for length	1.75 ± 0.93	0.75 ± 0.90	0.10 ± 0.84	p < .0001

TABLE 4: Regression coefficients of 18 month screening head circumference. cm.

(n = 28)

Dependent variable	Regression coefficient	Standardized regression coefficient	p value
Constant	19.79	-	.000
9 month head circumference. cm.	0.78	0.70	.000
Pediatric parenteral amino acid	0.76	0.38	.000
Hyponatremia	2.15	0.24	.000
Other infant problems	0.44	0.23	.000
Weight z-score at 4 months	0.42	0.21	.000
Gender	0.34	0.09	.000
Discharge weight. gm.	0.00	0.07	.017
Jaundice	0.20	0.05	.031
Enteral feeding started. day	-0.08	-0.10	.003
9 month length. cm.	-0.12	-0.16	.000
Age at discharge. day	-0.02	-0.33	.000

A COMMUNITY NUTRITION INTERVENTION WITH FAMILIES OF PRETERM LOW BIRTH WEIGHT INFANTS

A paper to be submitted to the Journal of the American Dietetic Association

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Abstract

Objective

To investigate the outcome of a telephone intervention providing monthly nutritional guidance and support to families on growth and development of infants born at less than 1750 grams and to evaluate the effects of the support offered in the intervention on the stress levels of the infants' mothers.

Design

A randomized prospective family centered intervention was designed to provide anticipatory nutritional guidance and support for family feeding decisions. Randomization occurred within 3 birth weight groups.

Subjects/Setting

Infants born at less than 1750 grams were recruited at discharge from a level three neonatal intensive care unit (n = 29). The intervention group was followed at home through monthly phone visits.

Statistical analyses performed

Growth measurements were standardized by calculating z-scores using national standards. Regression modeling was done using growth data. Spearman correlations were calculated using the intervention variable and maternal scores from the Parenting Stress Index®: short form.

Results

Growth in length was normalized at one year adjusted age ($p = .08$) after using regression modeling to control for the effects of bronchopulmonary dysplasia. Maternal stress related to parental expectations was negatively correlated with the intervention ($p = .027$). Infant's 24-hour recall intake results were pooled and averaged 117 kcal/kg at the 4 month screening visit: significantly higher than the RDA for infants birth to six months of age ($p = 0.008$).

Application

Interventions that focus on early catch-up growth and ensuring that preterm infants have an intake higher than the RDA for age in the first few months of life may normalize growth and developmental outcomes and decrease maternal stress.

Introduction

Nutritional interventions have shown positive results in the growth and development of low birth weight infants (1, 2, 3). Although illness, socioeconomic status and family factors can also influence growth and development (4, 5, 6, 7, 8), good nutrition may compensate for the negative effects of some socioeconomic factors (4, 9). Poor health and/or nutrition have been implicated in the origin of developmental delays seen in low birth weight infants or poorly growing children because of alterations in parental perceptions of and expectations for their child (1, 10, 11). However, preterm infants who are able to grow well in the first year of life have been shown to have improved developmental outcomes (12, 13).

Families of children with special health care needs are interested in the nutrition and growth of their children (14, 15, 16), but research has show that these needs are not being

met with current systems of nutritional care delivery (14, 16). In addition to growth and developmental outcomes, positive effects of intervention can also be measured in terms of improved communication or increased information (16).

A nutritional intervention was designed to provide anticipatory nutritional guidance and support for family's decisions to meet the need, identified by families, for feeding and nutritional information. This intervention looks at the effects of nutritional guidance and support in the first year of life to see if nutritional status, growth rates and general health could be improved in a randomized group of low birth weight infants. It also examines the effects of an intervention on maternal stress.

Methods

Families were recruited from a mid-western children's hospital neonatal intensive care unit (NICU). Infants born at less than 1750 grams, both single and twin birth, whose families had a telephone and a primary caregiver who spoke English were referred. Two infants of a twin birth with a birth weight over 1750 grams were included in the study as the other twin met the birth weight guidelines. All infants were preterm, although that was not a specific selection criterion. Fifty-six families were identified as possible study participants, and 35 (63%) agreed to participate in the study. Two families withdrew from the intervention group, one because of returning to work and the other because of changing medical care for her child. Nine families were lost to follow up, five from the control group and four from the intervention group, leaving 24 families (29 infants, as twin births were included). There were 11 families and 14 infants in the intervention group and 14 families and 15 infants in the control group.

At entry into the study, families were randomly assigned to an intervention or control group within 3 birth weight groupings: <1000 gm, 1000 gm to 1449 gm, and >1500 gm. Mothers in both the intervention and control groups were asked to complete the parent distress section of the short form of the Parenting Stress Index ® (PSI) at entry into the study and to complete the entire form at the end of the intervention period (17). This instrument measures adjustment to the parenting role and has three subset scores as well as a total score. The subsets are: *personal distress*; or stress in life not directly related to the parenting role; *parent-child interaction*; which focuses on the parent's expectations for and perceptions of their child and how the child lives up to these, and the *difficult child* section; which looks at issues of child behavior and temperament (17). Reliability for the total score is alpha 0.91 and ranges from 0.80 to 0.87 for the subsets. Validity is derived from a correlation of .95 with the long form of the index. The instrument also includes a test for *defensive responding* or presenting an overly positive view of the situation. Four of the 23 responses were discarded for not meeting minimum scores on the defensive responding test. All of the families in the intervention group returned the PSI at one year of adjusted age, but only 60% (9/15) of the families in the control group. Socioeconomic status was calculated by the Hollingshead four factor social index from education and employment information provided by families (18). Medical information from the NICU hospitalization was collected from the hospital discharge summary. The Human Subject Review Boards of both the university and the referring hospital approved the study.

Families in both the intervention and control groups received regular medical care, but the infants were also evaluated for developmental progress at 4, 9, and 12 months, either at the referring hospital's developmental clinic or by the researcher who was trained in

developmental evaluation and growth measurement. The developmental clinic visit included growth measurements, a developmental assessment, and a dietary intake assessment. Clinic visits were all conducted by the same nurse practitioner. Information was provided to families on the developmental progress of their child, including growth monitoring and nutritional guidance adjusted for the child's prematurity. Six families did not visit the developmental clinic, because of distance from the center or conflicts with work schedules, so the main researcher visited them at home for the developmental assessments, growth measurements, and dietary intake assessment. Any questions families had were answered at that time.

In addition to the previously described care, the intervention group received a monthly phone call from the main researcher. The interviewer discussed current intake and nutritional concerns with a parent, generally the mother, asked for any growth measurements and reviewed recent health information (see Appendix 1 for details). The intervention was designed to provide anticipatory nutritional guidance in line with the recommendations of the American Academy of Pediatrics (19) and to support appropriate feeding decisions made by the family. Growth goals designed to promote catch up growth and were set between the 25 and 75 percentile length for adjusted age (chronological age -weeks of prematurity = adjusted age) and 50 and 75% weight for adjusted age on National Center for Health Statistics (NCHS) growth charts (20). Growth goals and nutritional guidance were given for the adjusted age of the infant. Caloric intake goals were set between 100 and 150 kcal/kg/day, based on the RDA for infants (108 kcal/kg for infants birth to 6 months and 98 kcal for infants 6 to 12 months), with an additional allowance for catch-up growth (50 kcal/kg/day) (20, 21). The complete intervention protocol is provided in Appendix 2.

Growth, developmental screening results, dietary and medical condition data were collected from the three screening visits scheduled at 4 and 9 months actual age and 12 months adjusted age. To standardize growth data and to allow comparisons over time, z-scores were calculated by EPI Info, version 6.03 (Division of Surveillance and Epidemiology, Centers for Disease Control, 1995, Atlanta GA). A length or weight observation is converted into a z-score by subtracting the mean weight or length for a specific age of the reference population from the observed growth measurement and then dividing the result by the reference population's standard deviation.

