

**The Impact of Lead Poisoning and Asthma on Children's
Academic Achievement in Providence Public Schools**

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Executive Summary

This study assessed the effects of asthma and lead poisoning on academic achievement for children enrolled in the Providence public school system. Lead poisoning and asthma are the most important childhood environmental health concerns in Providence. Lead exposure produces a variety of adverse health effects in children who are in a period of growth and development of the central and peripheral nervous system. Early stages of childhood development are characterized by undergoing anatomic and physiologic changes that underlie language, visual, motor and cognitive development. Evidence strongly suggests that exposure to lead strongly impairs cognitive development and long-term effects of childhood exposure have been reported including learning disabilities, decreased intelligence, delayed reaction time, distractibility, and behavioral disorders-- all markers of poor academic achievement.

Asthma is the most common cause of absence from school. Children with asthma may experience problems in their adaptation to school and impediments to their learning. Frequent school absenteeism interrupts the process of learning and interferes with children's social interactions and participation in extracurricular activities. Although it has been found that asthma does not directly alter brain development or neuropsychological functioning, asthma symptoms may cause children to have more frequent absences from school and a general malaise which may affect academic performance. Children experiencing asthma or allergic symptoms may be unable to concentrate and consequently may be less able to learn new skills and information.

Fatigue, irritability, and intermittent hearing loss may accompany seasonal allergies which trigger asthma and can lead to inattentiveness in a classroom setting. The more significant effects affecting academic performance occur because of sleep loss and general ill feeling that accompany these conditions.

In this study, academic achievement was assessed using education data obtained by the Providence Plan from the Providence School Department and the Rhode Island Department of Education. Blood lead screening data obtained from the Rhode Island Department of Health for Providence residents for children tested in 1993 to 1998 were used in this analysis. Data for asthma hospitalizations were obtained from Lifespan. These data included emergency room visits, and inpatient and outpatient admissions at Rhode Island and Miriam Hospitals with a primary diagnosis of asthma between January 1978 and March 2000. Blood lead levels (BLLs) measured in 1993 to 1996 were used for correlating with promotion to the next grade. Data for blood lead tests in 1993 to 1998 were used for correlating with standardized educational test scores. The educational measures that were used in this analysis are promotion to the next grade for 1993 to 1998 academic years and scores on standardized tests taken in the 3rd and 4th grades in 1996 to 1999.

A case-control analysis was used to test for correlations of lead poisoning [15+ $\mu\text{g}/\text{dl}$] with promotion to the next grade and standardized test scores. BLLs were used to classify exposed and unexposed populations as the independent variable. The cases were the students who repeated a grade or had low test scores and the controls were the students who advanced a grade or had high test scores. The cases and controls were arranged in a 2X2 table. The odds ratio and 95% confidence intervals were calculated. A

cohort study based on cumulative incidence was used to correlate asthma hospitalizations with promotion to the next grade and standardized test scores. All members of the population not identified by hospital visits as asthmatic were categorized as non-asthmatics. Thus, this cohort includes a larger number of children than is considered in the case-control analysis. The cases are the students who repeated a grade or had low test scores and the controls are the students who advanced a grade or had high test scores. Data was also arranged in a 2X2 table. Odds ratio and 95% confidence intervals were also calculated. In addition, two linear regression models for two tests were done, one of which raw scores were available. This allows us to see the relationship between individual's BLLs and their corresponding test score. The results for the case-control and cohort analysis for lead and asthma are shown in the following two tables:

Summary of Lead Results:

Test:	Year of Test:	Grade:	Odds Ratio:	95% CI: Lower Bound	95% CI: Upper Bound	Cases:	Controls:
ELA Reading: Understn.	1998	4	1.6	1	2.5	195	373
ELA Reading: Analysis	1998	4	2	1.3	3.2	214	354
ELA Writing Std. Level	1998	4	1.4	0.9	2	234	334
ELA Writing Convention	1998	4	1.5	1	2.4	267	301
Math: Concepts	1998	4	1.3	0.7	1.8	425	144
Math: Skills	1998	4	1.6	1	2.5	171	398
Math: Problem Solving	1998	4	4.8	1.2	20	516	53
Math	1996	4	0.74	-	-	58	44
Writing	1998	3	1.5	1	2.3	740	187
Writing	1999	3	2.1	1.5	3	750	367

