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The association of cumulative risk scoring with ASQ-3 outcomes in a rural impoverished region of Guatemala

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Abstract

Background: Child development is a global health priority. Cumulative risk scoring may be a useful tool to design more effective interventions to help high-risk young children reach their developmental potential in impoverished rural regions.

Objective: To develop a risk score comprised of easily obtainable factors to design interventions and identify high-risk children who would most benefit from the interventions.

Methods: Mother-child behavior interaction surveys and Ages and Stages Questionnaire, Third Edition (ASQ-3) developmental screens were completed in a convenience sample of 148 mothers with children aged 12-52 months in rural Guatemala. Associations between abnormal scores in the ASQ-3 developmental domains and demographic variables and mother-child interactions were examined. Scores were calculated by assigning 1 point for each of the included factors: 1) Maternal Demographic Risk score (DR): having no formal education, cannot read and write, having 3 or more children, and having 4 or more pregnancies; 2) Mother-Child Interaction score (MCI): sings songs, tells stories, plays with child with toys, converses with child while feeding, points to and names objects for child, and reads books to child; and 3) Combined Risk score (CR): combined two significant demographic elements and two significant negative mother-child interactions.

Results: At baseline, 58% of children had abnormal scores in ≥1 ASQ-3 domain, and 35% in ≥2 domains. The probability of having ≥2 domains with abnormal scores increased significantly with an increasing DR score (OR, 1.46 [95% CI, 1.15-1.86] $p<0.05$) and an increasing CR score (OR, 2.08 [95% CI, 1.41-3.07], $p<0.05$).

Conclusion: Rural Guatemalan children have high rates of ASQ-3 defined abnormal scores. A combined demographic and mother-child interaction cumulative risk index appears to be a useful tool to predict which children have abnormal scores across multiple domains. This CRI should be validated with more structured developmental testing that is not based on parent report.

Introduction

Child development is a global health priority. Approximately 4 in 10 children living in the developing world have developmental delays early in life. This risk of developmental delay is probably considerably higher for children born into rural impoverished communities [1]. Multiple studies document that children exposed to adverse environmental factors are at increased risk for atypical brain development, developmental delay, increased psychological stress, poor school readiness and poor academic achievement [2-13]. Recognizing the importance of these factors, the American Academy of Pediatrics Committee on Children with Disabilities recommends assessing the risk of developmental delay in conjunction with developmental surveillance and screening [14]. Adverse environmental factors are mediated through the 'home 'cognitive environment", which supports the development of young children through the quality and quantity of mother (caregiver)-child interactions especially talking, playing, reading/storytelling and praise. These will impact the child's long-term developmental trajectory and future academic success [5]. Having stressful or traumatic experiences in early childhood and/or having a mother with depression will adversely impact the home cognitive environment [2,15-17]. Assessing the risk of developmental delay for children living in impoverished communities in low- and middle-income countries (LMICs) is challenging because multiple factors in addition to adverse home environmental factors adversely impact the developmental trajectories of these children. These factors include low birth weight (prematurity and intrauterine growth retardation), neonatal infections, microcephaly, post-natal acute malnutrition and stunting (chronic malnutrition), iron deficiency anemia, and exposure to lead and other possible toxins [1,15,16]. While interventions to minimize these factors are important, enhancing the home cognitive environment remains one of the most effective interventions to promote development.

Assessing potentially useful ways to determine the impact of risk factors on the home cognitive environment, subsequent developmental milestones and academic functioning would be useful in designing and implementing effective interventions. The concept of cumulative risk

