Predicting to 9-Month Performance of Premature Infants

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This article identifies variables found to be predictive of sensorimotor and psychosocial performance in infants at 9 months adjusted age. The subjects were 102 infants with a birth weight of less than 1,500 g, who were participants in an early intervention project. Multiple regression analyses disclosed that poor 9-month performance was related to a lack of special Neonatal Intensive Care Unit (NICU) intervention, to minority group membership, to birth weight, and to performance on selected tests administered in the NICU. We present implications for the early prediction of handicapping conditions and for further research.

Key Words: *Child development disorders; Infant, premature; Physical therapy.*

Physical therapists are becoming more active in neonatal intensive care, both in treating infants and in teaching parents. In addition to treating infants with identified handicaps and providing enrichment to counter the infant's isolation from a normal home environment, the Neonatal Intensive Care Unit (NICU) therapist must identify potentially handicapping conditions at the earliest possible stage. Although effective intervention appears to be enhanced when initiated early, the ability to predict many handicapping conditions accurately is somewhat restricted.

A recent comprehensive review of 16 studies of infants who weighed less than 1,500 g at birth disclosed that 9% to 29% had substantial neurological handicaps (eg, cerebral palsy, deafness, visual impairment, hydrocephalus, and mental retardation).[1] The early identification of this potentially handicapped population is important for the therapist designing programs to influence the acquisition of optimal motor skills and general development. At present, however, few experts agree on which indicators are most effective in identifying potentially handicapped infants. Although socioeconomic status has been cited by several researchers as the most important variable in predicting developmental outcome,[2,3] other important indicators of poor outcome in premature infants are birth weight, birth head circumference, one-minute Apgar scores,[4] head growth by six weeks,[5] and hypertonicity.[6]

Standard infant psychometric tests have shown poor predictive validity, particularly when administered to a general population comprising a full range of potentially normal and abnormal subjects. When administered to a high-risk population at the chronological age of 3 months, however, the Bayley Motor Scale has been found to predict an abnormal neurological outcome at 1 to 3 years of age.[7]

Evidence exists that infants at highest risk of developing handicaps can be identified at or shortly after birth. Fitzhardinge et al report that 85% of those infants who survived intracranial hemorrhage, 53% of those infants identified as being small for gestational age (SGA), and 30% of those infants who weighed less than 1,000 g at birth had significant handicaps at age 2 years.[8] Other recent research has found that the presence of a disability and hyperactive behavior predicted lower performance on Bayley tests at ages 1 and 2 years.[9] Others, however, urge caution in predicting handicaps, citing findings from the National Collaborative Perinatal Project's longitudinal study of 229 infants diagnosed as having cerebral palsy at 1 year of age, which found that only 45% still had signs of motor impairment at 7 years of age.[10]

Although low birth weight has been known to predict visual-motor and performance scores on cognitive tests administered between 7 and 9 years of age,[11] other predictors have proven more equivocal. For example, neurological assessments were found to have poor validity in predicting long-term prognosis.[12] Medical complications related to the obstetric neonatal periods were not found to be predictive of developmental outcome at age 2 years in one study,[13] but were identified as predictors of 1-year outcome in a second study.[14] Brazelton interactive and motoric process scores collected during the neonatal or predischarge period also were found to predict sensorimotor and psychosocial performance at age 1 year.[14]

Little consensus exists on the efficacy of many medical indicators as predictors of developmental outcomes, but evidence is growing that family demographic characteristics are related closely to infant development. Parental socioeconomic status frequently has been identified as one of the strongest predictors of infant development.[3,15] Such income-related variables as mother's age at birth of child, mother's level of education, and parental ethnicity also have been shown to be related to prematurity.[15] Because the indigenous people in our project area had been identified as being decidedly more at risk for producing infant and neonatal mortality and

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congenital abnormalities than other ethnic groups,[16] we chose to evaluate ethnic group membership as a predictor of infant development.