Summary of Asthma Results:

Test:	Year of Test:	Grade:	Odds Ratio:	95% CI: Lower Bound	95% CI: Upper Bound	Cases:	Controls:
ELA Reading: Understn.	1998	4	1.4	1	1.9	576	1228
ELA Reading: Analysis	1998	4	1.4	1.1	1.9	630	1174
ELA Writing Std. Level	1998	4	1.6	1.3	2	732	1072
ELA Writing Convention	1998	4	1.3	1	1.7	799	1005
Math: Concepts	1998	4	1.04	0.9	1.2	1403	482
Math: Skills	1998	4	0.95	0.63	1.42	591	1294
Math: Problem Solving	1998	4	1.04	0.97	1.1	1687	198

This study does not establish a causal relationship between lead poisoning/asthma and educational success measures. It establishes that some educational success measures have significant negative correlations with lead poisoning and asthma. There are confounders such as income level and parents' education which are not corrected for in this analysis. These variables are known to influence a student's academic achievement. Extensions of this study should attempt to control for socio-economic status. Parent education, language proficiency, family structure, and the community's socioeconomic status are strong predictors of student academic achievement and in the future, may be accounted for if the data are available.

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Chapter 1:

Developmental Effects of Lead Exposure

Introduction:

Exposure to lead produces a variety of adverse health effects in sensitive populations through its impact on different organs and systems. The nature of the effects is a complex function of such factors as the magnitude of exposure, the physiologic and behavioral characteristics of the exposed person, and the relative importance of the lead-injured organ to overall health and well-being. The toxic effects of lead range from recently-revealed subtle, subclinical responses to overt serious intoxication.

Childhood lead poisoning involves injury in at least three organ systems: the central nervous system (specifically the brain), the kidney, and the blood-forming organs. Other systems are also affected, but the nature of their toxic injury has not been as well characterized. Lead exposure has been found to play a significant role in the intellectual development of young children. Lead exposure even at low doses affects the academic success of lead poisoned children. Studies have demonstrated that lead exposure is a cause, rather than a marker, of decreased intellectual performance.¹ Evidence strongly suggests that exposure to lead strongly impairs cognitive development and long-term effects of childhood exposure have been reported including learning disabilities, decreased intelligence, and behavioral disorders. Lead-related impaired reaction time, distractibility, disorganization, impulsivity, and restlessness suggest that a lead-poisoned

¹ William H. Sciarillo, Greg Alexander, and Katherine P. Farrell, 1356.

child is at high risk for later delinquent behavior, a correlate of poor academic achievement.²

Young children, particularly from ages one to three, are especially vulnerable to the toxic effects of lead.³ Prenatal lead exposure also occurs since lead readily passes the placental barrier, exposing the fetus to lead circulating in the mother's bloodstream. Lead exposure is a greater threat for an infant or a young child than for an adult.⁴ Exposure to toxic levels of lead at different stages of development can produce different neurophysiological outcomes.⁵ Blood levels as low as 10 mg/dl may result in subtle physical, cognitive, and psycho-behavioral deficits in lead poisoned children.⁶

The fetus and young children are particularly susceptible to the neurotoxic effects of lead because they are in a period of rapid growth and early development of the central and peripheral nervous systems, including the brain. During the early stages of child development, connections between brain cells are undergoing marked anatomic and physiologic changes that underlie language, visual, motor, and cognitive development. Lead interferes with these processes and leads to clinically observable effects on learning and behavior.⁷ The increased sensitivity of young brain cells connections to chemical neurotransmitters required for brain healing in response to injury may also make the child's brain more sensitive to adverse toxic effects.⁸ The hand-to-mouth and pica behavior of young children also place them at a higher risk of lead ingestion.