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recognizes that risk increases as the number of adverse environmental factors to which a child is exposed increases. In 1979, Michael Rutter described how chronic psycho-social stresses interact with and potentiate each other, creating a larger effect on psychiatric outcomes in children [9]. Rutter demonstrated that this effect is greater than when the impact of each stress is considered singly and then added together. The cumulative risk index (CRI) described by Sameroff et. al.in 1987 is a simple, additive score based on the number of specified environmental factors to which a child is exposed [10]. The CRI uses only the number of risks to which a child is exposed, ignoring both the intensity and pattern of the exposure. The CRI was derived by counting a child's exposure to a possible 10 personal and family risk factors and correlating the score with IQ at age 4 and 13 years of age. In his analysis there was a significant drop in IQ scores as the number of risks increased. Five of the 10 factors used were simple demographic family characteristics, such as low maternal education, and low income. Since Sameroff's publication, CRIs have been widely used in developmental psychology to analyze the effects of multiple risk exposure on developmental outcomes. Pati et al. [11] studied 12 personal, family and environmental risk factors, present at age 2. He reported that four of these factors (low maternal education, low income, racial/ethnic minority and single-parent household) were strong predictors of poor academic achievement scores in 6 and 7 year old children. These four factors are commonly used in studies of CRI effects on development [18,19] Similar findings have been reported in LMIC settings. A 1996 study of Guatemalan school children demonstrated a linear relationship between an increasing number of risk factors encountered by age three years and subsequent decrease in school achievement and cognition [12]. Cumulative risk may become a useful tool for predicting the neuro-developmental outcomes of interventions in low, middle- and high-income countries and for targeting interventions to the most vulnerable children who are most likely to benefit.

In 2011, the Center for Global Health at the Colorado School of Public Health, in partnership with a local agro-business foundation, began a community-based nursing program in a rural impoverished area in southwestern Guatemala [20]. Prior to designing the program, Ages and Stages Questionnaire, Third Edition (ASQ-3) screens [21] and a maternal –child interaction survey were obtained from a convenience sample of children under 3 years of age to determine the baseline distribution of normal, borderline, and abnormal scores. We constructed a several cumulative risk scores using both sociodemographic factors and mother -child interactions to predict which children would have borderline, and abnormal scores. We then assessed how this information would be useful in identifying key elements of an effective intervention program and targeting families to be enrolled.

Methods

Location and participants

From July to August of 2012, we conducted an ASQ-3 screen and a cross-sectional survey of 148 mothers with children between the ages of 12 to 52 months living in five rural communities in southwest Guatemala. Children who were sick at that time, were known to have a complicated past medical history, or appeared to have a significant developmental delay by a faculty pediatrician were excluded from participating in this baseline assessment.

Demographic and survey data

We administered the initial survey to the baseline cohort using a standardized questionnaire that included the child's age and gender, as well as the mother's age, level of formal education, literacy, marital status, number of children in the family, and number of pregnancies. Maternal behaviors included: 1) sings songs, 2) tells stories, 3) plays with child with toys, 4) converses with child while feeding, 5) points to and names objects for child, and 6) reads books to child. These are caregiver behaviors that have been included in validated instruments on the home cognitive environment such as the StimQ [22], and the HOME Interview [23].

ASQ-3 screening and definitions

We chose the ASQ-3 for its easy administration and its wide use among diverse populations [21,24-34]. The Spanish version of the ASQ-3 was administered to assess five domains: Gross Motor (arm, leg, and body movements), Fine Motor (hand and finger movements), Communication (vocalization and comprehension), Personal-Social (solitary and social play), and Problem Solving (learning and understanding). Community health workers and nurses were trained to administer the ASQ-3 and were supervised by a pediatrician and a trained medical student. Whenever possible we tried to have mothers demonstrate that their child could carry out the task. We categorized numerical scores as "normal, "borderline," or "abnormal" based on ASQ-defined age and gender standards. An abnormal score was defined as two standard deviations below the mean of the United States domain reference group as the cut-off, and borderline scores were defined as one to two standard deviations below the same mean. For the purpose of this evaluation, ASQ-3 borderline scores were considered abnormal in the regression and comparative analyses.

Statistical analysis

Chi-square or Fisher's exact tests for dichotomous variables and t-tests for continuous variables, respectively, were used to assess the associations between ASQ-3 scores with demographic variables and mother-child interactions for three age groups (12-24 month-olds, 25-36 month-olds, and 37-52 month-old children) as well as the entire cohort. We examined associations between the five developmental domains of the ASQ-3 and the frequency of domains with abnormal scores with demographic variables and mother-child interactions.

In order to develop a Demographic Risk (DR) score for maternal demographic variables, we dichotomized categorical and continuous variables (presence or absence of risk factor) whenever possible to produce the most precise and easily quantifiable scoring system. Variables that showed little variance in our study population (i.e., maternal employment, marital status) were excluded from the analysis. We calculated the DR score by assigning one point for each of the following factors: having no formal education, not able to read and write, having three or more children, and having four or more pregnancies (higher scores are worse). Univariate and multivariable logistic regression analyses were used to evaluate the associations between the DR score and the five ASQ-3 domains and frequency of abnormal scores in each domain, controlling for confounders. Adjustment variables included child's age and gender.