For the physical therapist, the problem remains one of combining global predictors, such as income and birth weight, with increasingly available assessment scores, such as those obtained by the Brazelton and Bayley scales, to provide information of assistance in the development of individual treatment programs for neonates.

The importance of early intervention for later infant development has been a controversial topic in recent years, with proponents of intervention noting improved weight gain[17] and motor,[18] social,[19] and cognitive development,[20] and detractors reporting no significant improvements over control groups.[21] Our study was conducted as part of an Office of Special Education-sponsored project focusing on the impact of family-centered care for NICU infants, which had as its goals 1) to promote optimum infant development, 2) to enhance parent-infant interaction, 3) to assess the effectiveness of different intervention strategies, and 4) to identify predictors of developmental outcomes. Thus, we were able to assess the value of NICU intervention as a predictor of later performance.

The purpose of this study was to assess the predictive abilities of several standard and unique measures administered to NICU infants during and immediately following hospitalization. We also considered selected family demographic variables and participation in the various treatment protocols as predictive measures. Because of the design characteristics of the project, the current analysis is restricted to an assessment of our indicators as predictors of sensorimotor and psychosocial performance at 9 months adjusted age.

METHOD

Subjects

The subjects were 102 infants who were born at, or transported to, Kapiolani Women's and Children's Medical Center and admitted to the NICU between January 1981 and January 1983. Infants were assigned randomly to one of three intervention groups. Thirty-six infants were in the Infant-Parent Intervention group, 32 were in the Parent-Only Intervention group, and 34 were in the Control group. (Distribution across groups was unequal as a result of infant deaths and withdrawals from the program before completion of the data collection.) Fifty-three of the infants (52%) were boys and 49 (48%) were girls. The mean gestational age was 30 weeks, and mean birth weight was 1,193 g. The average weight of the infants when discharged from the hospital was 2,300 g. The mean length of hospital stay was 77 days, with a range from 10 to 148 days.

Reflecting Hawaii's multicultural population, 28% of the infants were part Hawaiian, 24% were of mixed Oriental ancestry, 12% were of Japanese ancestry, 11% were of European ancestry, and 19% were classified in other categories. Sixty-nine percent of the mothers were married, 22% were single without a partner, and 9% were single and living with a partner. Parent education averaged 13 years for both fathers and mothers. The mother's age at the infant's birth averaged 26 years (range, 13-38), and the father's age averaged 29 years (range, 16-52).

To test the effectiveness of random assignment, we compared the infants' medical condition and the parents' demographic characteristics across the three treatment groups using analysis of variance techniques. We found no significant preintervention differences between the groups on any of the measures tested.

Procedure

With the informed consent of the attending physician and the parents, infants admitted to the hospital's NICU were considered for the project. Criteria for admission to the project were a birth weight of 1,500 g or less or up to 2,000 g if the infants were on a ventilator longer than 48 hours. Ninety-six percent of the infants weighed less than 1,500 g. Infants with identifiable central nervous system dysfunction at birth or those with birth defects were excluded because physical therapy and occupational therapy services already were routinely available for this population, and the intent of the project was to treat an underserviced population. After an infant's eligibility was determined, the subject was assigned randomly to one of three treatment groups.

Infant-Parent Intervention group. Infants in this group received the services of a transdisciplinary team. These services included individualized assessment of the infant and a treatment program designed by the physical, occupational, and speech therapists and an educator. Activities designed to meet objectives set by the team were taught to the parents by a designated care manager. The parents received instruction on working with their infants and general information on child care, growth, and development. The infants received a daily, 15- to 30-minute activity session, five days a week, administered by either the parent or the care manager. Follow-up contacts were scheduled twice a month after discharge.