Analysis of variance and regression modeling were done using SAS, version 6.12 (SAS Institute, 1996, Cary NC). Frequency calculations were done using SPSS for Windows (Statistical Package for the Social Sciences, version 7.5, 1996, SPSS, Inc., Chicago IL.)

Results

Very low birth weight infants (< 1500gm at birth) were 66% of the total study population: 37% of all the infants had a birth weight less than 1000 grams. Sixteen out of the 29 (55%) were born at 30 weeks gestation or earlier. On average, the infants spent almost 9 weeks in the hospital after birth. Characteristics for the intervention and control group are presented in Table 1; none were significantly different. Twin births were 41% of the sample, 5 sets of twins and 2 infants whose twin died in the hospital. There were 13 girls and 16 boys, equally distributed between intervention and control groups (chi square $p = .57$). The most common medical complications during the period immediately after birth, obtained from the hospital discharge summaries, were sepsis, (82%), jaundice (79%), feeding difficulties of prematurity (69%), apnea, (69%) and respiratory distress (66%). Nine

infants developed bronchopulmonary dysplasia (BPD). 5 had an intraventricular hemorrhage, and 1 developed necrotizing enterocolitis. At 12 months adjusted age, 66% (19/29) of all the infants were developing normally when evaluated by the Denver II Developmental Screen, 10.3% had questionable results and 24% (7/29) had abnormal results. There was no significant difference between the intervention and control groups in developmental outcome.

The PSI was returned at one year by all of the intervention families (11) but only 9 of the 14 control group families, despite two follow up calls per family. One score in the intervention group did not meet the minimum for defensive responding and was discarded and three scores in the control group were discarded for the same reason. The mean total PSI score and that of the personal distress and difficult child subsets of all the mothers, both intervention and control, were scaled by the instrument at the 50-65 percentile of the general population (Table 2). In these three areas, mothers in our families were comparable to the general population. However, while the mean score of mothers in the parental expectations area in the intervention group was slightly higher than average (55th percentile), the mean score of the control group was at the 90th percentile, indicating that they are disappointed in their child (17). The intervention was negatively correlated with the parent-child interaction subset of the PSI (Spearman's rho correlation coefficient -0.568 , $p = .027$), suggesting that parents were more comfortable with their expectations of their child in the intervention group than in the control group.

Analysis of variance with blocking for birth weight groups showed no differences in weight for age, length for age and weight for length z-scores at 12 months (Table 3). Regression analysis was done to control for the effect of BPD on growth, as 6 of the 9

infants with BPD were in the intervention group. Results of the regression model suggested improved growth in the intervention group as measured by length for age z-score ($p = .08$). The model including the intervention/control variable and BPD explained 14.6% of the variability in length observed at 12 months actual age. After removing the effects of BPD, the mean length at 12 months adjusted age in the intervention group was essentially normal with a length for age z-score of -0.04 (z-score = 0 is average), while the control group had a length z-score of -0.79.

There was a trend toward decreased sickness in the smallest birthweight infants in the intervention group (chi-square: $p = 0.14$). Sickness was defined as any major illness requiring hospitalization or three or more occasions of minor illness, such as ear infection or colds, reported in any one screening period. Of the infants born at less than 1000 gm, 3 out of 5 control infants were positive for 'sickness', but only one of seven in the intervention group. The average birth weight in this group was only 895 grams, so even a small reduction in the rate of repeat illness may have much larger effects when viewed in terms of either the cost of medical care or of the effects on the family's quality of life. No significant effect was found from the intervention when the effects of socioeconomic status, maternal age, initial maternal stress, gestational age, and weight gain in the hospital were considered in the regression modeling process.

Information on formula use is presented in Table 5. Six infants were started on a special formula designed for preterm infants after hospital discharge, which the NICU physicians only recommended for exclusively formula fed infants with a birth weight less than 1000 gm. All the infants started solids between the four and nine month screening. At discharge from the study, at 12 months adjusted age, one infant from the control group was

still breast fed. One infant from each group received whole milk treated to reduce lactose levels, and one infant from each group received 2% milk, while one infant in the control group received 1% milk. The remaining infants were receiving whole milk at one year of age. 12 of 14 from the intervention group and 11 of 15 control infants.

Examination of entries from a log kept of the monthly phone calls to the families in the intervention group, revealed that all the families expressed at least one nutrition related concern. Information about the introduction of solids and finger food was requested by 10 of 11 families. Five families were concerned about early introduction of solid foods, before the child's adjusted age of six months. More than half (6/11) of the families had questions about gagging or difficulty swallowing. Two families requested information on allergies and medication. Additional questions were on microwaving food, use of vitamin supplements and adding salt to baby food. Nutritional concerns expressed after the infants were successfully eating baby food were minimal and of a general nature. At discharge visits, however, there were several questions about weaning from the bottle.

Recommendations were made to increase caloric intake to three families. The first was in response to a mother's request, with evidence of good weight gain. The other two were as a result of poor formula intake reported on the recall section of the interview. One mother was nonresponsive to the suggestion, as her first child "never took that much." The other child was admitted to the hospital soon after with pneumonia. At the developmental visit the next month, the chart contained a notation of 'excessive intake' suggesting the mother followed advice to feed the baby when she was hungry

Discussion

The finding of a relationship between the intervention and scores on the PSI has positive implications for future development. High total scores on the long form of the PSI have been negatively correlated with development in early childhood in research by Robson (11). The average score in the parent child interaction section of the test suggests that the intervention contributed to a positive establishment of the parent child bond, while the higher score in the control group suggest poor attachment and parental disappointment with the child (17). These changes in parental perception are consistent with those postulated to contribute to the development of delays in preterm infants (10, 11)

While the intervention showed significant effects in the area of stress reduction, there are a variety of explanations for the failure of the intervention to show more significant results in the area of growth. The power calculations performed in the planning phase were done using sample data from the referring hospital and the variability in the study was less than in the sample group, indicating a need for a larger sample size. Recent work in our group suggests that the intervention may have been too conservative. Weight for length at over the 90% early in life may be a better marker for nutritional catch-up growth than the weight and length for adjusted age goals used in the current intervention. The nurse practitioner who saw all but the six families evaluated at their home in the developmental clinic provided anticipatory guidance in line with that included in the intervention. This may have been an important confounding factor. Additionally, there was great variability in the nutritional guidance provided by the infant's regular medical practitioners. A qualitative study done as part of this project found that there was a difference in comfort with medical

advice based on family perceptions. Three of the six families interviewed were uncomfortable with aspects of the nutritional advice given them by their medical caregivers.

A significant finding from this study was that the intake of all the infants, both intervention and control, at 4 months actual age was higher (t test $p = 0.008$) than the RDA (20) for infants birth to six months (Table 2). This finding is consistent with previous findings from our group of 116 kcal/kg of intake at 2 months average age, from Johnson (22) of 114 kcal/kg at 2 months and from Lucas et al. of 137 kcal/kg at 1 month and 116 kcal/kg at 2 months (23). Of the four infants with intakes under 100 kcal /kg: three were sick the day of the developmental visit with an upper respiratory infection which could limit intake. During the recall, the mother of the remaining infant reported the child had 'GI distress' and the child was changed to soy formula soon after.

Energy requirements for infants are primarily calculated from intake data (21), so the finding that preterm infants voluntarily consume significant amounts more than the estimated requirement is strong evidence that preterm infants have higher energy needs. Currently, the American Academy of Pediatrics suggests preterm infants, after hospital discharge, have intakes similar to term infants (19). By applying intake guidelines appropriate for term infants, we may be limiting the energy intake of preterm infant to levels below their needs. The infants in our study were able to communicate to their caregivers their need for increased intakes, but many preterm infants are tube fed and require the intervention of a nutritionist, aware of the increased needs of preterm infants, to assure that energy needs are met.

