

An Anthropological Approach to the Evaluation of Preschool Children Exposed to Pesticides in Mexico

Elizabeth A. Guillette,¹ María Mercedes Meza,² María Guadalupe Aquilar,² Alma Delia Soto,² and Idalia Enedina García²

¹Bureau of Applied Research in Anthropology, University of Arizona, Tucson, AZ 85721 USA; ²Dirección de Investigación y Estudios de Postgrado, Instituto Tecnológico de Sonora, Obregón, Sonora, México

In this comparative study, we compensated for many of the known variables that influence children's growth and development by selecting two groups of 4–5-year-old Yaqui children who reside in the Yaqui Valley of northwestern Mexico. These children share similar genetic backgrounds, diets, water mineral contents, cultural patterns, and social behaviors. The major difference was their exposure to pesticides. Pesticides have been applied to the agricultural area of the valley since the late 1940s. In 1990, high levels of multiple pesticides were found in the cord blood of newborns and in breast milk. Building on anthropological methods for rapid rural appraisal of problems within the environment, a Rapid Assessment Tool for Preschool Children (RATPC) was developed to measure growth and development. The children of the agrarian region were compared to children living in the foothills, where pesticide use is avoided. The RATPC measured varied aspects of physical growth and abilities to perform, or function in, normal childhood activities. No differences were found in growth patterns. Functionally, the exposed children demonstrated decreases in stamina, gross and fine eye–hand coordination, 30-minute memory, and the ability to draw a person. The RATPC also pointed out areas in which more in-depth research on the toxicology of pesticides would be valuable. **Key words:** children, Mexico, pesticides, Yaqui. *Environ Health Perspect* 106:347–353 (1998). [Online 18 May 1998] <http://ehpnet1.niehs.nih.gov/docs/1998/106p347-353guillette/abstract.html>

Major difficulties exist in evaluating the effects of pesticide exposure on children. One reason is that within the United States, the majority of children tend to differ in physical, environmental, cultural, and social experiences that influence growth and development. Genetic backgrounds differ, creating morphologic variation within and between groups of individuals. Families move into and out of areas, complicating issues regarding historical and present exposures to contaminants, both for the types and degree of bodily intake. Taken a step further, variations in parental exposure complicate the issues regarding the effects of contaminants in creating genetic aberrations in sperm and ova, plus the amount of maternal transference of pesticides and other man-made chemicals during pregnancy and lactation. The multitudes of diverse social factors, including socioeconomic status, the multiple facets of traditional customs and/or acculturation, and dietary patterns, add additional drawbacks for both matching the study group with a similar but less pesticide-exposed control or reference group and for the interpretation of findings regarding the two groups. Frequently, these factors are used to question, criticize, and even discount research findings involving the impact of pesticides on a child's growth and development.

Research on children has generally concentrated on the interaction between a single contaminant, usually passed from mother to

child *in utero* and through lactation, with the child's growth and development. Unfortunately, such studies usually arise when pregnant women are accidentally exposed to contamination. Although findings should be considered valid, a similar accident (to provide additional strength to the research through repetition) is unlikely to occur. Also, we readily accept the paradigm that a single contaminant, or class of contaminants, creates its own unique syndrome of human aberrations. One danger is that this resulting syndrome may be preselected with limited end points that reflect the researcher's area of expertise. In addition, it is easy to assume that the child has experienced no additional deleterious exposures, especially with longitudinal studies involving the initial study cohort. Studies performed in this manner indicate that *in utero* and lactational exposure to polychlorinated biphenyls (PCBs) impairs mental and motor abilities, including a lowering of intelligence (1). Multiple birth defects also have been associated with maternal exposure to chlorophyrifos (Dursban) (2).

Other studies take an analytical epidemiological approach, investigating health changes over a period of time. This avoids single agent paradigms, instead substituting environmental change as the causative factor. Assorted population changes, ranging from a decline in the proportion of males being born in Denmark

to a temporal rise in general cancer rates among younger children (3) have been investigated with this approach. Other studies indicate apparent increases in cryptorchidism and testicular cancer over time, during which unknown environmental change has occurred (4). Contamination is a suspected major environmental contributor, but cannot be definitively identified (5). Also, each population under study incorporates a host of varied biological, social, and technological factors that influence the environment.

An Expanded Approach for Evaluating Preschool Children Exposed to Multiple Pesticides

Much of our knowledge about the physiological mechanisms of pesticides that lead to detrimental effects is the result of wildlife and laboratory studies. These studies have led to a hypothesis that pesticide- or industrial contaminant-related hormonal disruptions can modify human physiologic development and functioning (6,7). Exposure to endocrine disrupting contaminants (EDCs) may occur *in utero* and result in modification of normal anatomical development. Such modification may be observable immediately at birth or expressed later in life (8). Additional exposure can continue after birth.

Although blood levels of pesticides indicate their presence in the body, there is no readily available means to identify when an individual was first exposed to a single compound or mixture of chemicals or the degree of exposure occurring during critical periods of embryonic or neonatal development.

Address correspondence to E.A. Guillette, 32 SW 43rd Terrace, Gainesville, FL 32607 USA.

The authors would like to acknowledge Gonzalo Robles Monteverde and José Luis Navarro of the Secretaría de Salud Pública, Sonora, and Jose Manuel López and Juan Manuel Morsan of the Instituto Tecnológico de Sonora for their assistance in making this study possible. We thank Howard Bern and Theo Colborn for valuable comments on earlier drafts of this manuscript and Lou Guillette for assistance with statistics. This work was funded in part by the Bureau of Applied Research in Anthropology, University of Arizona, Dirección de Investigación y Estudios de Postgrado, Instituto Tecnológico de Sonora and Secretaría de Salud Pública, Sonora. Received 5 September 1997; accepted 10 March 1998.