Parent-Only group. Parents in this group received education about premature infant behaviors, infant growth and development, and general infant care procedures from the clinical nurse specialist. They were encouraged to handle and interact with their infants, but they were not given the specific suggestions or demonstrations provided to parents in the Infant-Parent Intervention group. The nurse met with the parents one to two times a week during the hospital phase or maintained telephone contact with those unable to visit the hospital. After the infants were discharged from the hospital, a home visit was made approximately twice monthly to families on Oahu. Contact with families on neighboring islands was maintained by telephone. Two important features of the intervention process for both the Infant-Parent and Parent-Only groups were the intensive support services provided by the team social worker and the opportunity for parents to observe the administration to their infants of the Brazelton Neonatal Behavioral Assessment Scale.

Control group. This group received the usual services that are available in a standard hospital's special care nursery treatment regimen. This care included all the medical and nursing expertise that would be expected in a regional perinatal center. Social work and occupational and physical therapy services were provided if requested by the physician. The follow-up performance and capabilities of the infants in this group served as a baseline for comparison with the more intensive intervention models.

Additional details about the intervention procedures have been presented elsewhere.[22,23] For the purposes of analysis in this study of predictors, we distinguished only between being in the Control group (receiving no special intervention) or not being in the Control group. The intervention variable was coded dichotomous because earlier analyses revealed that, although intervention resulted in a significant improvement in performance at 9 months when compared with the Control group subjects, the mode of intervention did not make a difference.[22]

Assessment Instruments

A variety of assessment instruments and procedures were used during different phases of the project. Only those that pertain to the results that are reported in this article will be described. Detailed descriptions of additional instruments can be found in another report on the project.[23]

Bayley Scales of Infant Development.[24] This test provides measures of mental and psychomotor development. These scales were administered at the 9-month adjusted age outpatient phase.

Gesell developmental schedules.[25] This developmental assessment measures an infant's skills in personal-social, language, fine motor, gross motor, and adaptive areas. It also provides a developmental quotient as a summary score. This test was administered at the age-adjusted 3- and 9-month outpatient phases.

Adapted Amiel-Tison/Range-of-Motion (AT/ROM) test. An adapted version of the Neurological Evaluation of Amiel-Tison[26] was devised by the project's occupational therapist, physical therapist, and developmental pediatrician. The items selected from the Amiel-Tison test were those that the literature or our experience had identified to be relevant indicators of disabilities in infants. Infants received an overall score of "normal" or "questionable" in three areas: the neck and upper trunk, the upper extremities, and the lower extremities. (Initial scoring identified normal, questionable, and abnormal performance, but the latter two categories were combined for statistical purposes.) This test was administered at the inpatient recovery phase, at discharge from the hospital, and at age-adjusted 3- and 9-month outpatient phases. Items on the neck and upper trunk scale measured muscle tone. Items on the upper extremity and lower extremity scales measured joint range of motion.

Brazelton Neonatal Behavioral Assessment Scale (NBAS).[27] A priori clustering of the items on the NBAS was used (according to Lester et al[28]), giving composite scores relating to

1. ability to shut out disturbing stimuli (habituation);
2. auditory and visual responsiveness (orientation);
3. muscle tone and activity level (motor performance);
4. irritability and level of excitement (range of state);
5. capacity to cuddle and self-console (regulation of state);
6. tremor, startling, and skin color (autonomic regulation); and
7. reflexes.

The NBAS was administered at hospital recovery and discharge phases and one month after discharge. We used the NBAS instead of the Assessment of Preterm Infant Behavior (APIB) Scale,[29] a more recent version of the NBAS for preterm infants, because training in the APIB was not available at the beginning of the project. We used the NBAS after the infant reached a gestational age of 38 weeks if the infant was medically stable.