Application

There are indications that a telephone based intervention can positively affect parental expectations and growth in length in preterm low birth weight infants. In infants born at less than 1000 gm. fewer infants were sick in the intervention group than in the control group ($p = .14$). An intervention that focused more strongly on increased caloric intakes immediately after hospital discharge encouraging increased velocity of weight gain might have been more successful.

Meeting energy needs is critical for attaining appropriate growth rates and intake studies are important indicators of energy needs in infants (21). This work suggests that intakes well over the RDA for age are required for preterm infants. This is particularly important as not all preterm infants have the stamina or oral motor coordination to take in the volume required for a higher caloric intake. Infants with these difficulties may require higher caloric densities than those found in regular term infant formula. An intervention similar to the one described could be implemented by early intervention education programs and might demonstrate an increase in effectiveness by employing a multidisciplinary team approach (1, 15). A proactive anticipatory approach to nutritional guidance and dietary modification may be more effective than waiting for evidence of growth failure to emerge.

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Table 1: Mean maternal (n = 25) and infant (n = 29) characteristics:

	intervention	control	p value t- test
Maternal characteristics: mean	n = 11	n = 14	
age	28	27	0.49
SES ^	39	34	0.37
initial parent stress. % ^^	55	50	0.70
<u>Infant Characteristics</u>			
	n = 14	n = 15	
birth weight, grams	1144	1320	0.27
gestational age, weeks	30	30	1.00
NICU weight gain, gm/day	23	21	0.28

^ Hollingshead four factor index of social status (18): 30-39 is lower middle class

^^ Parenting Stress Index®: short form (17)

Table 2: Mean maternal Parenting Stress Index® percentile at child's age of 12 months adjusted.

	intervention n = 10	control n = 6
total score	50	50
personal distress	50	55
parent child interaction	50	90
difficult child	50	65

Table 3: Mean z-score for intervention and control group at 12 months

	intervention	control
	n = 14	n = 15
weight for age z-score	-0.56	-0.39
length for age z-score	-0.14	-0.74
weight for length z-score	-0.10	0.20

Table 4: Average intake of bottle fed infants at 4 month screening. N = 28

RDA	mean intake	SD ^	95% CI ^^
birth -6 mo.			
108 kcal/kg	117 kcal/kg	18.3	110-125

^ SD: standard deviation

^^ 95% CI: 95% confidence interval

Table 5: Formula use of intervention (I = 14) and control (C = 15) infants

	discharge diet		diet at 4 month		diet at 9 month	
	I	C	I	C	I	C
breast milk (BM)	2	2	1	1	-	1
BM and formula	2	2	2	2	-	-
formula	6	8	7	7	10	9
inc. kcal formula	3	3	2	2	2	1
other ^	1	-	2	3	2	3

^ other category included elemental formulas and soy formula.

APPENDIX 1

INTERVIEW PROTOCOL

Hi! This is --- from ISU. How are you and name, doing this month? Have you adjusted to having name home yet? *or similar small talk on family situation based on past calls.*

- What is name eating this month?

Purpose: to discover amount and kind of formula and or solid foods

Prompts: to discover amounts of food and fluids and route of administration, i.e. breast, bottle, spoon, finger foods.

- Do you have any concerns about how name is doing eating?

Purpose: to discover if there are any feeding difficulties, if there are parental concerns about ability to tolerate or to swallow foods.

Prompts: Does name have any problems choking or gagging when eating? Does he/she have problems with coughing or a lot of colds? Does he/she have problems with constipation or diarrhea?

- Has name been to the doctor lately?

Prompts: What did the doctor say? Did MD give any feeding advice? If so what?

- Does name take any medications?

- Do you have any other questions or concerns?
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APPENDIX 2**INTERVENTION PROTOCOL**

- ❖ Encourage family to follow American Academy of Pediatrics (1993) advice: delay solids until four to six months or developmentally appropriate, continue formula feeding until one year, provide appropriate vitamin and mineral supplementation. Support mother to follow recommendations if she receives conflicting advice. Provide factual information to support or refute other advice in areas of concern
- ❖ Encourage intake of 100 to 150 cal. per kg to allow catch-up growth. Discuss with family ways to achieve intake goals, by changing feeding schedule, using higher calorie solid foods, increasing concentration of formula if appropriate.
- ❖ Discuss progress on growth chart. Use age adjusted values on NCHS growth charts with goal of achieving 50 to 75% weight for adjusted age and 25 to 75% length for adjusted age. Discuss with family if these are appropriate values based on parental heights and sibling growth patterns.
- ❖ Provide information and/or referrals as requested or as indicated by families concerns.

**MAKING FEEDING DECISIONS FOR PRETERM LOW BIRTH WEIGHT
INFANTS:
A FAMILY SYSTEMS APPROACH**

A paper to be submitted to Topics in Clinical Nutrition

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Abstract

Using a family system model and a qualitative research approach, the transcripts of interviews of mothers of low birth weight preterm infants were analyzed to provide nutritionists with valuable insights into the decision making practices of families. Analysis of the interviews showed that concerns about the nutritional care of their infants influenced the mothers' perceptions of medical care in their infants first year of life. Families identified a need for more information regarding the nutritional care of their infants, particularly following discharge from the hospital. Nutritionists with supplemental training in child development are uniquely qualified to meet this need.

Introduction

Family centered care for children with special health care needs is becoming the norm (1). To function most effectively on a multidisciplinary team, nutritionists need to understand how a family system model allows them to better understand feeding decisions made by families (2, 3).

Families with children with special needs have identified improved nutritional care as an important need (4). However, perceptions by health professionals of needs are not always the same as the perceptions of families (2, 5-6). Nutritionists generally use a model of care centered on an individual's well being, and are often dismayed to find that families are uncooperative or non-compliant. Closer examination of the situation, using a family

systems approach, may suggest that the family did not implement our intervention because they felt that the cost to the family's quality of life did not justify the changes necessary to promote maximum well being, or health, for a single member of the family. A family systems approach acknowledges that families make decisions to maximize the "quality of family life," or the family's satisfaction with life (7). This model also provides some insight into how families maintain this delicate balance between the family's quality of life and an individual's well being (8).

Research into effectiveness of early educational interventions demonstrated that a family's ability to carry out the prescribed intervention for their developmentally delayed toddler was significantly correlated to money management skills. Families with fewer concerns about money had more resources to devote to the care of their child with developmental delays (8). Although nutrition interventions improve the health and well being of a child with special needs (9, 10), family systems research has found that following feeding tube placement, families have increased stress secondary to decreased social support and experience a sense of loss because they no longer "feed" their child in a physical, nurturing sense (2, 6).

By examining the perceptions, feelings and interactions surrounding the feeding of low birth weight premature infants in the first year of life, nutritionists and other professionals can identify family needs and structure their interventions in a way that contributes to families' quality of life, in addition to the well being of the infants.

Methods

Six mothers of low birth weight premature infants were selected, using purposive sampling, from a larger study to represent a range of maternal age, socioeconomic status,

infant birth weight, and outcome. One father also participated in an interview. All infants were initially cared for in the same neonatal intensive care unit (NICU) in a mid-western city. The families were referred at discharge to a study examining growth and development of preterm, low birth weight infants during the first year of life. This sample was drawn from families that agreed to participate in that study. One family chosen for the interview declined and was replaced by a family with similar maternal and infant characteristics.

Data were available from the larger study on birth weight, medical care and developmental outcomes. Socioeconomic status was calculated using the Hollingshead four factor index (11). Maternal parenting stress was determined using the Parenting Stress Index ®; short form (PSI). Only the parent distress section of the PSI was administered initially and the entire instrument was administered at the end of the study (12). The interviews were performed at the end of the study period, when the children were one year adjusted age (chronological age - weeks of prematurity = adjusted age). The study was approved by the Human Studies Committee of Iowa State University.