Additionally, it is difficult to establish reliable temporal exposure patterns for most individuals. Therefore, it is important to select a study population in which all mothers and their children experience relative equality in their contact with pesticides. Only then can it be assumed that the children under study have a similar probability in their timing of exposure and levels of exposure to similar mixtures of pesticides—both *in utero* and following birth. In turn, the reference population must meet the requirement of sharing minimal exposure to the ambient contamination. In today's world, complete avoidance of exposure is an impossibility.

The many assorted variables that confound pesticide studies must also be addressed. Delemarre-van de Wall (9) delineated a host of environmental factors that influence growth and development, including diet. Diet is frequently implicated for birth defects, mental deficiencies, and growth retardation, all of which are associated with pesticide exposure (10). The test and reference groups must have a very comparable diet in all aspects. In developing countries, where traditions remain strong and diets retain symbolic culture values, diet is fairly uniform regardless of income (11). American diets tend to be influenced more by family preferences and finances than by historic cultural practices and food item availability, thus varying among households (12). Dietary history may be used to decrease the variable, but dietary recall, including the foods eaten even in the past week, is notoriously inaccurate (13). As well as families having varied diets, differences among ethnic groups in body metabolism and organ function are documented (14). Any differences in terms of physiological responses to pesticides in relation to racial group are unknown and remain to be investigated. Therefore, a similar genetic makeup should be shared among members of the study and between reference groups. Finally, the role of sociocultural practices, including stress, parenting practices, and standards of living, are known to influence learning and behavior (9). As neurological dysfunction has been related to contaminant exposure, the sociocultural atmosphere including standards of behavior of all participants should be as similar as possible. Is it possible to fulfill these requirements? The answer is probably "no" if we insist on limiting ourselves to research at convenient sites in the developed nations. However, the mentioned requirements can be met elsewhere, where families remain in place and superimpose their traditional practices and lifestyles on daily life, even with advances in modernization.

A second aspect in developing an ideal study is to admit that we honestly do not

know everything that we should be investigating. Dysfunction in the reproductive, immune, neurological, and skeletal systems is implied, as demonstrated in wildlife exposed to pesticides (7,15,16). Similar dysfunction is noted with human subpopulations following either accidental or long-term exposure to PCBs (1,17–19). These epidemiological and case studies provide indications that thought and behavioral processes are altered, and their long-term ramifications to the individual, the family, and society need to be considered. Are the same deleterious effects found in the residents of areas where pesticides are used according to accepted agricultural practice? We must begin to consider the broader picture. How does exposure to contaminants influence the total health and daily functioning of a child? Finally, as we enter the time frame of multigenerational exposure to pesticides, are the total health and the related normal activities of the population at risk? All of this must be combined in order to provide a multidimensional approach to a complex, multifaceted problem.

Directing Pesticide Research with Rapid Appraisal Techniques

An emerging area of techniques in applied anthropology is that of rapid assessment. Rapid assessment has been used in environmental studies to determine if a problem exists within a community and to direct the areas in which future research and action is desirable (20). We have adapted this concept to the evaluation of children, with the goal of developing a technique in which a representative number of individuals could be evaluated within a relatively limited time period. The technique is not intended to provide comprehensive data on specific areas, but to identify problem areas and stimulate thought on new directions for research. The purpose of this study was to determine if children living in an agricultural environment were at risk in terms of normal growth and development, as expressed in normal childhood play. The emphasis was placed on determining if the community children were at risk rather than identifying individual children at risk. Instead of a specific disease or deficit-centered approach, a Rapid Assessment Tool for Pre-School Children (RATPC) was developed to evaluate children within a community in a more holistic manner. Specifically, this included the multiple aspects of body growth and the functional abilities for normal childhood activities.

Materials And Methods

The study population. A search was conducted to find a population which minimized the variables that can affect the outcome of a

pesticide study on child growth and development. The population had to meet the requirements of similar genetic origin, living conditions, and related cultural and social values and behaviors, all of which are necessary for comparable study and reference groups. A site visit prior to selection confirmed that the two study groups filled these requirements, apparently differing only in the degree of pesticide exposure.

The Yaqui are an indigenous group living and working in the environs of the Yaqui Valley of Sonora, Mexico. Traditionally, the Yaqui Valley has been an agricultural region, with numerous residents embracing pesticide and chemical fertilizers in the late 1940s. Concurrently, farm operations became mechanized, and irrigation and transport systems were established. The result was a "Green Revolution," with farming becoming big business (21). Yaqui families from the nearby mountain foothills moved into the valley for employment, while some valley residents moved into the foothills in protest of the change. Others remained in place (22).

Today, the Yaqui living in both the foothills and the valley accept the technological advances provided by modernization but tenaciously resist changes in their social and cultural identity (23,24). Relatives separated by the "Green Revolution" report visiting between areas, but there is no household relocation between the highlands and lowlands. Culturally, Yaqui marry Yaqui. Observations during a site-determination visit indicated that family structure remains strong, with aging parents living with an adult child and grandchildren. Educational and health services, introduced in the 1950s, are well accepted and are similar in both areas (25). Children are usually breast fed, then weaned onto household foods. Diet continues to be based on traditional patterns involving fresh potatoes, corn, peppers, beans, and tortillas, with occasional meat (23). These foods, produced locally, are almost always purchased. Processed foods were not observed in households. Lead is below detectable levels in water for both areas (M.M. Meza, unpublished data). The historical high degree of poverty has continued to exist in both areas (22,25). Thus, there are two groups sharing genetic, cultural, and social traits but separated by location and type of employment—ranching in the foothills versus agriculture in the valley.