Postnatal factors scale.[30] During hospitalization, a low score on this scale identified infants with potential problems. The scale accumulated information related to respiratory distress, infection, ventilatory assistance, illness, metabolic disturbance, convulsions, hyperbilirubinemia, temperature disturb-

TABLE 1
Correlations Between 9-Month Outcome Measures and Selected Predictors (N = 102)

	Bayley		Amiel-Tison			Gesell Developmental Schedules						
	Psychomotor	Mental	Neck	Upper Extremity	Lower Extremity	Personal-Social	Language	Fine Motor	Gross Motor	Adaptive	Overall DQ^a	Marker Item
Control group	−.24^b	−.24	.26		.43^c				−.26^d			
Hawaiian ancestry			.23			−.22		−.23				−.25
Morbidity	−.34^d											
Birth weight	.27		−.32^d					.28^d	.23		.23	
Postnatal factors	.36^c		−.24		−.28^d			.29^d	.27^c		.27^d	.24
DP^e AT/ROM^f neck	−.32			.29								
DP AT/ROM upper extremities						.26						
DP AT/ROM lower extremities				.29		−.25			−.26			
DP Brazelton habituation	.59^d	−.73^c	.67^c	.55	.39	−.40			−.55^c	−.52^c	−.52^c	−.54^c
DP Brazelton orientation	.31^d	.44^c	−.25						.28^d			
DP Brazelton motor		.42^c			−.25							
DP Brazelton						−.25	−.27^d		−.24		−.23	
Supplemental O_2	−.48^c					−.26^c	−.25	.24	−.35^c	−.32^d	−.35^c	−.24

^{a} DQ = developmental quotient.
^{b} No footnote = $.05 < p < .10$.
^{c} $p < .01$.
^{d} $p < .05$.
^{e} DP = discharge phase.
^{f} AT/ROM = Amiel-Tison/Range-of-Motion test.

ance, surgery, and feeding problems within 48 hours.

Morbidity scale.[31] This scale assesses the potential risk of an infant's problems based on factors dealing with the birth and delivery and the initial characteristics of the infant. This scale was completed during the acute phase.

Additional physiological measures. We also studied other factors that have been found to be associated with poor developmental outcome. These included birth weight, head circumference, appropriateness of gestational age compared with weight, amount of apnea, and number of days that the infant received supplemental oxygen.

Data Analysis

Recognizing the possibility of inflating chance significance when analyzing the large amounts of data gathered on NICU infants, product-moment correlations were computed only for a priori selected combinations of predictor and performance variables. Only performance (ie, outcome) measures assessed at 9 months adjusted age were used.

In establishing appropriate predictors for inclusion into stepwise regression analyses of the outcome variables, we were restricted by the need to maintain a reasonable balance between sample size and number of predictors. A few potentially useful predictors were omitted from the analyses because missing data substantially reduced the sample size.

The predictors selected for inclusion in the regression models for the Bayley scales were birth weight, postnatal factors score, and the discharge phase Brazelton orientation and motor performance scale scores. Two dichotomous variables that were developed from the demographic data—intervention and ethnicity—also were included. The intervention variable represented nonmembership (0) or membership (1) in the Control group. The ethnicity variable tested the predictive value of belonging to non-Hawaiian (0) or Hawaiian (1) ethnic groups. Models for the 9-month AT/ROM outcomes used these predictors and the matching scales from the discharge phase AT/ROM administration. The Gesell models included the addition of all three discharge phase AT/ROM scales.

Because of the low sample size to predictor variable ratio and our own reservations concerning the sample-specific optimization of regression values common with the stepwise regression model, we caution practitioners against drawing conclusions solely from the results of our study. Recognizing the need for early intervention, however, we do encourage the heuristic use of stepwise regressions for the analysis of potential predictors of developmental outcomes.