The mothers were interviewed at their homes and the taped interviews were transcribed and reviewed by three reviewers, two nutritionists and a family health educator. An emergent design was used where the initial interview questions are periodically revised to reflect the emergence of new issues or to probe for more information on issues of interest. After the first three interviews, the initial set of questions was revised to focus on obtaining additional information regarding family support systems and information sources for the family.

The questions asked included:

- Can you describe for me your memory of how your child started eating in the NICU?
- How were decisions made about how your child was fed in the NICU?
- How satisfied were you with your role in the decision making process?
- What kinds of nutrition issues were you concerned about when you brought your baby home?
- What would you tell another mother to expect when she brought a baby like yours home?

The researchers read the transcripts and identified major themes with supporting statements from the transcripts. The major themes were then organized and integrated into the family systems framework. The process ended after six interviews as no new themes were emerging and the issues identified were consistent with those issues discussed by families in the larger study. A portion of the larger study group had monthly encounters with the main author, and discussed feeding problems. The issues raised in these encounters served as a member check for the in-depth interviews and prevented any themes from being missed.

Summary of Results

Brotherson, et al. (2) modified the classic family system model to fit nutrition issues. Figure 1 describes the model, with the addition of the major themes identified from this research. There are five areas that interact to describe family functions: *family characteristics*, objective descriptors that define the family; *family interactions*, including family member roles, extended family support and the use of other support systems; *family*

perceptions, or the meaning the family places on events or how they interpret information; and *family quality of life*, or how the family feels about their ability to meet family member's need for happiness and satisfaction. The effects of time and growth surround the other factors and are represented by the *life cycle* area. Each of the model's areas will be discussed in terms of the major themes and issues faced by our group of families of low birth weight preterm infants.

Family characteristics

Data describing the make up of the families are presented in Table 1. The PSI scores are presented as percentiles, with lower numbers reflecting less stress. Five families were Caucasian and one was Hispanic, reflective of the local population. Only one family had additional children. Three major issues were identified in this category: the effects of maternal medical condition on the decision to breastfeed; differences in perceptions based on the child's feeding progress in the hospital; and issues related to involvement in, and satisfaction with, the medical care of the child.

Maternal medical condition and breastfeeding All the mothers acknowledged the importance of breastfeeding their infant. Two women had chronic medical conditions managed by medications that were incompatible with breastfeeding. Another did not breastfeed because of concerns about her post partum medication and breastfeeding. Of the mothers who did breastfeed, one had nursed her two previous children, but stopped early because "*I didn't have enough milk, ..I think it was the stress and that I didn't gain very much weight with her.*" Another mother was committed to breastfeeding all along, but the third was ambivalent about the decision: "*I had thought about breastfeeding but I didn't*

know what I was going to do and then it came to the point that breastfeeding was all I could do to care for the twins.”

Infant feeding problems All of the infants had feeding delays related to their prematurity, but three developed some additional complications in the hospital related to feeding. The mothers of these infants were less willing to try feeding changes than the physicians. As one mother said, describing her son's second incidence of bloody stools on a milk based formula, *“The frustrating part was the feeling he shouldn't have gotten sick a second time. They (the NICU) should have been more cautious about taking him off (the formula) because he was doing just fine.”*

Medical care of the child There seemed to be differences in families' feelings about medical care based on the distance the family lived from the hospital and how often they could visit. The family who lived closest said, about the father who was laid off and spent a great deal of time at the hospital: *“They gave him a report every, every hour, every little detail.”* While the families that lived the furthest away talked about phone calls in the middle of the night and said, *“You can't just expect the doctors to tell you because they are not going to.”*

Family interactions

This area describes the interactions within the family, between the nuclear family and the extended family, and the family and the community. Three issues were identified in this area: mothers viewed themselves as in charge of the care of the infant, with fathers playing a more or less supportive role; family life during the hospitalization was curtailed because of travel to, and time spent at the hospital; and the extended family and community were not mentioned very often as a resource.

Maternal caregiver The mothers seemed to view themselves in charge of the infant's care. "*because my husband isn't all that good with all he needs to know.*" Even when the father became the primary care giver because of financial needs, the mom said, "*I left him a schedule of what I did in the morning. So he just went by my schedule so everything was to the T.*" The major role that fathers seemed to have was to be emotionally supportive.

Curtailment of family life Families went to incredible lengths to be with their infants in the hospital. "*We both worked full time, came home, hopped in the car and went to the hospital.*" Another family, "*We were there all the time. He got home from work at 6 or 7 and we would go up there and stay until 10 and then when we got home it was time to go to bed ...I'd travel up there during the day and stay up there about all day and then I'd go back with him at night. Forty miles drive each time.*" Family interaction was almost totally devoted to concern for the hospitalized child.

Extended family and community resources We found it remarkable that only one family described help from their extended family during the hospitalization, even though we probed on this issue. Two families commented that extended family members, particularly grandmothers, gave unappreciated and inappropriate feeding advice after the child came home. In contrast, another family reported that a sister in law with four children was their main resource for feeding advice. One family made extensive use of their community hospital's walk in well baby growth clinic in addition to regular medical care. The researcher in charge of the project became a major support for one of the families. Three families reported reading books or magazines for feeding advice.

Family perceptions

Published personal experiences and research into recall of the neonatal experience show that the emotions of the time remain, but that families are more objective about the NICU experience after some time has passed (13, 14). All of the families trusted the care they received in the hospital but also felt that more information was needed about feeding issues in the hospital. After discharge, they had concerns about the information they received on feeding if they did not attend the medical center clinics. We also questioned families about the perceived role of different health professionals in the hospital.

Need for more information As was discussed under family characteristics, parents who lived farther away seemed to be less satisfied with the care of their child. However when probed about specific needs for information, or when discussing feeding situations, five out of the six families expressed concerns about nutritional care in the hospital. This ranged from a discussion of reflux, *"he did it in the hospital and it didn't upset them so I never mentioned it to his doctor;"* and sleeping, *"every time it was her feeding ...they would wake her up and feed her and cause she was so sleepy she would spit her milk out,... after she came home, I let her sleep;"* to confusion about quantities of formula necessary after the infants came home, *"I was frustrated. Am I feeding them enough? You don't know because I wasn't sure how the hospital calculated it."* Lack of information about the nutritional needs and problems of premature infants lead one mother to overlook a potentially serious problem, another to underfeed her infant in the period immediately post discharge and caused a third increased anxiety.

Concerns with nutritional guidance outside the medical center Two of the six families continued their infant's medical care at the children's hospital. Both of those

families were happy with the nutritional guidance provided which met the recommendations of the American Academy of Pediatrics and was adjusted for the developmental status of the infant (15, 16). An additional family was happy with the care provided by the local medical provider, but this advice was not adjusted for prematurity. The other three families were unhappy with the nutritional care provided in the community. Two families did not follow medical advice to start solids. *"We weren't real comfortable with our local doctor. He wanted to start them on solids and we thought we needed to correct their age because they didn't have the skills to be able to swallow. You feel like you have to be the responsible person."* Another family had concerns about the growth of their child that were never adequately addressed. They said, *"We tried to convince ourselves that (medical professionals) are smarter than we are, but the baby just never seemed to gain."*

Role of professionals in the NICU Physicians were seen as controlling nutrition decisions in the hospital. One family had concerns about continuity of care within the group practice in the NICU. Nurses were seen as expert caregivers and communicated the families concerns to the physicians. Most of the families had no memory of the dietitian, although two said she calculated the needs of the infants. One family had discussed a nutritional problem with the dietitian and found her an excellent source of information, but did not feel she had any authority to help them resolve their concerns.

Quality of life

This area deals with the family's satisfaction with life. Although the families acknowledged the stress of the situation, our group of mostly first time parents (5 out of 6) saw some benefits from the training in infant care at the hospital. When asked what advice

they would offer to another family faced with the birth of a premature low birth weight child, they stressed the importance of finding support and information.