² Herbert L. Needleman, Julie A. Reiss, Micheal J. Tobin, Gretchen E. Biesecker, Joel B. Greenhouse, 363.

³ Robert T. Tuthill, 2.

⁴ P.M. Rodler, 121.

⁵ G.W. Goldstein, 384.

⁶ Herbert L. Needleman and David Bellinger, 111.

⁷ *Ibid*, 116.

⁸ J.W. McDonald and M.V. Johnston, 41.

Developmental Neurotoxicity of Lead:

Certain biochemical properties of lead which contribute to its neurotoxicity demonstrate that perinatal lead exposure disrupts nervous system development.⁹ There are subtle neurologic deficits in children which appear to be the effects of low concentrations of lead in the body. These are physiologic, cognitive, and psycho-behavioral symptoms. The physiologic symptoms include the disturbance of body balance mechanisms, hearing decrement, and reduced reaction times. The cognitive symptoms are associated with diminished intellectual development, poor reading skills, and spelling abilities. Behavioral problems characterize children as aggressive and difficult to manage. The psycho-behavioral symptoms include distractibility, inability to follow instructions, and disruptive behavior.¹⁰

In 1943, Randolph Byers asserted that lead not only killed cells, but interfered with the normal development of the central nervous system neurons. Several representative developmental parameters have been evaluated by numerous investigators examining the effects of perinatal lead exposure on development of rodents with blood lead levels ranging from 25 to 89 mg/dl. These studies use a variety of neurological, physiological, and biochemical endpoints. In all studies, lead exposure produced a delay in normal maturation. Delays were observed in the development of the righting reflex, sexual maturation in females, thermoregulation, visual potential, cerebral cytochrome concentrations, and cerebral synaptogenesis.¹¹ The results illustrate that early lead exposure produces additive effects resulting in a significant delay in neurological maturation. The effects on behavior persist beyond the immediate exposure period

⁹ J. Julian Chisolm and David M. O'Hara, 44.

¹⁰ Tuthill, 2.

suggesting that lead poisoning causes permanent alterations in the functioning of the nervous system as a result of perinatal exposure.

The neurobehavioral consequences of lead exposure, particularly the developmental consequences, may reflect a disruption of certain biochemical processes including mitochondrial respiration, enzyme activity, and calcium-dependent neurotransmitter release. Lead exposure both in-vivo and in-vitro has been shown to inhibit brain mitochondrial respiration in rodents. This disruption of energy metabolism caused by exposure of isolated mitochondria to lead results in the inhibition of succinate oxidation, producing dramatic effects on the developing, metabolically active nervous system. A wide variety of enzyme systems are sensitive to lead exposure. The affinity of lead to these systems, such as the imidazole nitrogen and the ϵ -amino group of lysine, can affect the nervous system. An effect may be caused by the perturbation of the structural integrity of enzymes or by the disruption of substrate-enzyme binding. Lead has also been shown in a variety of biological systems to inhibit calcium competitively. Since calcium is required for normal neurotransmitter release, this competition would be expected to interfere with synaptic transmission. Kostial and Vouk (1957) first demonstrated this effect using the cat superior cervical ganglion. They found that the postsynaptic response to presynaptic stimulation was reduced when lead was added to the bathing solution and that this inhibition was reversed by excess calcium. Kober and Cooper (1976), using the frog ganglion, demonstrated that the entry of calcium into the presynaptic terminals was blocked by lead and that this effect was reversed by calcium. Their kinetic data demonstrated that this effect was due to competitive inhibition.¹²

¹¹ Needleman and Bellinger, 138.

¹² Chisolm and O'Hara, 48-9.