TABLE 2
Regression of the Twelve 9-Month Outcome Assessments

Outcome Assessment	Multiple R^2	Number of Significant Variables	*F*	*p*
Bayley				
Psychomotor scale	.30	3	5.12	.005
Mental scale	.44	4	6.97	.0003
Gesell				
Personal-social	.26	4	3.58	.01
Language	.13	1	6.32	.02
Fine motor	.32	3	6.30	.001
Gross motor	.29	3	5.44	.003
Adaptive	.24	2	6.68	.003
Overall DQ[a]	.30	3	5.89	.002
Under 80 DQ	.12	1	5.69	.02
AT/ROM[b] Neck and upper trunk	.18	2	3.87	.03
AT/ROM Upper extremity	.08	1	2.57	NS
AT/ROM Lower extremity	.41	4	5.85	.001

[a] DQ = developmental quotient.
[b] AT/ROM = Amiel-Tison/Range-of-Motion test.

TABLE 3
Best Subset Regression of the 10 Selected Predictors to the Bayley at 9 Months Adjusted Age[a]

	Cumulative R^2	*F*	*df*	*p*
Bayley psychomotor performance test		5.12	3, 39	.005
Control group membership	.13			
DP[b] Brazelton orientation	.24			
Postnatal factors	.30			
Bayley mental performance test		6.97	4, 39	.003
DP Brazelton orientation	.20			
Control group membership	.31			
Hawaiian group membership	.39			
DP Brazelton motor performance	.44			

[a] N = 102 (missing data account for lower sample sizes within the individual analysis).
[b] DP = discharge phase.

RESULTS

Predicting Outcomes—Bivariate Correlations

The product-moment correlations for the birth weight, the postnatal factors, and the discharge phase Brazelton scale data showed a regular pattern of relationships with the outcome scores at 9 months adjusted age. As can be noted from Table 1, the postnatal factors scale correlated significantly with the Bayley psychomotor scale and the Gesell fine motor, gross motor, and developmental quotient (DQ) scales. Birth weight correlated significantly with the AT/ROM neck and upper trunk scale and the Gesell fine motor scale. The discharge phase Brazelton habituation data had a significant negative correlation with most of the outcome measures, and the autonomic regulation scale data weakly related to many of the Gesell scale data. The Bayley psychomotor and mental scale results correlated significantly with the discharge phase Brazelton habituation and orientation scale results. The Bayley mental scale results also correlated significantly with the Brazelton motor performance scale results.

Additional variables were included in the correlation analysis but failed to exhibit any significant relationships with

TABLE 4
Best Subset Regression of the Seven Selected Predictors to the Gesell Developmental Schedules at 9 Months Adjusted Age[a]

	Cumulative R^2	*F*	*df*	*p*
Personal-social		3.58	4, 44	.01
Hawaiian group membership	.09			
DP[b] AT/ROM[c] lower extremity	.15			
Birth weight	.20			
DP AT/ROM upper extremity	.26			
Language		6.32	1, 44	.01
Hawaiian group membership	.13			
Fine motor performance		6.30	3, 44	.001
Birth weight	.16			
Hawaiian group membership	.26			
DP AT/ROM lower extremity	.32			
Motor performance		6.44	3, 44	.003
Postnatal factors	.13			
DP Brazelton orientation	.22			
Control group membership	.28			
Adaptive		6.68	2, 44	.003
Hawaiian group membership	.12			
Birth weight	.24			
Overall DQ[d]		5.89	3, 44	.002
Birth weight	.12			
Hawaiian group membership	.23			
DP AT/ROM lower extremity	.30			
Marker		5.69	1, 44	.022
Hawaiian group membership	.12			

[a] N = 102 (missing data account for lower sample sizes within the individual analysis).
[b] DP = discharge phase.
[c] AT/ROM = Amiel-Tison/Range-of-Motion test.
[d] DQ = developmental quotient.

the outcome variables. These additional variables were sex of infant, age of mother at birth of infant, family income, whether infant was SGA, and head circumference at birth.