We also created a Mother-Child Interaction (MCI) score for each child based on maternal report of whether or not the mother performed six positive parenting behaviors: 1) sings songs, 2) tells stories, 3) plays with child with toys, 4) converses with child while feeding, 5) points to and names objects for child, and 6) reads books to child (higher scores are better). Univariate and multivariable logistic regression analyses were used to evaluate the associations between the MCI score and the five ASQ-3 domains and frequency of abnormal scores in each domain as described above.

We then used multivariable logistic regression to develop a model that included variables from both the DR and MCI scores, called the Combined Risk score (CR). When two similar variables were both found to be significantly ($p<0.05$) associated with one or more of the outcome variables (i.e. mother's literacy and mother's education; number of children and number of pregnancies), the variable with the strongest relationship with the outcome was retained. Variables that did not show a significant relationship ($p<0.05$) with an abnormal score in at least one of the outcomes ASQ-3 domains were eliminated. The final CR score (higher scores are worse) combined two demographic elements (no formal education and four or more pregnancies) and two negative mother-child interactions (doesn't play with toys and doesn't converse while feeding), all adjusted for child's age and gender.

All data were analyzed using SAS software, Version 9.3 (SAS Institute, Inc.; Cary, NC), with an alpha level of 0.05.

Ethics review

This project was considered a quality improvement exempt project by the Colorado Institutional Review Board.

Results

Table 1 shows maternal demographic data for 148 children in the three age groups studied. No significant differences were found between the age groups with respect to baseline characteristics. Approximately one third of the mothers were illiterate and the average number of children in the family was 3.2. The mean annual family income was USD $964 ($2.65 per day).

Mother–child interactions

Only five (3.5%) mothers reported having any children's books available at home, and 82 (56%) mothers reported having ever read a book to their child. Of those, 26 (18%) mothers reported reading to their child more than once per week. Similarly, 79 (54%) mothers reported telling stories to their child, but only 19 (13%) did so more than once per week. The majority of mothers, however, reported that they had engaged in various language-promoting activities such as playing with toys with their child (n=129, 88%), talking to their child while feeding them (n=134, 91%), and pointing to and naming objects for their child (n=138, 94%).

ASQ-3 scores

The ASQ-3 scores in the five developmental domains stratified by three age groups and the frequency of normal, borderline, and abnormal scores are shown in table 2. Eighty-six children (58%) had an abnormal score in at least one ASQ-3 category, and 51 (35%) had an abnormal score in two or more categories. The Fine Motor domain accounted for most of the abnormal scores (n=59, 40%), followed by Problem Solving (n=42, 29%), Gross Motor (n=37, 25%), Personal-Social (n=24, 16%), and Communication (n=13, 8.8%). When each age category was examined individually, younger children were more likely to screen positive for one or more domains with abnormal scores than older children (70% vs 63% vs 42%, respectively; p=0.01), and Fine Motor borderline or abnormal scores were more frequently identified in the 12-24 month age group compared with children in the two older age categories (79 % vs 63% vs 50%, respectively; p=0.02).

The relationship of demographic variables to ASQ-3 scores

We performed univariate logistic regression analyses to assess the probability of scoring "abnormal" (borderline or abnormal scores) on each of the five ASQ-3 domains based on certain demographic variables (Table 3). Older children were less likely to have abnormal Fine Motor scores (OR, 0.96 [95% CI, 0.93-0.99]). Children of mothers with no formal education were approximately 3.57 times as likely to have abnormal scores in the Problem-Solving domain (OR, 3.57 [95% CI, 1.54-8.33]). The probability of having an abnormal ASQ-3 domain when examined separately for each domain did not reach significance for child's gender, mother's age, or mother having four or more pregnancies. However, when mothers did have four or more pregnancies, the likelihood of having an abnormal score on Gross Motor (OR, 1.12 [95% CI, 0.98-1.28]), Problem Solving (OR, 1.15 [95% CI, 0.99-1.33]), and Personal Social (OR, 1.10 [95% CI, 0.96-1.25]) domains were marginally significant with $p< 0.10$. The probability of having two or more domains with abnormal scores decreased significantly for older children (OR, 0.96 [95% CI, 0.93-0.99]), and increased significantly with older maternal age (OR, 1.06 [95% CI, 1.01-1.11]), mothers with no formal education (OR, 3.80 [95% CI, 1.79-8.07]), and mothers with four or more pregnancies (OR, 1.21 [95% CI, 1.05-1.39]).