Pesticide use is high in the lowland agricultural communities, with aerial spraying and mechanical and hand application (26). Farmers reported that two crops a year may be planted, with pesticides applied up to 45 times between planting and harvesting per crop. Compounds

include multiple organophosphate and organochlorine mixtures and pyrethroids. Thirty-three different compounds were used for the control of cotton pests alone from 1959 to 1990. This list includes DDT, dieldrin, endosulfan, endrin, heptachlor, and parathion-methyl, to name but a few agents (27). As recently as 1986, 163 different pesticide formulations were sold in the southern region of the state of Sonora, Mexico. Substances banned in the United States, such as lindane and endrin, are readily available to farmers (28). Pesticide use is widespread and continues throughout the year, with little governmental control (26). Contamination of the resident human population has been documented, with milk concentrations of lindane, heptachlor, benzene hexachloride, aldrin, and endrin all above limits of the Food and Agricultural Organization of the United Nations after 1 month of lactation (see Table 1) (26). An initial site visit revealed that household bug sprays were usually applied each day throughout the year in the lowland homes. In contrast, the foothill residents maintained traditional intercropping for pest control in gardens and swatting of bugs in the home. These people cited their only exposure to pesticides as with the governmental DDT spraying each spring for the control of malaria. (Identical DDT spraying also occurs in the agricultural areas and is repeated if a case of malaria occurs.)

Sampling procedure. The sampling methods, research design, and test instruments were examined and approved by the Gobierno del Estado de Sonora, Secretaria de Salud Publica (Secretary of Public Health, Sonora, Mexico). All children selected for the study were between the ages of 48 and 62 months (4- and 5-year-olds).

Table 1. Concentrations of pesticides (mean $\pm$ standard deviation) in cord blood at time of birth and in mother's milk 1 month post partum from Pueblo Yaqui, Sonora, Mexico

Pesticide	Cord blood (ppm) (n = 19)	Milk (ppm) corrected for fat (n = 20)
α -HCH	0.030 $\pm$ 0.03	0.8599 $\pm$ 2.75
β -HCH	0	0.3791 $\pm$ 1.08
Lindane	0.084 $\pm$ 0.06	0.6710 $\pm$ 0.59*
Δ -HCH	0.0039 $\pm$ 0.1	0.4432 $\pm$ 0.84
Heptachlor	0	1.269 $\pm$ 1.65*
BHC	0.003 $\pm$ 0.002	0.6270 $\pm$ 0.66*
Aldrin	0	0.2363 $\pm$ 0.59*
Dieldrin	0.159 $\pm$ 0.12	0.0487 $\pm$ 0.08
Endrin	0.022 $\pm$ 0.02	0.5238 $\pm$ 1.1*
p,p' DDE	0.03 $\pm$ 0.03	6.31 $\pm$ 5.9
Σ DDE	0.0434	6.52*

Abbreviations: HCH, hexachlorocyclohexane; BHC, benzene hexachloride. Data from Garcia and Meza (26).

*All exceed Food and Agricultural Organization/World Health Organization established limits.

The 33 children exposed to elevated levels of pesticides, hereafter referred to as valley children, came from three towns and corresponding rural areas within the Yaqui Valley. The towns were Quetchehueca ($n = 10$), Bacum ($n = 12$), and Pueblo Yaqui ($n = 11$), all 10–30 feet above sea level. The criteria for town selection included a historical, continual use of pesticides since 1950, based on data from Hewitt de Alcanara (22) and a history of Yaqui Indian settlement. A previous study, which examined the village of Pueblo Yaqui, observed elevated levels of a number of pesticides or metabolites in 100% of the cord blood and mother's milk samples (see Table 1). Tesopaco, located in the foothills of the mountains (elevation 400 m), is a Yaqui settlement based on ranching. This town was used as the source of reference children ($n = 17$). All of the towns, regardless of location, were similar in infrastructure and the interfacing of tradition with modernization (25).

Homes were approached along streets on the north, south, east, and west and center of each town and in outlying areas. Children were found by asking if the household contained 4- or 5-year-olds. Criteria for child selection included age, Yaqui heritage, and a history of residency for both parents and grandparents. Participation involved a 30-min interview with the mother concurrent with a 30-min evaluation of the child. All interviews occurred in the home. All of the eligible foothill families agreed to participate. Approximately 90% of valley families with eligible children agreed to participate. Fathers were most likely to deny permission. With discussion, they admitted that they suspected pesticides were harmful for children and did not want to know about their specific child.

The research instruments. The research instruments were based on the hypothesis that endocrine disruptors could influence all body systems. Physical growth patterns were considered, in addition to physiological and mental functioning. A major end point was to determine if a rapid assessment could identify if children of a given community demonstrate changes in play behavior indicative of endocrine disruption and to identify specific areas for further investigation. The instruments were pretested in an urban setting with mothers and 4-year-old children. The children were able to perform all the involved activities.

The questionnaire for mothers centered on family lifestyle including diet, the number of pregnancies and any related complications, the types and frequency of family illness, and practices and perceived exposure to pesticides. Along with obtaining an

obstetrical and lifestyle history, this interview served to validate population similarities in the contextual and genetic variables affecting growth and development. Each interview was conducted by one of the two researchers from the Instituto Tecnológico De Sonora.