Predicting Outcomes—Multiple Regressions

Table 2 summarizes the results of the regression analyses of all 12 outcome variables. The best subsets of predictors for each of the outcome variables are presented in separate tables for the Bayley, Gesell, and AT/ROM scales. Following standard conventions for stepwise techniques, we set minimum entry and staying significance levels at .15.[3,8,32]

Predicting performance by the Bayley scales. Three variables met the requirements for entry into the predictive model for Bayley psychomotor performance at 9 months adjusted age (Tab. 3). The discharge phase Brazelton orientation and postnatal factors variables were positively related to the outcome measure. A lack of participation in the intervention groups predicted poorer Bayley psychomotor performance. Overall, 30% of the variance in Bayley psychomotor performance at 9 months was accounted for by the three predictors. High overall prediction was obtained on the Bayley mental performance scale (R^2 = .44) with four variables contributing significantly to performance on this scale. Membership in the Hawaiian ethnic group was negatively related to Bayley mental performance at 9 months, as was membership in the Control group. High performance on the discharge phase Brazelton orientation and motor performance measures was positively related to high mental performance.

Predicting performance by the Gesell scales. Modest predictability was found for performance on the Gesell personal-social scale, with R^2 = .26 for four predictor variables (Tab. 4). Those predictors with negative weights were Hawaiian ancestry and discharge phase AT/ROM lower extremity performance. Birth weight and discharge phase AT/ROM upper extremity measures were positively related to personal-social performance.

Hawaiian ancestry was the only significant predictor for the Gesell language scale. Membership in this ethnic group was related to poorer performance on the outcome variable with R^2 = .13.

Hawaiian ancestry was again a significant contributor of prediction in the model for Gesell fine motor performance. Hawaiian ancestry and the discharge phase AT/ROM lower extremity scores were negatively related to fine motor performance. Birth weight predicted positively to fine motor performance. The overall regression value reached .32.

Among the best predictors for gross motor performance on the Gesell scale was performance in an intervention group (ie, not belonging to the Control group). Postnatal factors and the discharge phase Brazelton orientation were positively related to gross motor performance. The overall regression value was .29.

The regression value obtained with the model for the Gesell overall DQ was .30. Hawaiian ancestry again was negatively related to performance. The other negatively weighted predictor was the discharge phase AT/ROM lower extremity measurement. Birth weight was positively related to overall DQ.

Hawaiian ancestry was the only significant predictor of results of the Gesell item with a low value of R^2 = .12. Because high scores on the item reflect DQs greater than 80, the negative weighting in the model implies that Hawaiian ancestry related to lower DQ scores.

Because early diagnostic ability should assist the physical therapist in the development of intervention programs, the above regression results might be more meaningful to practitioners if summarized by predictors. The *F* values drawn from the final regression model for each outcome have been included in Table 5 for the eight variables found to contribute to the prediction of one or more motor performance outcome measures. Neither the discharge phase AT/ROM neck and upper trunk measurement nor the morbidity scale were found to be important predictors of motor outcome.

Predicting performance by the modified AT/ROM scales. Only two variables predicted performance on the AT/ROM neck and upper trunk scale (Tab. 6). Low birth weight and low discharge phase Brazelton orientation scores both predicted poorer performance on this measure. While the regression value was significant, only 18% of the variance was accounted for by these predictors.

The overall regression value for the AT/ROM upper extremity model was not significantly better than chance ($R^2 = .08$), although one predictor variable met the criterion for entry into the model. The best predictor of poor performance on the upper extremity measure was membership in the Control group.

Performance on the AT/ROM lower extremity scale had four significant predictors. Membership in the Control group was a strong predictor of poor lower extremity performance. The discharge phase Brazelton motor performance score, the postnatal factors score, and the discharge phase AT/ROM lower extremity score were negatively related to lower extremity performance. Overall, prediction was fairly high, with 41% of the variance accounted for by these four predictors.