Practice in infant care We were initially struck by the lack of concerns voiced by the families about coming home with a premature infant. One family did express concerns about the apnea monitor, but most stated they knew the infant's schedule and had good information on the initial feeding needs of the infants. As one mom said about her twins, *"We knew what to expect, we felt they were somewhat on a schedule, the hospital had given us guidelines... We felt more ready to bring these babies home than if we just had twins and brought them home two days later."*

Need for support and information When asked what they would tell another mother with a premature infant, the overwhelming response was to get more support and information. All the mothers stressed the importance of finding someone you could trust and/or someone who had been through the experience. They also felt that getting as much information as possible in the hospital was important and several said they would participate in team meetings with the NICU staff sooner than they had.

Life cycle

For families with growing children change is inevitable. Researchers in child development have suggested that parents of preterm infants continue to see their children as vulnerable long after the NICU experience (17, 18). The mothers we interviewed continued to express nutritional concerns about the growth and development of their children. These could involve a specific decision to make adjustments as, *"Our goal is to get rid of the bottle at bed time, but we're going to rethink that because his weight gain has really tapered;"* or a more general concern expressed as, *"I think she is just going to be small."*

Case study to illustrate application of the model

To demonstrate how the family system approach can help us understand how families make decisions about feeding, we would like to review the case of a woman with twins. She was initially undecided about breastfeeding, but decided to express breast milk because *“that was all I could do.”* When asked about how her husband reacted during this early period, she talked about how he *“carried the cooler with the milk to the hospital.”* Even after going back to work she continued to pump breast milk. Clearly, the fact that her twins were premature (family characteristic) influenced her decision, as well as her feeling that by breastfeeding she could care for her children (perception).

However, she changed her mind about breastfeeding when the babies got big enough to be put to the breast. *“It was so frustrating to try and breastfeed because they were so little they didn’t get it. So you saw a baby for 20 minutes while your husband was having fun with the other baby and then it was like OK switch and fight another baby. So I was bitter. (but) I continued to pump until they came home.”* To her, the negative interaction with the infants was not worth the added nutritional benefit gained by putting the babies to breast. Initially, quality of life was enhanced by breastfeeding, but by the time of discharge, the negative interactions with her infants and feelings of jealousy of her husband’s perceived “good times” with the twins were not worth the added nutritional benefits of breastfeeding.

Implications for practice

Other researchers have found that families have identified nutrition services and nutrition information as important needs in caring for their child. But families have also expressed difficulties with getting the information and services they need and want (3-6). It

seems that professionals are most concerned with the health effects of decisions and issues of compliance, while families are most concerned with getting as much good information as possible and the social consequences of the decisions. Neither group discounts the importance of the other's concerns, but the end result of the difference in emphasis is that professionals and parents seem to be talking at cross purposes.

This group of families identified the same concerns and problems. They recognized the importance of nutrition to the growth and development of their child, but had difficulties getting the information they needed. Often the information they did get was incorrect or was perceived to not meet the family's needs.

The results of this work supports previously published indications that professionals do not do a good enough job identifying the problems families face in caring for their children with special needs (3-6). A family systems model is another tool nutritionists and other health professionals can use to better understand family's needs. Nutritionists already tailor their nutritional care plan based on individual characteristics and receive training in interviewing techniques, making them uniquely qualified to ask the questions necessary to probe the quality of life effects of recommended nutritional interventions. By considering family interactions, perceptions and quality of life issues when developing a care plan, nutritionists can provide the information and support needed and desired by families, and can better communicate with other members of a family centered multidisciplinary care team.

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Table 1: Family Characteristics.

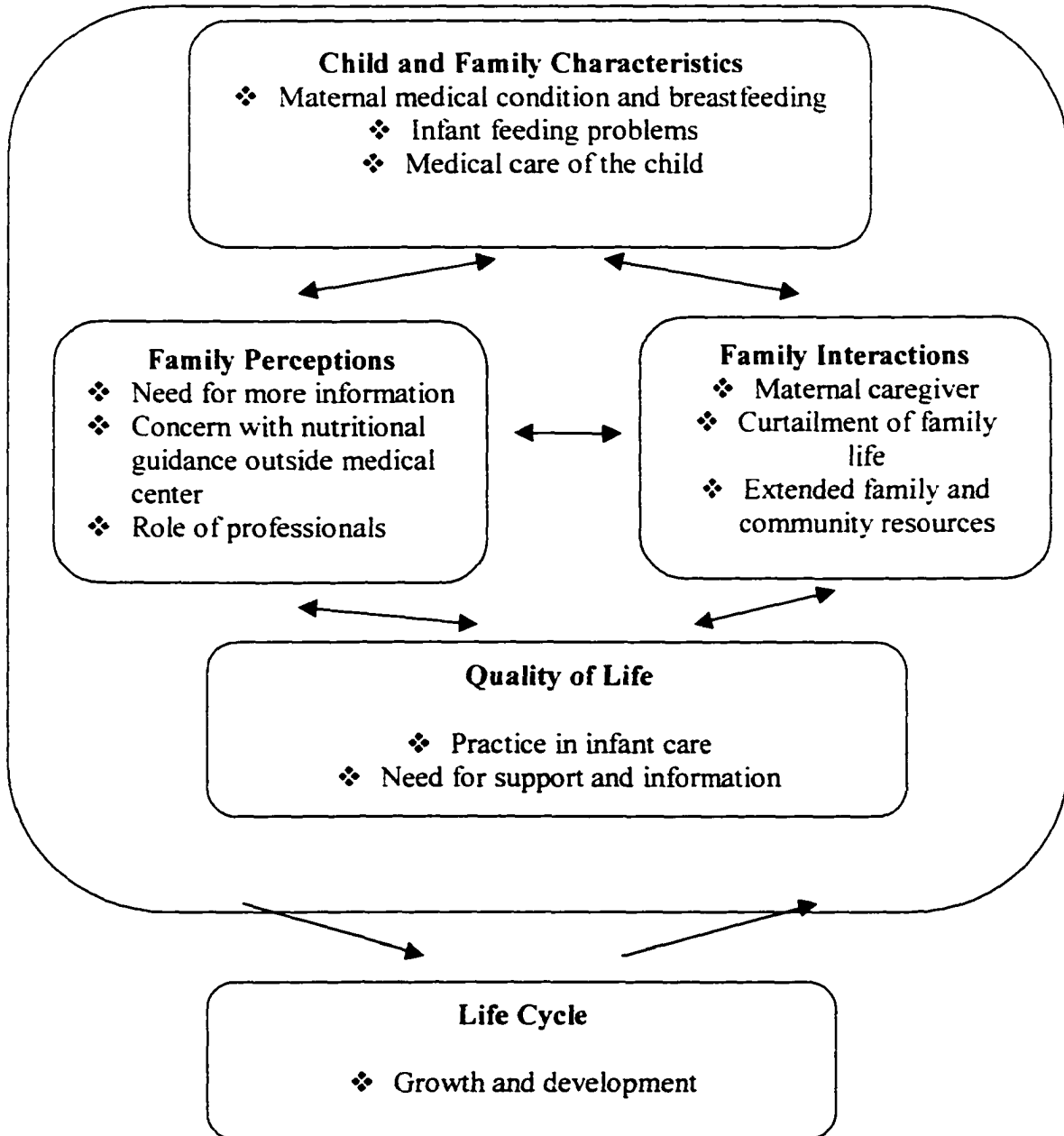
Family	Age of mother	SES #	PSI % discharge	PSI % at 1 year old	Birth weight (grams), sex	Weeks gestation	Breast fed	Denver screening result ##
1	37	lower middle	55	65	1700 g, F	35	NO	normal
2	31	upper lower	20	50	845 g, M 990 g, M	27	NO	questionable normal
3	36	upper	5	1	1180 g, M	27	YES	normal
4	30	upper middle	15	20	890 g, M 997 g, F	26.5	YES	abnormal normal
5	22	upper middle	60	10	1472 g, F	33	NO	normal
6	25	upper lower	30	5	770 g, F	26	YES	abnormal

SES: socioeconomic status as calculated by Hollingshead 4 factor social index (11)

^ PSI: maternal stress as measured by parenting stress index (12) at discharge of infant from the hospital, and entry into the study.