Evaluation of each child was conducted in Spanish by one of two Mexican graduate students. The format was based on a play approach to evaluate physical stamina and coordination along with mental processes. Several standardized cognitive and developmental tests have gained acceptance for developmental assessment. These include the Bayley Developmental Scales (infants to 30 months of age) and the Battelle Developmental Inventory and McCarthy Scales (preschool age). These lengthy, in-depth evaluative tools were used to provide direction in developing the rapid assessment tool, i.e., the drawing of a person. Other aspects of the RATPC were original and untested, such as the 30-min memory exercise. The lack of complexity in each of the tested play behaviors, and known correlation between given behaviors and physical development, contributed to validity of the instrument (13). Discussions with the mothers about children's abilities were also used to substantiate findings. Overall, the results of the RATPC were not to provide an index of a given child's ability, but to provide a broad picture of children within a given community. In addition, no total score was assigned to individuals, as scoring procedures were not designed to be cumulative.

Each evaluation was introduced with the following:

Hello, my name is _____. I will ask a few questions and we will play some games. When I am finished I will give you a red balloon. [As some of the children did not know the colors by name, an object was pointed out as being red.] Do you like balloons?

The testing then began with exercises interpreted by the child as normal play. Initial hesitancy was decreased or eliminated as siblings and/or friends were allowed to participate in the initial physical exercises, although only the child under study was actually evaluated for performance.

The first activity was designed to evaluate gross motor coordination. The child was to catch a 30.5-cm diameter ball from 1, 2, and 3 m away. This exercise was repeated with a 6.5-cm tennis ball from the same distances. The sense of balance was tested by asking the child to stand on one foot as long as possible, first with eyes open and then with eyes closed. Stamina was regarded as the time a child could jump in place

before quitting from shortness of breath. Quieter activities followed. To investigate perception abilities, the child was asked to draw a person. (Scoring was based on one point each for head, body, arms, legs, and facial features placed in correct spatial orientation with a total possible score of 5.) Number repetition indicated short-term memory abilities. Fine eye-hand and motor coordination was tested by dropping raisins in a bottle cap from a distance of 15 cm. The completion time for the described introduction and exercises was programmed for 30 min. The child was then asked to recall what he or she would receive, asking for the color if it was not spontaneously stated. All children were given a balloon, regardless of if they remembered the object or its color.

The session ended by obtaining physical body measurements which included head circumference, head breadth and length, chest circumference, height, and weight. Long bone growth was approximated by subtracting sitting height from standing height. Gross measurements of this type fail to detect small differences in bone shape and length, which may be detectable by X ray.

Statistical analysis. Data were analyzed using various analyses based on data type. Morphometric data on children from the reference and exposed populations were compared for significance by analysis of variance (ANOVA), followed by Scheffe's F tests. Significance was set at $p < 0.05$. Stamina, where time was the measurement, and activities in which the calculation of

success was based on real number units (number of raisins dropped in a cap) were examined in a similar manner. Where scores consisted of nonparametric data, such as scores on stick figure drawings, data were analyzed for significance using Mann-Whitney *U* tests. To determine if functional ability was related to interview order (time of day), we performed Kendall Rank Correlations. Comparisons of frequency data were analyzed using chi-square. All analyses were performed on a computer using commercial statistical software (Stat-view II, Abacus Concepts, Inc., Berkeley, CA).

Results

Mothers. No significant differences were found between the valley and foothill mothers in regard to mother's age, the number of pregnancies, and the number of living children (Table 2). Although valley mothers experienced more problems associated with pregnancies, there was no statistical difference between the groups in spontaneous abortion rates, prematurity, neonatal death, and birth defects. However, when examined as a composite of problem pregnancies, women from the valley had an elevated frequency rate (Table 3). The children's initial food intake of breast milk, followed with regular diet, was also not significantly different. Although not directly measured, foothill mothers believed that the valley children ate more fresh vegetables and fruit because of lower cost and availability. Genitals in all children were reported by the mothers as being normal.

Children. The foothill and valley children were similar in terms of age (mean ages were 60.7 months and 58.7 months, respectively). The children were also similar in birth order (2.5 for the foothills and 3.1 for the valley). No statistical differences were found in regard to height, weight, chest or head circumference, and head breadth and length (Table 3). The subtraction of sitting height from standing height, which can reflect long leg bone growth, also

showed no significant difference (Table 4).

Although the groups were similar in physical growth, a comparison of functional abilities showed differences among the study groups. Kendall Rank Correlations indicated that no relationships existed between performance of any activity measured and interview rank based on time of day ($p > 0.1$ for all comparisons). Generalized physical endurance, measured by having the child jump in place for as long as possible, demonstrated that foothill children had more stamina ($F = 4.1$; $df = 1, 43$; $p = 0.05$). Jumping was perceived by the children as a contest, with the children trying to jump longer than the interviewer. (Sometimes interviewers had to jump for each other when a child excelled at this activity.) The longest a valley child jumped was 110 sec, compared to 336 sec for a foothill child [mean ± 1 standard error (SE) was 52.2 ± 5.4 for valley children and 86.9 ± 22.2 for foothill children]. An attempt to evaluate the sense of balance by having each child stand on one foot with eyes open and then stand on one foot with eyes closed failed. Urban Mexican children were able to perform these activities without difficulty during pretesting. Yaqui children, however, are taught that standing on one foot causes a person to fall and injure themselves. Many refused to try at all, and those who did insisted on holding on to a wall or person.