DISCUSSION

This study was designed to evaluate the importance of NICU intervention approaches and other demographic and early assessment variables as predictors of performance at 9 months adjusted age. Multiple regression analyses revealed that an infant's presence in the Control group (ie, lacking a planned full intervention program) predicted poorer performance on both of the Bayley scales, the AT/ROM upper extremity and lower extremity scales, and the Gesell gross motor scale. Detailed discussion of intervention-group differences and suggestions for NICU intervention have been presented elsewhere.[22] Membership in the group that received only standard NICU care, however, was a major predictor of poor performance on several measures at 9 months adjusted age. From our data, early intervention appears to be positively related to infant development.

Our study identified several measures administered during hospitalization that proved to be significant predictors of performance at 9 months. These measures deserve consideration for use in identifying high-risk infants. The adapted AT/ROM scales for upper extremity and lower extremity assessments performed at hospital discharge predicted poor outcome on the Gesell personal-social scale. Additionally, the AT/ROM lower extremity scale predicted to

TABLE 5
***F* Values from Final Regression Models of Selected Variables Predicting to Outcome Measures at 9 Months Adjusted Age**

	F	*p*
DP[a] AT/ROM[b] upper extremities		
Gesell personal-social	3.53	NS
DP AT/ROM lower extremities		
Gesell personal-social	3.96	.05
Gesell fine motor	3.19	NS
Gesell overall DQ[c]	4.36	.04
9-month AT/ROM lower extremities	4.26	.05
DP Brazelton orientation		
Bayley mental	4.84	.03
Bayley psychomotor	4.02	.05
Gesell gross motor	5.67	.02
AT/ROM neck and upper trunk	2.55	NS
DP Brazelton motor performance		
AT/ROM lower extremities	5.46	.03
Bayley mental	3.26	NS
Postnatal factors score		
Bayley psychomotor	3.12	NS
AT/ROM lower extremities	4.08	.05
Gesell gross motor	4.45	.04
Birth weight		
Gesell personal-social	3.89	NS
Gesell fine motor	11.30	.002
Gesell adaptive	6.45	.02
Gesell overall DQ	3.97	.005
AT/ROM neck and upper trunk	4.79	.04
Hawaiian ethnic group		
Bayley mental	6.48	.02
Bayley personal-social	3.06	NS
Gesell language	6.32	.02
Gesell fine motor	5.35	.03
Gesell adaptive	6.88	.01
Gesell overall DQ	5.29	.03
Gesell marker item	5.69	.02
Control group membership		
Bayley psychomotor	6.04	.02
Bayley mental	6.61	.01
AT/ROM upper extremities	2.57	.12
AT/ROM lower extremities	9.80	.004
Gesell gross motor	3.57	NS

[a] DP = discharge phase.
[b] AT/ROM = Amiel-Tison/Range-of-Motion test.
[c] DQ = developmental quotient.

TABLE 6
Best Subset Regression of the Eight Selected Predictors to the Amiel-Tison/Range-of-Motion (AT/ROM) Test at 9 Months Adjusted Age[a]

	Cumulative R^2	*F*	*df*	*p*
AT/ROM neck and upper trunk test		3.87	2, 38	.03
Birth weight	.12			
DP[b] Brazelton orientation	.18			
AT/ROM upper extremity test		2.57	1, 31	NS
Control group membership	.08			
AT/ROM lower extremity test		5.85	4, 38	.001
Control group membership	.20			
DP Brazelton motor performance	.27			
DP AT/ROM lower extremity test	.34			
Postnatal factors	.41			

[a] N = 102 (missing data account for lower sample sizes within the individual analysis).
[b] DP = discharge phase.

itself at 9 months and to the Gesell fine motor and overall DQ outcome measures at 9 months.