Table 1. Demographic characteristics of the participants by age group

	12-24 months	25-36 months	37-52 months	Total
Number of children [n]	46	52	50	148
Average age of child [age in months (SD)]	18.4 (±3.4)	30.7 (±3.5)	43.4 (±4.8)	31.2 (±10.8)
Female gender [n (%)]	30 (66.7)	28 (52.8)	21 (42.0)	79 (53.0)
Average age of mother [age in years (SD)]	24.3 (±6.0)	27.2 (±8.6)	28.0 (±7.0)	26.6 (±7.5)
Mother had some formal education* [n (%)]	30 (66.7)	38 (71.7)	37 (74.0)	105 (70.9)
Mother is literate [n (%)]	30 (69.8)	35 (66.0)	32 (64.0)	97 (66.4)
Average number of children in the family (SD)	2.98 (±2.0)	3.1 (±2.5)	3.6 (±2.4)	3.2 (±2.3)
Average number of pregnancies (SD)	3.17 (±2.3)	3.35 (±2.5)	3.90 (±2.8)	3.47 (±2.6)
Mother is married/living with partner [n (%)]	37 (82.2)	47 (88.7)	45 (90.0)	129 (87.2)

*Mother attended school for any number of years

Table 2. Frequency of ASQ-3 scores in five developmental domains, stratified by age group

ASQ Category and Result Scores		**12-24 months**	**25-36 months**	**37-52 months**	**Total Group**
		Total n 46	Total n 52	Total n 50	Total n 148
		n (%)	n (%)	n (%)	n (%)
Communication	Normal	37 (80)	38 (73)	39 (78)	114 (77)
	Borderline	5 (11)	7 (13)	8 (16)	21 (14)
	Abnormal	4 (9)	7 (13)	3 (6)	13 (8)
Gross Motor	Normal	28 (61)	29 (56)	39 (78)	96 (65)
	Borderline	6 (13)	8 (15)	1 (2)	15 (10)
	Abnormal	12 (26)	15 (29)	10 (20)	37 (25)
Fine Motor	Normal	10 (22)	19 (37)	25 (50)	54 (36)
	Borderline	9 (20)	12 (23)	14 (28)	35 (24)
	Abnormal	27 (59)	21 (40)	11 (22)	59 (40)
Problem Solving	Normal	18 (39)	24 (46)	18 (38)	60 (41)
	Borderline	15 (33)	9 (17)	20 (42)	44 (30)
	Abnormal	13 (28)	19 (37)	10 (21)	42 (29)
Personal-Social	Normal	28 (61)	26 (50)	36 (75)	90 (62)
	Borderline	9 (20)	15 (29)	8 (17)	32 (22)
	Abnormal	9 (20)	11 (21)	4 (8)	24 (16)
≥ 1 Abnormal Scores	Yes	32 (70)	33 (63)	21 (42)	86 (58)
	No	14 (30)	19 (37)	29 (58)	62 (41)
≥ 2 Abnormal Scores	Yes	21 (46)	20 (38)	10 (21)	51 (35)
	No	25 (54)	32 (62)	38 (79)	95 (65)
Total n		46	52	50	148

Table 3. Univariate logistic regression of the association between descriptive variables and ASQ-3 domains by probability of scoring "abnormal" on ASQ-3 [Odds Ratios (95% CI)]†