Valley children had a significant decrease in their ability to catch a large ball ($p = 0.034$) at the distance of 3 m. This inability to catch a ball increased as the ball size decreased. Foothill children outperformed the valley children in catching the tennis ball at 1, 2, and 3 m ($p = 0.05, 0.01$, and 0.003 , respectively). A stronger difference was found between the two groups in regard to fine eye-hand coordination; foothill children were better able to drop a raisin into a bottle cap ($F = 7.3$; $df = 1, 44$; $p = 0.009$). Interestingly, the location of the child's home—valley versus foothills—had a significant effect on these measurements,

Table 2. Data on pregnancies and lactation for the Yaqui mothers of the children studied

	Valley (<i>n</i> = 28)	Foothills (<i>n</i> = 17)
Mean mother's age (years)	30.9 $\pm$ 1.0	33.2 $\pm$ 1.0
Mean pregnancies	3.89 $\pm$ 0.4	3.12 $\pm$ 0.3
Male/female birth ratio	1.004	0.946
Mean no. children breast fed	3.00 $\pm$ 0.4	2.25 $\pm$ 0.5
Mean time breast fed (months)	10.16 $\pm$ 1.8	8.46 $\pm$ 1.1
Difficulty conceiving (%)	14.3	0

Table 3. Difficulties in pregnancies of the Yaqui mothers of the children studied (percent)

	Valley (<i>n</i> = 109) ^a	Foothills (<i>n</i> = 53) ^a
Spontaneous abortion	4.6	3.8
Premature birth	6.4	3.7
Birth defect	4.6	0
Stillbirths	2.8	0
Total problem pregnancies ^b	18.3	7.5

^aTotal number of pregnancies.

^bProblem pregnancies include premature birth, spontaneous abortion, birth defect, or neonatal death. Percentage reported is based on total number of pregnancies. A single pregnancy having more than one of the above was only counted once.

Table 4. Morphometric information (mean $\pm$ standard error) for Yaqui children of the lowland and foothill study populations

Measurement	Male		Female	
	Valley (<i>n</i> = 18)	Foothill (<i>n</i> = 9)	Valley (<i>n</i> = 16)	Foothill (<i>n</i> = 8)
Height (cm)	104.5 $\pm$ 2.4	108.6 $\pm$ 1.8	103.8 $\pm$ 2.0	107.6 $\pm$ 2.9
Weight (kg)	16.7 $\pm$ 1.1	17.4 $\pm$ 0.9	16.7 $\pm$ 0.7	18.2 $\pm$ 0.9
Sitting height (cm)	57.2 $\pm$ 1.6	57.8 $\pm$ 1.4	56.5 $\pm$ 0.8	58.6 $\pm$ 1.6
Head circumference (cm)	52.4 $\pm$ 0.7	51.8 $\pm$ 0.8	51.7 $\pm$ 0.7	51.6 $\pm$ 0.4
Head breadth (cm)	13.5 $\pm$ 0.2	13.6 $\pm$ 0.1	13.2 $\pm$ 0.1	13.5 $\pm$ 0.2
Head length (cm)	16.8 $\pm$ 0.1	16.6 $\pm$ 0.3	16.5 $\pm$ 0.2	16.5 $\pm$ 0.3
Upper arm circumference (cm)	17.0 $\pm$ 0.6	17.7 $\pm$ 0.2	17.8 $\pm$ 0.4	18.1 $\pm$ 0.5
Chest circumference (cm)	57.3 $\pm$ 1.3	57.4 $\pm$ 0.7	56.1 $\pm$ 0.7	55.8 $\pm$ 1.0
Skin fold (cm)	6.9 $\pm$ 0.4	7.4 $\pm$ 0.4	7.6 $\pm$ 0.5	8.4 $\pm$ 0.7

but the child's sex had no relationship to any of these outcomes.

Children in both locations performed equally well in the immediate recall of numbers up to four digits. The valley children had more difficulty grasping the concept of repeating the numbers, although marked differences were found between towns. Children with such difficulty were encouraged to repeat one and then two vowel sounds made by the interviewer. Thus, the movement into repeating numbers became more comprehensible. Marked differences in recall were seen with 30-min memory ($\chi^2 = 14.3$; $p = 0.027$). In recalling their gift, 59% of the 17 foothill children remembered both the object and its color, with all but one of the remaining children remembering just the balloon. In contrast, 27% of the 33 valley children recalled the balloon and color, 55% recalled the balloon only, and 18% could recall neither the object nor the color.

One of the most striking differences between the exposed and unexposed children was in the ability to draw a person ($U = 59.0$; $p < 0.0001$). The valley children averaged 1.6 body parts to a drawing, compared to the foothill children's 4.4 body parts. Valley females performed better than males, but still remained significantly below that of foothill children, regardless of their sex. In addition, it was noticed that foothill children moved the paper about for better positioning in drawing a specific body part and compared their drawing to an actual person to make necessary corrections. Valley children would look at an individual but continue to draw meaningless circles. Representative drawings are presented in Figures 1 and 2.