Denver screening results: Denver II developmental screening was done at 12 months adjusted age. Results are classified as normal, questionable, or abnormal.

Figure 1: Family systems model for feeding a premature low birth weight infant. Adapted from Brotherson et al., 1995.



APPENDIX 1

INTERVIEW PROTOCOL:

Thank you for agreeing to talk with us about your experience with name in some more depth and for allowing us to tape the discussion. As you know I am looking at the nutritional care of babies who are born very small in the hope of providing some guidance to physicians, hospitals and families about the nutritional needs of low birth weight babies. Because you are the ones who have lived through this your thoughts and feelings are important piece of this project. I would like to talk with you for about the next hour about the issues you faced with name while he/she was in the hospital and after he/she came home.

Questions

1. Let`s begin by remembering how name started eating. Can you describe for me your memory of that experience?

Prompts: Use of TPN

Breast feeding

Formula changes

Tube feeding

Did name get any information about feeding? How did he feel about this?

2. Describe how decisions were made about how your child was fed?

Prompts: What was the nutritionist`s role? How if at all was the dietitian involved?

What was the role of the physician/ nurse?

2b. How satisfied were you with your role in the decisions made about feeding?

If you could have had a different role, what would it have been?

3. What kinds of nutrition issues were you concerned about when you brought the baby home?

Prompts: If you had questions or problems **WHO** would you ask?

What were you **TOLD**

How did you **feel about** this advice?

4. Who gave you advice about feeding your baby? How did you feel about this advice?

Did you read any books or magazines, watch any TV shows?

5. What would you tell another mom to expect when she comes home with a baby like yours?

What suggestion would you give to someone else about coping?

Prompt: **PUSH** for quality of life issues

6. What would you like to tell me about this issue that I haven't asked?

Conclusion: Thank you for your time and thoughts on this issue. You have been a great help.

Revised 1/30/98

GENERAL CONCLUSIONS

Summary

When children grow well, they develop normally. Although it seems a simple enough statement, a review of the literature suggests there are a variety of very basic unknowns. Which is most 'normal:' the rates of growth seen in breastfed or bottle-fed infants? What is the relationship between growth and development? Is maximizing physical growth best, or do we define 'normal,' for humans, as maximizing cognitive abilities? Before we start making decisions that affect children and families, we need to acknowledge how much more we still need to find out.

Recent research has shown that nutrition can affect both the growth and cognitive development of children (Pollitt et al., 1995; Grantham-McGregor et al., 1991, 1997; Lucas et al., 1990, 1992). Nutritional effects are subtle and may be protective rather than enabling. Good nutrition is necessary for normal development and can ameliorate the effects of negative environmental factors, but it is not a panacea. It cannot fix problems with physical disability, with chronic medical conditions or with sterile emotional or educational environments (Brown &, Pollitt, 1996). As pointed out by the Canadian Paediatric Association (1994), poor nutrition can compound the effects of poor health or a poor environment.

The work reported here examined the relationship between growth and nutritional status in preterm, low birth weight infants from three different research perspectives: observational, randomized controlled intervention, and a qualitative study. In summary the findings were:

- ◆ Observational study of 29 low birth weight infants from birth to age 18 months:
 - Significant catch-up growth in length and weight.
 - A high use of breast milk. 73 % early in life
 - Intakes of 116 kcal /kg at 4 month developmental visit, more than the RDA for age.
 - Regression modeling predicting final head circumference identified growth and nutrition related variables, such as time of first feeding, use of pediatric parenteral amino acids and 9 month head circumference and 4 month weight z-score.

 - ◆ Randomized intervention study providing anticipatory nutritional guidance to 14 families in intervention group with 15 families in the control group.
 - Growth was normalized in the intervention group as compared to the control when the effects of BPD on growth were removed with regression modeling ($p = .08$).
 - Maternal stress related to infant expectation was negatively correlated with the intervention/control variable.
 - The pooled intake of all the infants at the 4 months developmental visit was 117 kcal/kg; significantly higher than the RDA for age.

 - ◆ Qualitative analysis of six interviews with mothers of NICU graduates at 12 months adjusted age.
 - Concerns about nutritional care influenced maternal perceptions of medical care.
 - A need for more information on infant nutrition was identified.
-

The importance of breast milk to preterm infants is supported in this work. In the *observational study* of normally developing preterm infants, 79% received some breast milk, over the national breastfeeding rate of 54% (Janke, 1993). Breastfeeding was important not only in a strictly nutritional sense, but as a quality of life issue as well. In our *qualitative study*, women breast-fed because it was good for the baby and because it was a unique way to contribute to their infants' care at a critical time in the baby's life. Other work by our group suggests that providing food in a nurturing sense is a very important part of the role of mother (Brotherson et al. 1995). These feelings can assist medical care givers in encouraging women to breastfeed.

Brown and Pollitt's (1996) suggestion that nutrition's effects on development are protective and enabling was supported by the research. When we studied preterm infants who thrived, in the *observational study*, there were a variety of nutrition related variables identified by the regression model, but with the *intervention*, where the sample was representative of the entire population, effects on growth were not seen until the influence of a medical condition, BPD, was removed.

Results of the research suggest alterations to clinical guidelines for nutritional care of the preterm infants. The *observational study* suggests that typical growth in preterm infants is first an increase in weight, and then an increase in length. By 4 to 6 months actual age, weight for length measures over the 90th percentile on NCHS growth charts were typical and should be used as a marker of normal growth, with further nutritional assessment indicated if that goal is not reached. Nutrition guidelines for care of high-risk children in the community suggest preterm infants only need 100 kcal/kg (Isaacs et al., 1997), less than the RDA for their age (Food and Nutrition Board, 1989). The mean energy intake in the *intervention and*

observational study was 116–117 cal/kg. and is supported by other researchers (Johnson, 1995; Bishop et al. 1992). An increase in the guidelines to at least that level is indicated and further research into intakes during the first year of life is warranted. Our work suggests that healthy infants are able to achieve much greater catch-up growth than was previously thought (Casey et al., 1991). It appeared that growth rates could normalize by 12 months of age, if the calories needed to support this growth are consumed in the first 4 to 6 months. Additional research with larger groups of infants might confirm this hypothesis.

Finally, the *intervention and qualitative* studies indicated how well nutrition services could fit into the early education intervention programs established by the Individuals with Disabilities Education Act. The Act mandates family centered care, or care that addresses the needs of family first, not just needs identified by professionals (Cloud, 1997). Families have said that nutritional information is important to them. (Bonam et al., 1993; Cross-McClintic et al., 1994). By meeting this need through information provided by the *intervention*, maternal stress related to perceptions of their child decreased and the parent-child bond strengthened. By expanding nutrition services offered by early intervention educational programs, important family needs could be met. Currently nurses provide most of the earliest services in early intervention programs, focusing on medical care needs. A registered dietitian with training in developmental screening could take over these early monitoring tasks and provide nutritional support and guidance at the same time. Monthly phone calls similar to those provided to the intervention group could assess intake and monitor catch-up growth as well as allowing early identification of feeding problems. By meeting families' needs regarding nutritional information, a sense of trust would be established that would facilitate the introduction of other team members if additional

interventions were indicated. By integrating nutritional services into a multidisciplinary team, gains in effectiveness may be possible and would be an additional line of research to pursue (Bryson et al., 1997; Bonam et al., 1993).