	Communication	Fine Motor	Gross Motor	Problem Solving	Personal-Social	≥1 Abnormal scores	≥2 abnormal scores
Child's age (months)	1.005 (0.97, 1.04)	0.96* (0.93, 0.99)	0.98 (0.95, 1.01)	1.002 (0.97, 1.03)	0.98 (0.94, 1.01)	0.95* (0.92, 0.99)	0.96* (0.93, 0.99)
Child's gender (male)	0.62 (0.28, 1.33)	1.23 (0.63, 2.44)	1.16 (0.59,2.27)	0.96 (0.50, 1.85)	1.05 (0.54, 2.08)	1.13 (0.59, 2.17)	1.46 (0.73, 2.90)
Mother's age (years)	0.99 (0.93, 1.04)	1.02 (0.97, 1.06)	1.03 (0.98, 1.08)	1.04 (0.96, 1.12)	1.03 (0.98, 1.08)	1.04 (0.96, 1.12)	1.06* (1.01, 1.11)
Mother had no formal education	1.22 (0.53, 2.78)	1.72 (0.79, 3.70)	1.49 (0.72, 3.13)	3.57* (1.54, 8.33)	1.96 (0.95, 4.00)	3.24 (1.45, 7.24)	3.80* (1.79, 8.07)
Mother is single	0.88 (0.27, 2.85)	0.47 (0.17, 1.23)	0.45 (0.14, 1.45)	1.61 (0.57, 4.55)	0.38 (0.12, 1.23)	0.48 (0.18, 1.27)	0.48 (0.15, 1.55)
≥4 pregnancies	1.04 (0.90, 1.20)	1.09 (0.94, 1.25)	1.12 (0.98, 1.28)	1.15 (0.99, 1.33)	1.10 (0.96, 1.25)	1.09 (0.95, 1.25)	1.21* (1.05, 1.39)
Doesn't play with child with toys	4.17* (1.49, 11.11)	1.59(0.53, 4.76)	1.54 (0.57, 4.17)	2.78 (0.86, 9.09)	2.22 (0.81, 5.88)	2.06 (0.69, 6.11)	3.55* (1.28, 9.83)
Doesn't converse with child while feeding	2.27 (0.68, 7.69)	1.33 (0.39, 4.55)	2.33 (0.73, 7.14)	4.35 (0.92, 20.00)	0.68 (0.20, 2.33)	1.71 (0.50, 5.85)	1.71 (0.54, 5.41)
Doesn't sing songs	1.15 (0.48, 2.78)	0.88 (0.41, 1.92)	1.04 (0.48, 2.27)	0.98 (0.46, 2.13)	1.37 (0.64, 2.94)	1.03 (0.48, 2.20)	1.10 (0.50, 2.42)
Doesn't tell stories	2.33* (1.05, 5.00)	1.23 (0.63, 2.44)	0.90 (0.46, 1.79)	1.33 (0.68, 2.63)	0.87 (0.44, 1.69)	1.25 (0.65, 2.43)	0.89 (0.45, 1.78)
Doesn't point to and name objects	1.72 (0.41, 7.14)	1.18 (.28, 5.00)	2.44 (0.62, 9.09)	0.88 (0.22, 3.45)	1.30 (0.33, 5.00)	2.69 (0.54, 13.43)	2.53 (0.65, 9.87)
Doesn't read books	1.13 (0.54, 2.50)	1.79 (0.90, 3.57)	0.88 (0.45, 1.75)	2.00* (1.01, 4.00)	0.99 (0.51, 1.92)	1.48 (0.76, 2.87)	1.76 (0.88, 3.52)

*p<0.05
† borderline or abnormal scores were considered abnormal

We then performed multivariable logistic regression analyses to assess the probability of having an abnormal score (borderline or delayed) on each of the five ASQ-3 domains according to the DR score as shown in table 4. The probability of having abnormal Problem-Solving scores increased significantly with an increasing DR score (OR, 1.43 [95% CI, 1.12-1.79]). The associations between the DR score and both the Fine Motor (OR, 1.22 [95% CI, 0.97-1.54]) and Personal Social (OR, 1.20 [95% CI, 0.97-1.52]) domains were marginally significant ($p<0.10$). The probability of having two or more domains with abnormal scores increased significantly with an increasing DR score (OR, 1.46 [95% CI, 1.15-1.86]).