Discussion

A cursory look at the foothill and valley towns could easily lead one to the conclusion that no discernible differences were present in the Yaqui children. Heights varied between the tall and short for age, and weights ranged from the ultrathin to the obese. The lack of physical differences in growth patterns was borne out with anthropometric measurements. Anthropological participant observation (13) indicated that the type of play was different in the two areas. Group play was observed more frequently in the foothills, with pretend parties for dolls and street games. Valley children appeared less creative in their play; they roamed the area aimlessly or swam in irrigation canals with minimal group interaction. Some valley children were observed hitting their siblings when they passed by, and they became easily upset or angry with a minor corrective comment by a parent. These aggressive behaviors were not

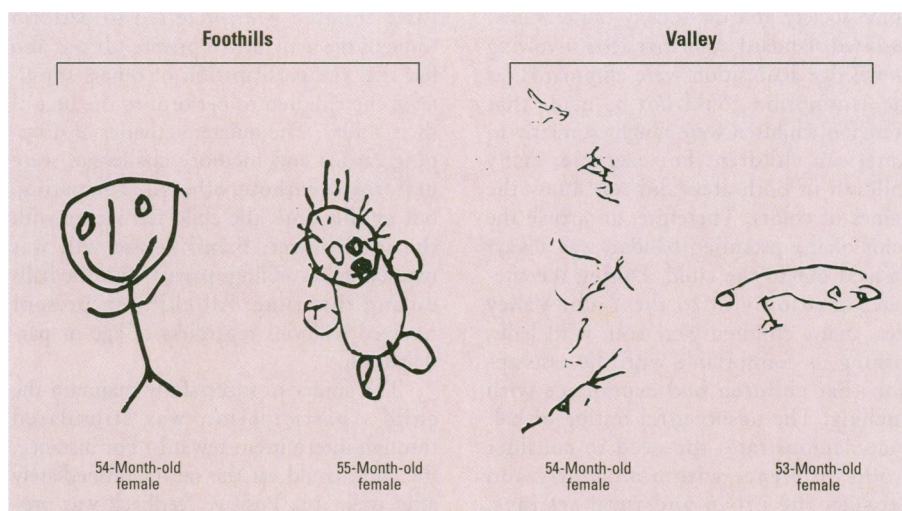


Figure 1. Representative drawings of a person by 4-year-old Yaqui children from the valley and foothills of Sonora, Mexico.

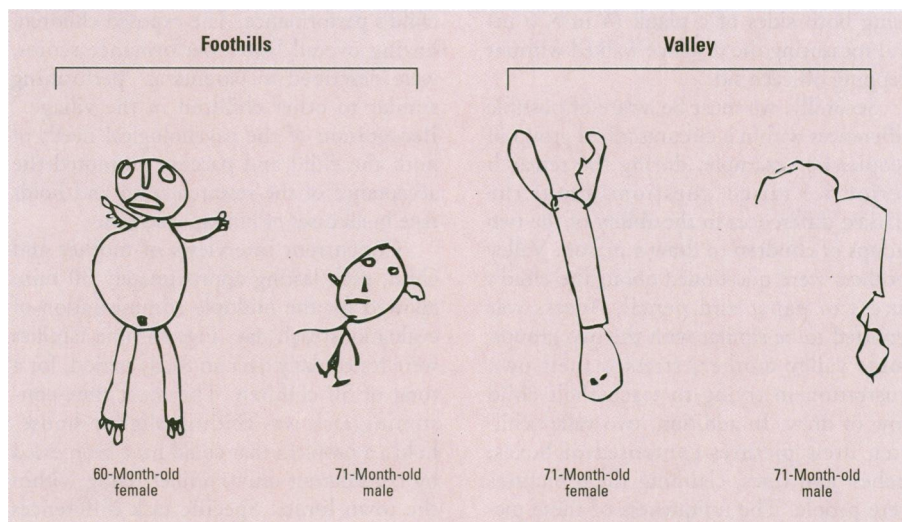


Figure 2. Representative drawings of a person by 5-year-old Yaqui children from the valley and foothills of Sonora, Mexico.

noted in the foothills. Such clues indicated that additional aspects of development may be affected by environmental change, as opportunities and toys for play were available at both sites. In both areas, mothers were generally home on a full-time basis and showed interest in their children.

The rapid assessment tool did show that psychological and physiological differences in functional abilities exist between the valley and foothill children at 4 and 5 years of age. The jumping assessment, reflecting a decrease in stamina for valley children, could be an indicator of the presence of a physiologic modifier resulting in reduced intensity and/or frequency of play. In addition, playing ball or other activities involving gross or fine eye-hand coordination are less exciting or fulfilling when the child cannot perform the required skills. Of increased concern are the differences found with activities involving

mental/neurological functioning. The inability to remember a meaningful statement after 30 min has implications for school performance and performance in social activity. The drawing of a person, often used as a non-verbal screening measure of cognitive ability, could also indicate a breakdown between visual sensory input and neuromuscular output, as found with brain dysfunction (29). The decreases in eye-hand coordination, as with catching the ball and dropping raisins into a circumscribed area, could also correlate with this type of brain dysfunction. This concept of breakdown between incoming sensory signals and neuromuscular output certainly deserves greater attention in future research.

The applied use of this rapid field assessment tool points out the need to recognize cultural differences. When working within developing countries, we must be aware of possible differences between the

home society and the society under study. Assorted standard evaluative tests involving knowledge acquisition were eliminated, as the assumption could not be made that preschool children were taught similarly to American children. For example, many children in both areas did not know the names of colors. Therefore, an article the color of the promised balloon was always pointed out to the child. During the site-determination visit to the Yaqui Valley area, many children were seen with balls, making us comfortable with the assumption that children had experience with catching. The unsuccessful testing of balance demonstrates the need to consider group difference within a country and between the urban and rural settings. Urban Mexican children had no hesitancy in standing on one foot. An alternative test for balance needs to be developed, such as using both sides of a plank (4 in × 6 in) and measuring the distance walked without stepping off each side.

Secondly, we must be aware of possible differences within a circumscribed group of people. For example, during the research period we raised questions about the marked differences in the ability of the two groups of children to draw a person. Valley mothers were questioned about the child's access to paper and pencil. Access was reported to be similar with the two groups. Some valley mothers stressed their own frustration in trying to teach their child how to draw. In addition, two valley children drew pictures composed of boxes, arches, and lines, claiming these pictures were people. The uniqueness of these pictures led us to inquire if these pictures were Yaqui representations or symbols. Parents and others denied this was so. As all children were preschoolers without formal education, possible differences between the individual school systems were removed as a confounding factor.