Although we present these results in the hope that PTs can use such predictive measures as the adapted AT/ROM, we caution therapists against the indiscriminate use of this adapted measure. The Amiel-Tison test has not been standardized, and its interobserver reliability varies from good to poor depending on the item.[26] Even though our results did not confirm the predictive value of increased neck extensor muscle tone, as reported by the National Collaborative Perinatal Project (NCPP),[6] this result may be related to the time of testing (the NCPP testing was performed at 4 months, and our testing occurred at about term). This difference highlights the current lack of standardization within the assessment area and supports the need for improved age-specific measures, particularly because recent research suggests that clear differences in preterm postures, strength, and range of motion may not exist along a developmental continuum.[33,34]

The cluster scores derived from the Brazelton scales administered at hospital discharge that showed evidence of potential usefulness as predictors were the orientation cluster (which positively predicted Bayley mental and psychomotor scores and Gesell gross motor scores) and the motor performance scale (which positively predicted Bayley psychomotor scores). These data support earlier findings that the Brazelton interaction and motoric process clusters predicted 12-month Bayley scores,[14] because those scales contained the items found on our orientation and motor performance clusters. Field et al suggest that these Brazelton cluster scores may reflect the same qualities at birth as the Bayley measures do in the older child.[14]

Because birth weight has been demonstrated in many studies to predict later outcomes, we were not surprised to find that birth weight related to several performance measures in our study, including the Gesell personal-social, fine motor, adaptive and overall DQ scales, and the AT/ROM neck and upper trunk scale. Although birth weight must be considered in relation to gestational age, we found that being SGA itself was not an important predictor of developmental delay, which agrees with findings such as those reported by Kitchen et al[11] but does not support the findings of others such as Low et al.[35]

Measures of the severity of illness of the infant often have been disappointing because of their inability to identify the future handicapped child. Earlier research found little difference in 12-month Bayley scores between infants under 1,250 g birth weight with evidence of intraventricular hemorrhage (IVH) and infants of similar weight without IVH.[36] The postnatal factors scale used in our study was designed as a cumulative risk score and has been used by others to adjust for differences between preterm and full-term infants.[37] Although the postnatal factors scale was found to be a significant predictor for three of the motor performance measures at 9 months, others have cautioned against using the scale in diagnosing an individual child.[38]

Infant ethnicity was found to be an important predictor of 9-month performance. Specifically, infants identified as Hawaiian or part-Hawaiian were found to perform poorly on the 9-month Bayley motor scale and on all the Gesell scales except gross motor. Although this result most likely reflects a positive relationship between socioeconomic status and developmental outcomes, as noted by others,[3,15] family income itself was not an important predictor in our analysis. This information, coupled with evidence that children in the Hawaiian community are more environmentally at risk than those of other ethnic groups in the state,[16] supports targeting intervention programs to address the specific sociocultural and health needs of minority populations.

Therapists should be cautioned that our outcome measures obtained at 9 months may not reflect a stable stage of development. Prediction of such outcomes may be more difficult or less reliable than for later developmental stages but, because referrals to infant programs are being made early, often on hospital discharge, it is important to be able to predict with reasonable accuracy which infants need intervention programs. We hope to clarify the value of our predictors with a longitudinal follow-up study of our NICU cohort; a three-year testing is underway, which may provide more stable outcome measures. We greatly need more longitudinal research, better testing standardization, and improved assessment measures if we are to optimize therapy programs in a period of declining resources.

SUMMARY

In summary, physical therapists skilled in motor and behavioral assessments of the preterm infant may be able to assist in the early identification of infants who will be developmentally delayed or handicapped. Although several measures of potential value in prediction have been identified, we support the continuing development of improved assessment measures and stress a conservative application of our regression data because these results are heavily dependent on the sample, the measures, and the age at testing. Therapists anxious to improve their identification of the potentially handicapped may consider such items as low birth weight, ethnic group membership, and high or low performance on selected scales as rough indicators of developmental potential. Because assigning relative weights to such indicators on the basis of our limited data is difficult, one use that practitioners might make of our results would be to focus more on the several predictors identified in our text. Infants who amass more negatives on these specific indicators appear to face greater risk of handicapping than those who amass more positives. Considerable additional research is needed before we can predict accurately individual developmental potential, but the possibility is within reach.

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