A source of considerable debate is whether or not blood lead levels below those associated with obvious symptoms have adverse effects on the brain. Due to the fact that the symptoms of milder lead toxification are not dramatic, and may therefore evade precise identification, many efforts have been made to determine whether lesser levels of lead are associated with undetected neuropsychologic impairment. A study conducted by Needleman, et al measured the neuropsychologic effects of unidentified childhood lead exposure by comparing the performance of 58 children with high and 100 with low dentine lead levels. Human deciduous teeth accumulate lead in substantial quantities over their embryonic and postnatal life, up to the time of shedding. Teeth have long been recognized as relatively useful tissues for assessing biologic markers of long-term lead accumulation.¹³

Needleman's subjects for the study were a group of children in the first and second grades from Chelsea and Somerville, Massachusetts, all of whom were considered asymptomatic for lead intoxication. They were studied in two ways: those ranked in the highest and lowest 10th percentile for dentine lead concentrations were evaluated in the neuropsychologic laboratory. Their classroom behavior was also measured by teachers' ratings. In addition, all children whose teeth were analyzed had their classroom behavior evaluated by the same rating scale.

Children with high and low lead levels were very similar in most non-lead variables measured. The following variables, which differed $P < 0.1$, were controlled as covariates in the analysis of covariance: fathers' socioeconomic status (consisting of education and occupation score); mothers' age at subjects' birth; number of pregnancies; mothers' education and parental IQ. Children with high lead levels performed

¹³ National Research Council, 159.

significantly less well on the Weschler Intelligence Scale, particularly the verbal items, on three measures of auditory and verbal processing, on attentional performance as measured by reaction time under conditions of varying delay, and on most items of teachers' behavioral rating. As compared to controls, children with high lead levels appeared particularly less competent in areas of verbal performance and auditory processing. They had lower scores on all tests of the Seashore Rhythm Test, which requires the subject to discriminate whether pairs of tone sequences of increasing complexity are alike or different. In the Token Test, the task is to respond to verbal instructions of increasing complexity and to manipulate tokens of different shapes and colors. The four subtests are presented in order of increasing complexity and difficulty. The Sentence Repetition Test, which requires the immediate repetition of previously stated sentences of increasing length and syntactic complexity, was also sensitive to the effect of lead exposure.¹⁴

The classification of earlier lead exposure according to dentine lead levels has been validated in a number of earlier studies. Lead exists in dentine in a closed storage system. Tooth lead levels in baboons do not change after a pulsed dose of lead. They are elevated in children with unequivocal plumbism, urban children living in the 'lead belt,' and those who live in decaying homes or homes near a major lead processor. Tooth lead levels also vary in relation to the concentration of lead in the domestic water supply and the duration of exposure to that water.¹⁵

Subjects with high and low lead levels accepted for neuropsychologic evaluation in this study are an unbiased sample of children with lead burdens of this order in their

¹⁴ Herbert L. Needleman, Charles Gunnoe, Alan Leviton, Robert Reed, Henry Peresie, Cornelius Maher, and Peter Barrett, 692.

communities. Subjects tested in this study do not differ in gender, prevalence of elevated dentine lead levels or classroom behavior from those excluded. Groups with high and low lead levels who were evaluated in this study were remarkably alike in most of the 39 non-lead variables measured. They were only different at $P < 0.05$ on three variables: fathers' education, fathers' socioeconomic status, and subjects' age at the time of testing.¹⁶

In this study, the outcome measures that appear to be most sensitive to the effects of lead are those that evaluate verbal and auditory processing, attention (measured by reaction time), and classroom behavior. At the relatively low dose experienced by the exposed group, verbal and attentional processes appear most vulnerable to lead. Other investigators have reported that lead effects are most evident in the performance areas of the Wechsler Intelligence Scale for Children and in perceptual and motor functions. The differences expressed in the effects of lead reflect many factors, including magnitude and duration of exposure as well as the age at the time of exposure.¹⁷

Reaction time under varying intervals of delay is one measure of the attentional process. The ability of subjects with high lead levels to maintain attention was clearly impaired, as measured by reaction time at varying intervals of delay. Needleman found that boys seven and eight years old with earlier blood lead levels greater than 50 mg/dl had longer reaction times than controls whose earlier blood lead levels were less than 30 mg/dl. This finding suggests that disturbances of attentional function are a consistent effect of lead exposure. The validity of this finding is further supported by the teachers' reports of increased distractibility, increased prevalence of daydreaming, lack of

¹⁵ *Ibid*, 692-3.