Recommendation to the referring hospital

As part of our project, we agreed to provide feedback to our referring institution based on the research findings. The hospital has several important strengths they should strive to maintain. The first is the rate of breastfeeding success they are able to achieve. Discussion with the medical director of the NICU suggests that they have initial rates of breastfeeding comparable to national averages for term infants (Janke, 1993). Given the developmental gains demonstrated by Lucas et al. (1992), this provides a great advantage to the infants. Second, the daily weight gain achieved by the infants was higher for all but one study reported in the literature, and that was in the 'fast gain group,' not the unit average (De Klerk et al., 1997; Lucas et al., 1990; Simmer et al., 1997). Finally, the hospital has overcome the cost problems associated with the use of pediatric parenteral amino acids and now uses them routinely. In the observational study, the use of pediatric parenteral amino acids conferred a growth and developmental advantage.

Given the questions families had with local medical care in the qualitative study, any nutritional anticipatory guidance the unit could offer at discharge would be helpful. A handout could be developed that discussed early increased weight for length; the need for increased caloric intakes; and the importance of delaying solids until appropriate developmentally maturation has occurred. A phone messaging system could be implemented so families could reach the nutritionist after discharge with pertinent questions. Additionally, the inclusion of an extended discussion of these issues at the 4 month

developmental clinic visit might be helpful. A similar handout could be developed for distribution at that time. The addition of a nutritionist to the developmental screening clinic would assure that nutritional concerns were met and problems were identified in a pre clinical stage.

Proposed model

The relationships between growth and nutrition seen in the observational and intervention study suggest an alteration to the classic model of nutritional disease suggested by Arroyave (Young & Scrimshaw, 1979). The importance of growth to normal development in childhood suggests that anthropometric measures of nutritional status may have an earlier and more profound effect on the development of nutritional disease in children than biochemical markers of nutritional status. Currently, the diagnosis of nutritional problems is based on a model (Figure 1) with alterations in biochemical markers as the earliest clinical signs of a deficit (Young & Scrimshaw, 1979).

The proposed model (Figure 3) describes the sequence of metabolic and pathologic events in the development of nutritional growth retardation and shows the relationship between growth, normal development, infection and illness. The central area of the figure describes the progressive stepwise development of the disease with decreased growth as an initial step, progressing to nonspecific signs and symptoms, such as attention changes, then evidence of metabolic alteration and finally permanent damage, or stunting. The model indicates that with the onset of poor dietary intake, the child adapts to diminished intake by decreasing the rate of growth (Scott et al., 1992; Zeitlin et al., 1990). As the duration of the poor diet continues, there are non-specific changes in attitude and attention that affect learning (Zeitlin et al., 1990; Scott et al., 1992). Further duration of poor nutrition causes

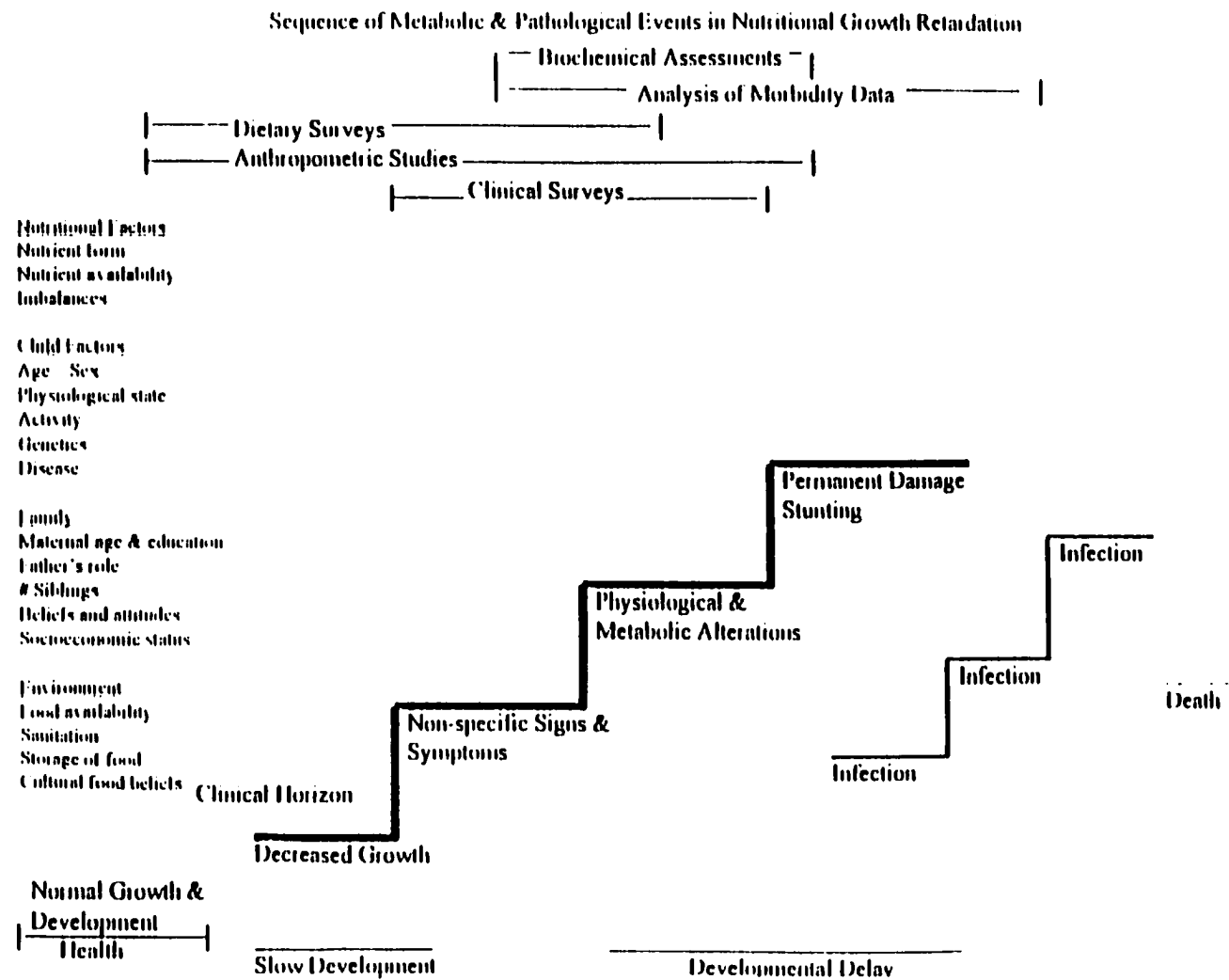


Figure 3: Sequence of metabolic and pathologic events in the development of nutritional growth retardation and its relationship to child development (modified from Young and Scrimshaw, 1979).

physiological and metabolic changes as evidenced by altered immune function (Chandra, 1991) and changes in hormone and protein levels (Zeitlin et al., 1990). If left uncorrected, the child's growth curve flattens out and permanent stunting results (Keller, 1988). Unlike the Arroyave model (Young & Scrimshaw, 1979), the inability to attain normal growth, or stunting, as well as death characterize the level of permanent damage. The second set of steps indicates that effects of infection are pervasive, starting even at early stages of growth retardation. Even in mild malnutrition, evidenced by growth delays, there is an increased incidence of mortality (Pelletier, 1994).

The ability to achieve normal growth and development is influenced by nutritional factors (Young & Scrimshaw, 1979), child factors (Scott et al., 1992), family factors (Zeitlin, et al., 1990) and environmental factors (Young & Scrimshaw, 1979; Zeitlin et al., 1990). Examples are listed on the right side of the model (Figure 3).