The relationship of mother-child interactions to ASQ-3 scores

Univariate logistic regression analyses to assess the probability of scoring abnormal (borderline or abnormal) on each of the five ASQ-3 domains with mother–child interactions showed that not playing with toys and not telling stories increased the probability of having an abnormal Communication score (OR, 4.17 [95% CI, 1.49-11.11] and OR, 2.33 [95% CI, 1.05-5.00] respectively). Not reading books increased the probability of a having an abnormal problem-solving score (OR, 2.00 [95% CI, 1.01-4.00]). Not conversing while feeding was marginally significantly associated with an abnormal problem-solving score (OR, 4.35 [95% CI, 0.92-20.00] $p<0.10$). Not playing with toys significantly increased the probability of having two or more domains with abnormal scores (OR, 3.55 [95% CI, 1.28-9.83]).

Multivariable regression analyses for the probability of having an abnormal score on each of the five ASQ-3 domains according to the six-point MCI score (Table 5) revealed that the probability of having an abnormal Communication score decreased significantly with an increasing MCI score (OR, 0.65 [95% CI, 0.45-0.91]). An increasing MCI score was also marginally significantly associated with a decreased probability of having two or more domains with abnormal scores (OR, 0.74 [95% CI, 0.54-1.02] $p=0.06$).

Relationship of a combined demographic and mother child interaction risk score to ASQ-3 scores

Multivariable regression analyses for the probability having an abnormal score on each of the five ASQ-3 domains according to the Combined Risk score are shown in table 6. The probability of having abnormal Communication (OR, 1.45 [95% CI, 1.00-2.13]), Problem Solving (OR, 2.00 [95% CI, 1.33-3.03]), and Personal Social (OR, 1.43 [95% CI1.003-2.00]) scores increased significantly with an increasing CR score. The association between an increasing CR score and having abnormal Fine Motor (OR, 1.41 [95% CI, 0.96-2.04] $p=0.08$) and Gross Motor (OR, 1.39 [95% CI, 0.98-1.96] $p=0.06$) scores were marginally significant. The probability of having two or more domains with

Table 4. Multivariable logistic regression analysis of the association between ASQ-3 domains and the Demographic Risk score (Probability of having an abnormal score)†

Outcome variable	N	OR (95% CI)	p-value
ASQ communication	146	1.12 (0.88, 1.45)	0.34
ASQ fine motor	146	1.22 (0.97, 1.54)	0.09
ASQ gross motor	146	1.18 (0.94, 1.47)	0.14
ASQ problem solving	144	1.43 (1.12, 1.79)	0.004*
ASQ personal/social	144	1.20 (0.97, 1.52)	0.09
≥1 abnormal scores	146	1.40 (1.11, 1.78)	0.005*
≥2 abnormal scores	144	1.46 (1.15, 1.86)	0.002*

Adjusted for child's age and gender
† borderline or abnormal scores were considered abnormal

Table 5. Multivariable logistic regression analysis of the association between ASQ-3 domains and the Mother-Child Interaction score (Probability of having an abnormal score)†

Outcome variable	N	OR (95% CI)	p-value
ASQ communication	146	0.65 (0.45, 0.91)	0.01*
ASQ fine motor	146	0.83 (0.60, 1.14)	0.23
ASQ gross motor	146	0.92 (0.68, 1.23)	0.57
ASQ problem solving	144	0.70 (0.42, 1.16	0.16
ASQ personal/social	144	0.93 (0.69, 1.27)	0.67
≥1 abnormal scores	146	0.78 (0.57, 1.07)	0.12
≥2 abnormal scores	144	0.74 (0.54, 1.02)	0.06

Adjusted for child's age and gender
† borderline or abnormal scores were considered abnormal

Table 6. Multivariable logistic regression analysis of the association between ASQ-3 domains and the Combined Risk score (Probability of having an abnormal score)†.

Outcome variable	N	OR (95% CI)	p-value
ASQ communication	147	1.45 (1.00, 2.13)	0.05*
ASQ fine motor	147	1.41 (0.96, 2.04)	0.08
ASQ gross motor	147	1.39 (0.98, 1.96)	0.06
ASQ problem solving	145	2.00 (1.33, 3.03)	0.0008*
ASQ personal/social	145	1.43 (1.003, 2.00)	0.048*
≥1 abnormal score	147	1.74 (1.17, 2.58)	0.006*
≥2 abnormal score	145	2.08 (1.41, 3.07)	0.0002*

Adjusted for child's age and gender
† borderline or abnormal scores were considered abnormal

abnormal scores increased significantly with an increasing CR score (OR, 2.08 [95% CI, 1.41-3.07]).