The situation of testing in the field deserves consideration. The usual format for evaluating mental abilities involves a large group situation. In contrast, evaluation of physical abilities usually occurs in private. Neither held true in this investigation, nor can privacy be anticipated with most field work in developing countries. In this investigation, siblings and sometimes friends performed the research activities as extended family watched the evaluative process. This promoted goodwill, as families saw the children having fun. The sense of being a test subject was removed from the subject with the participation of other children in the initial activities. Overall, this increased each child's willingness to participate. (Astute observation identified

three children who preferred to perform some of the activities in private.) It was also felt that the participation of others stimulated the children to perform to the best of their ability. The quieter activities of dropping raisins and memory challenges were performed without others participating, but by this time, the child felt secure with the interviewer. Family good will was maintained as siblings played with the balls during this time. All children present received balloons regardless of age or participation.

The ability to successfully maintain the child's participation was stimulated through intermittent rewards. For instance, the child could eat the raisins immediately after their use. Positive feedback was provided to each child, if only for willingness to try an activity. Immediate generalized feedback was provided to parents about the child's performance. The exposed children, having overall lower performance scores, were described to parents as "performing similar to other children in the village." Recognition of the psychological needs of both the child and parents promoted the acceptance of the research team and holds true in all cases of human research.

Concurrent interviews of mother and child, each lasting approximately 30 min, allowed for the multiple administration of evaluations each day. Five to nine families were tested daily over an 8-day period, for a total of 50 children. The most time-consuming task was finding eligible households, a problem that could have been eased by considering only families living within the town limits. Specific task differences between children in a given town and its rural environs were not significant, but this was not known at the onset of the study.

Ideally, a rapid assessment of this sort should include blood analysis for liver function, thyroid and reproductive hormone levels, and a comprehensive blood analysis for multiple contaminants including dioxin and PCBs. As an initial study with limited funding, such analyses were not possible. This study would have been improved with such an analysis, especially with the identification of other contaminants beyond pesticides. At the same time, the amount of blood that can be drawn from a preschooler is limited. Culture prevented the measurement of penis size of the males in the home setting by nonmedical females. Such measurement would be possible in a clinic setting, but that would defeat the purpose of a home-based rapid assessment. The same is true with including X rays of long bones.

The goal of the study was not to provide specific overall performance scores or to

identify specific children with deficits. Instead, the study should be viewed as identifying communities in which contamination is apparently having deleterious effects on children. The findings, although based on a relatively small sample size, do point out the existence of alterations in play behavior abilities within the agricultural area. Additional research is needed to address the depth to which these alterations occur.

Conclusions

Many of the genetic and cultural variables that influence the outcome of contaminant exposure on children's growth and development can be overcome through purposeful selection of the study population. Large numbers of children are thus available for evaluation, although circumstances limited participation in this initial study. The limited numbers of participants did not defeat the purpose of the study: to determine if a rapid assessment would identify growth and developmental differences between groups of children differing mainly in the degree of exposure to chemicals in the environment. The amounts and types of body contamination are unknown, but the elimination of other suspected causal factors "...implies that there must be a one-to-one relationship between a factor and its effects" (30).

A community-based rapid assessment approach to contamination, in this case with children representing the population, proved valuable in determining if problems exist before spending excessive time and money for outcome-specific research and possible interventions. The use of an interdisciplinary functional assessment, measuring the abilities to perform normal activities for 4- and 5-year-olds, identified new directions for future investigation (i.e., stamina, long-term memory) plus the need for in-depth study of other areas. For example, the role of pesticides on neuromuscular functioning and thought processes deserves such study. Other dimensions need to be added to the assessment, particularly in the areas of disease and organ dysfunction. Equally important is the potential use of rapid assessment to provide a foundation for the building of a longitudinal study to determine the continuing and delayed impacts of a lifetime of chemical exposure. Environmental change has placed the children of the agricultural area of the Yaqui valley at a disadvantage for participating in normal childhood activities. Will they remain at risk for functioning as healthy adults?

In this case, the RATPC reflects typical childhood activity plus the cultural and social attributes of the Yaqui tribe. Variables play a minor role in results. The lack of such a well-controlled reference

group should not deter the use of the tool elsewhere. Variables must be recognized and their possible impact on childhood clearly stated. The tool should not be regarded as limited to location. Childhood play occurs everywhere, making the tool applicable in various locations where any type of chemical exposure is suspected. The concept of environmental change should not be limited to contamination, as the RATPC could play a useful role in determining if other environmental factors influence children's growth and development. Usually, drought with the resulting malnutrition is investigated in terms of mental retardation and stunted growth. Would a rapid assessment of play behavior point to other areas for investigation? Does war or civil strife affect only the direction of play or the ability to perform play behaviors? Rapid assessment tools have the potential to answer these questions.