Poor diet also leads to a decrease in the rate of development as depicted by the bottom line of the model. The delay in growth may be evidence of decreased energy available to engage in learning behaviors leading to delays in motor and intellectual development (Scott et al., 1992; Zeitlin et al., 1990; Brown & Pollitt, 1966). A malnourished child will be less likely to interact with his/her environment than a sick well-nourished child will. If the duration of the growth delay is long enough, there are permanent changes in development (Grantham-McGregor et al., 1991, 1997; Scott et al., 1992).

The development of behavioral changes affecting dietary intake, as well as physiologic and metabolic alterations, leave the child susceptible to infection. Even the acute phase immune response caused by infection can increase the delay in growth by altering the child's nutritional needs (Chandra, 1991). Once there is increased incidence of

infection, the chance of death or permanent damage increases (Young & Scrimshaw, 1979; Zeitlin et al., 1990).

In studying preterm infants, we have seen a relationship between nutritional factors, like breastfeeding, parenteral protein sources and time of starting enteral feeding, as well as a relationship with growth parameters and markers for normal development like head circumference. Others have found relationships between breastfeeding (Lucas et al., 1992) and growth parameters and developmental markers (Hack & Breslau, 1986; Ross et al., 1983). In none of these studies, were biochemical abnormalities remarked upon. None of the children in our intervention or observational study were identified as having any biochemical abnormality except anemia, in one child, subsequently diagnosed with a genetic blood disorder. However, many of the infants experienced growth delays. The predominant role of growth over biochemical markers in children is also seen in children with marasmus who are growth retarded but have normal albumin levels. Mild malnutrition is best identified by changes in growth and anthropometric measures rather than in changes in biochemical markers (Scott et al., 1992; Zeitlin et al., 1990). These findings indicate the revised model is better able to reflect the importance of nutrition to the normal growth and development of the child (Young & Scrimshaw, 1979).

Across the top of the model are indications of the type of assessment measure appropriate for identifying a nutritional deficiency in the various stages of the development of nutritional disease. In contrast to the classic model (Young & Scrimshaw, 1979), anthropometric, and even clinical indications of nutritional status take precedence over biochemical markers. The results of this research, the review of the literature and clinical practice all indicate that by waiting until biochemical abnormalities are evident to provide

nutrition support to a child, we have waited too long and damage that may be irreversible has already been done.

It would be interesting to extend the observational study to a larger, more representative, population of infants. We attempted a logistic regression, based on growth over the 5th percentile, but did not have a large enough sample of poor outcomes to get understandable results. With a much larger sample, factor analysis could be done to look at the relationships between variables. In the regression modeling process, in the observational study, there appeared to be groups of variables, each individually approaching significance that dropped out when one of the group was added to the model. I am not aware of a factor analysis of growth and development including nutrition variables. A better understanding of risk factors and protective factors and the relationships between them would allow a more efficient delivery of services in programs like early educational intervention.

Implementing the intervention as part of continuing medical care might increase its effectiveness. A stronger emphasis on increased formula intakes and increased gains in weight, early in life, might lead to better developmental outcomes. A larger group with blocking on disease and birthweight might demonstrate more effectiveness in promoting normal growth. A longer follow up period might also demonstrate difference in growth and developmental outcomes. Finally, a more precise intake survey that included all of the first year would allow better guidelines to be developed for feeding preterm infants. With the pace of recent advances in the medical care of very small preterm infants, understanding the role of nutrition in their growth and development will continue to be a growing challenge.

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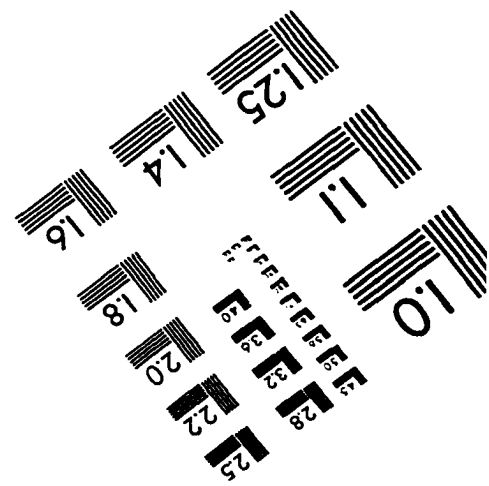
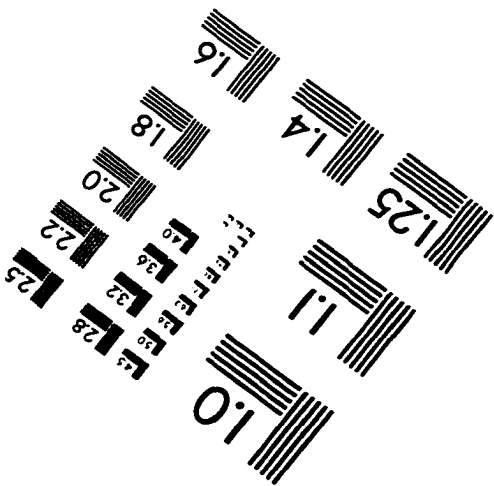
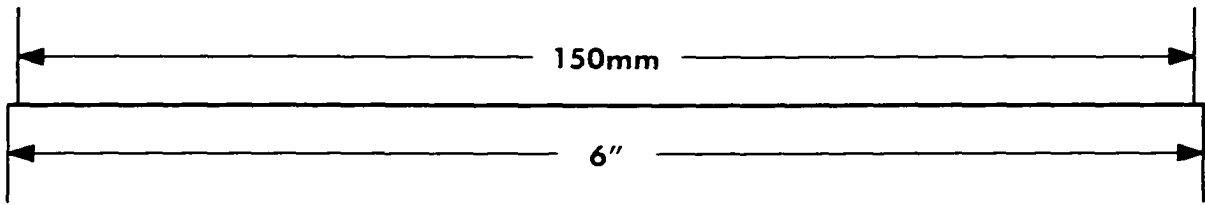
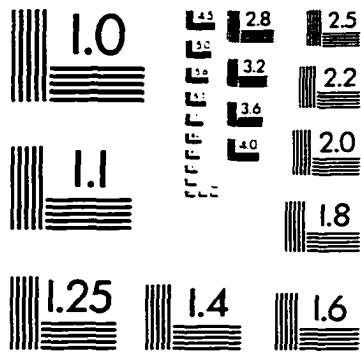
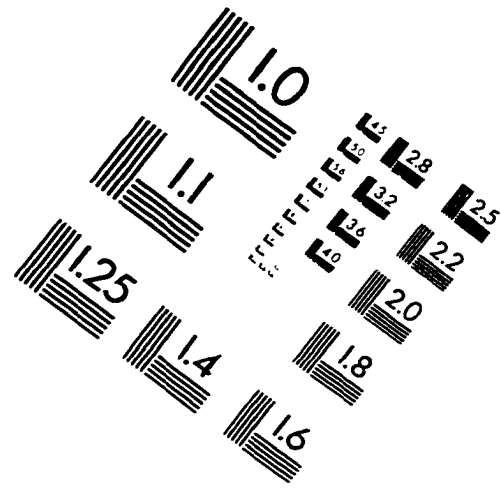
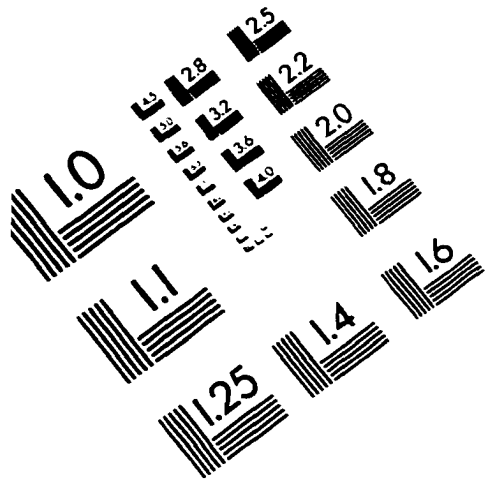
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IMAGE EVALUATION TEST TARGET (QA-3)



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