Discussion

The findings of this assessment show that abnormal ASQ-3 scores were common across all five domains in children from the southwest rural lowlands of Guatemala. Abnormal ASQ-3 scores in at least one domain were identified in 58% and two domains in 35% of children. Additionally, univariate regression analyses found that the children of mothers with larger families, mothers who were illiterate, and those with little formal education were more likely to have abnormal ASQ-3 scores.

The probability of having two or more domains with abnormal scores increased significantly with an increasing DR score (OR, 1.46 [95% CI, 1.15-1.86]). An increasing MCI score (having more positive interactions) was significantly associated with a decreased probability of having two or more domains with abnormal scores (OR, 0.74 [95% CI, 0.54-1.02] p=0.06). The probability of having abnormal scores in two or more domains doubled with the addition of each risk factor in the combined risk model (no formal education, four or more pregnancies, doesn't play with toys and doesn't converse while feeding).

Abnormal ASQ-3 scores in this population tended to be higher than abnormal scores reported from studies done in other low- and middle-income countries. In Ghana, abnormal ASQ screens in each domain ranged from 5.8-12.4% (children under age 12 months) [24]. In a Turkish study, 28.1% of children aged 3-72 months had abnormal ASQ screens in at least one domain (with a modified ASQ) (28). A study of Indian children at age three years found abnormal ASQ screens in each domain ranged from 27.7-42.5% [30]. In Ecuador, abnormal ASQ screens in each domain ranged from 17.3-33.6% (children 3-61 months of age) [33]. Abnormal ASQ screens ranged from 3.8-15.5% in a study of Peruvian children [34]. The ASQ questions were modified in some of these cited studies. Since we did not modify any of the questions, it is possible that some questions were not culturally appropriate to our community. It is also likely that our Guatemalan population was more impoverished than other populations in these reported studies. Subsequent studies carried out in this area have documented high rates of microcephaly as well as stunting and iron deficiency anemia, which would also affect the observed findings [35,36].

Our findings assessing combined risk are consistent with the 1996 study of Guatemalan school children that demonstrated a linear relationship between an increasing number of risk factors encountered by age three years and subsequent decrease in school achievement and cognition [12].

There are several lessons to be learned from our findings that are relevant to the design of interventions supporting the home cognitive environment. We designed our community nursing intervention to educate mothers on the importance of talking, reading, playing and praise. At our 2 months visit we introduced the mothers to the use of finger puppets to encourage more talking to their infants. We taught mothers how to make simple toys for their children. We provided books and worked with mothers on practicing dialogic reading and asking their children questions. We tried to meet the needs of mothers who are illiterate or have little education by providing picture books, describing how to use these books, and communicating the importance of storytelling in place of reading. We have incorporated these lessons into the development and implementation of our "Niños Sanos" (Healthy Children) integrated health and development program of community group visits and play groups [34]. In order to reduce adolescent pregnancies, we implemented a school based reproductive health curriculum in local schools and improved adolescent access to contraceptives including long acting reversible contraceptives (LARC). We have also started offering to place LARC at the 1-month home post-partum visit.

An important limitation of this study is the nature of the convenience sample. It is not clear how representative the baseline group sample is to the overall community. At the time of the enrolment, we had not mapped the community and had no feasible, affordable way of identifying a representative sample. A further limitation, as described above, is that the ASQ questions were not modified and culturally adapted and may have, been difficult for mothers to understand and correctly interpret. We have also learned from subsequent neurodevelopment activities that mothers in our area may respond to ASQ questions affirmatively when more formal testing documents that their child cannot perform the specified task. Therefore, the CRI should be validated with more structured developmental testing that is not based on parent report.

Conclusion

These findings show that children in the southwest region of Guatemala have high rates of ASQ-3 defined abnormal scores across multiple domains, indicating likely developmental delays. Preliminary findings suggest that a CRI that includes demographic factors of 1) no formal maternal education and 2) four or more pregnancies as well as the negative mother-child interactions of 3) doesn't play with toys and 4) doesn't converse while feeding can help design programs and identify the population of children at highest risk of having multiple developmental delays. This CRI should be validated in a larger population with more structured developmental testing that is not based on parent report.

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Ethics and consent

This project was considered a quality improvement exempt project by the Colorado Institutional Review Board.

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