REFERENCES AND NOTES

- Jacobson JL, Jacobson SW. *N Engl J Med* 335:783-789 (1996).
- Sherman JD. Chlorpyrifos (Dursban)-associated birth defects: a proposed syndrome, report of four cases, and discussion of the toxicology. *Int J Occup Med Toxicol* 4:417-431 (1995).
- Adami HO, Bergstrom R, Sørensen P, Baron J. Increasing cancer risk in younger birth cohorts in Sweden. *Lancet* 341:773-777 (1994).
- Toppari J, Larsen JC, Christiansen P, Giwercman A, Grandjean P, Guillette LJ Jr, Jegou B, Jensen TK, Jouannet P, Keiding N, et al. Male reproductive health and environmental xenoestrogens. *Environ Health Perspect* 104 (suppl 4):741-803 (1996).
- Sharpe RM, Skakkebaek NE. Are oestrogens involved in falling sperm counts and disorders of the male reproductive tract? *Lancet* 341:1392-1395 (1993).
- McLachlan JA. Functional toxicology: a new approach to detect biologically active xenobiotics. *Environ Health Perspect* 101:386-387 (1993).
- Colborn T, vom Saal FS, Soto AM. Developmental effects of endocrine-disrupting chemicals in wildlife and humans. *Environ Health Perspect* 101:378-384 (1993).
- Guillette LJ Jr, Crain DA, Rooney AA, Pickford DB. Organization versus activation: the role of endocrine-disrupting contaminants (EDCs) during embryonic development in wildlife. *Environ Health Perspect* 103 (suppl 7):157-164 (1995).
- Delemarre-van de Waal HA. Environmental factors influencing growth and pubertal development. *Environ Health Perspect* 101(suppl 2):39-44 (1993).
- Colborn T, Clement C, eds. *Chemically-induced Alterations in Sexual and Functional Development: The Wildlife/Human Connection*. Princeton:Princeton Scientific Publishers, 1992.
- Jerome NW, Kandel RF, Pelto GH. An ecological approach to nutritional anthropology. In: *Nutritional Anthropology: Contemporary Approaches to Diet and Culture* (Jerome NW, Kandel RF, Pelto GH, eds). Pleasantville, NY:Redgrave Publishing Company, 1980;13-45.
- Consumer attitudes and behavior regarding diet, nutrition and health. *Dairy Coun Dig* 65:31-36 (1994).
- Bernard HR. *Research Methods in Anthropology, Qualitative and Quantitative Approaches*. Thousand Oaks, CA:Sage Publications, 1994.
- Polednak AP. *Racial and Ethnic Differences in Disease*. New York:Oxford University Press, 1989.
- Guillette LJ Jr. Endocrine-disrupting environmental contaminants and reproduction: lessons from the study of wildlife. In: *Women's Health Today: Perspectives on Current Research and Clinical Practice* (Popkin DR, Peddle LJ, eds). New York:Parthenon Publishing Group, 1994;201-207.
- Crain DA, Guillette LJ Jr. Endocrine-disrupting contaminants and reproduction in vertebrate wildlife. *Rev Toxicol* 1:47-70 (1997).
- Jacobson JL, Jacobson SW, Humphrey HEB. Effects of exposure to PCBs and related compounds on growth and activity of children. *Neurotoxicol Teratol* 12:319-326 (1990).
- Chen Y-CJ, Guo Y-L, Hsu C-C, Rogan WJ. Cognitive development of Yu-Chen ("oil disease") children prenatally exposed to heat-degraded PCBs. *JAMA* 268:3213-3218 (1992).
- Guo YL, Lai TJ, Ju SH, Chen YC, Hsu CC. Sexual developments and biological findings in Yucheng children. *Chemosphere* 14:235-238 (1993).
- Spring A. *Project on Human Activities and Environmental Contaminants in the Lower Black River Morass*. Project Report. Miami, FL:North-South Center, 1995.
- Perkins JH. The Rockefeller Foundation and the Green Revolution, 1941-1956. *Agric Hum Values* 7:6-18 (1990).
- Hewitt de Alcantara C. *Modernizing Mexican Agriculture: Socioeconomic Implications of Technological Change 1940-1970*. Geneva:United Nations Research Institute for Social Development, 1976.
- Alumnos de Humanística II. *Musica, Cultura y Vida de los Yaquis*. Humanidades Hoy 53:15-18 (1995).
- Jacobo T. *Festival de la Cultura Yaqui*. Humanidades Hoy 53:12-14 (1995).
- Anuario Estadístico del Estado de Sonora. Aguascalientes, Ags.:Instituto Nacional de Estadística Geografía y Información, 1995.
- García BML, Meza MMM. Principales vías de contaminación por plaguicidas en neonatos-lactantes residentes en Pueblo Yaqui, Sonora, México. *Inst Tecnol Sonora DIEP* 1:33-42 (1991).
- Covarrubias J, Murphy K, unpublished data.
- Camara OA. *Biología molecular y metabolismo de degradación de suelos contaminados con pesticidas*. ITSON-DIEP 1:47-64 (1992).
- Kamphaus RW. *Clinical Assessment of Children's Intelligence*. Boston, MA:Allyn and Bacon, 1993.
- Fox GA. Practical causal inference for ecotoxicologists. *J Toxicol Environ Health* 33:359-373 (1991).

Big Ideas for your Health and Future



- An "environmental genome" study of how disease-susceptibility genes vary from person to person in a representative sector of the population. To help us see why you might get a nerve disorder from an exposure to a chemical whereas your friend Lee might not . . . Information to protect you and Lee, without guesstimates and fudge factors.
- A survey of chemicals polluting our blood — a look at what we, as a population, have been exposed to.
- Customized mice to quickly screen chemicals and drugs . . . and help conquer diseases like breast cancer.
- A study of mixtures. We don't face chemicals one on one. Why should science?

These ideas are Now at the National Institute of Environmental Health Sciences, one of the National Institutes of Health, and at the National Toxicology Program, which is headquartered at NIEHS.

Call our Jobline (919) 541-4331.
Visit NIEHS at 111 Alexander Drive, Research Triangle Park, NC.
See our Homepage: <http://www.niehs.nih.gov>.