¹⁶ *Ibid*, 693.

persistence, inability to follow directions, and lack of organization in subjects with high lead levels. These behaviors are often found in children labeled as “hyperactive.” Hyperactive behavior is a frequent sequel of lead poisoning and is suspected of being an effect of lead at lower doses. Hyperactivity and impulsivity, however, were reported relatively infrequently at all levels of dentine lead. The deficit of attention in the children with high lead levels demonstrated in this study may be responsible in part for impaired verbal learning.¹⁸ Higher dentine levels were also associated with lower class rank, increased absenteeism, lower scores on vocabulary and grammatical reasoning tests, significantly lower finger tapping speed, poorer eye-hand coordination, and lower reading scores.¹⁹

Teachers’ reports of classroom behavior also showed that children with high lead levels were rated significantly poorer on nine of eleven items, and that the sum score of these subjects was lower. The frequency of negative teachers’ behavioral ratings for every item increased with increasing dentine lead level, and was not limited to the group with highest lead levels.²⁰ This observation suggests that lead may increase the risk of undesirable behaviors in the classroom at doses considerably below those found in the group with high lead levels.²¹ In Scottish children, for example, lead was related to hyperactivity and aggressive antisocial scores on the Rutter teacher scale. New Zealand children had higher inattention and restlessness scores in relation to dentine lead levels.²²

¹⁷ *Ibid*, 694.

¹⁸ *Ibid*.

¹⁹ *Ibid*.

²⁰ Needleman, et al., 693.

²¹ *Ibid*, 694.

²² G.O.B. Thomson, G.M. Raab, W.S. Hepburn, R. Hunter, M. Fulton, D.P.H. Lazen, 515.

In males, when attention-deficit hyperactivity disorder is accompanied by aggression, an individual is at strong risk for later delinquent behavior.²³

Altered social behavior may be among the earliest expressions of lead toxicity.²⁴ Only one investigation of lead in relation to disciplinary problems, juvenile delinquency and adult criminality has been published. Denno studied 987 African American youths (487 males, 500 females) from birth through 22 years of age. After examining many factors, she found lead poisoning, in male subjects only to be the most significant predictor of disciplinary problems and among the most significant predictors of delinquency and adult criminality.²⁵

These observations have further encouraged study of the role of lead exposure as a risk factor in the genesis of anti-social behavior. Needleman pursued this question by studying a sample of 301 boys in primary public schools. Bone lead concentrations were measured by in-vivo x-ray fluorescence, a measure of cumulative exposure, and examined the relationship of bone lead burden to reports of antisocial behavior from three separate sources: parents, teachers, and the subjects themselves, further extending earlier studies. They also evaluated attentional function, neurobehavioral and academic performance in relation to bone lead content. To minimize confounding by other factors, nine relevant social and economic variables were controlled for and a comparison of outcome was made before and after covariate adjustment. The subjects were tested at two different times and behavioral questionnaires were obtained when the subjects were seven and eleven years of age.²⁶

²³ D.M. Fergusson, J. Horwood, M.T. Lynskey, 215.

²⁴ Needleman et al., 367.

²⁵ *Ibid*, 369.

²⁶ *Ibid*, 363.

In this study, male children considered asymptomatic for lead toxicity with elevated bone lead levels at 11 years of age were judged by both parents and teachers to be more aggressive, have higher delinquent scores, and have more somatic complaints than their low-lead counterparts. The subjects themselves reported lead-related increases in antisocial acts at the same age. Conduct disorders or aggression are strong predictors of criminality. Signaled reaction time, teachers' ratings of classroom behavior, and scores on structured behavioral inventories have been shown to affect attentional impairment, a strong risk factor for delinquent behavior.²⁷

There is no established threshold for the adverse effects of lead on intelligence at lower blood lead levels. Inhibitory effects of lead on enzymes at extremely low concentrations have been demonstrated. The evidence gathered supports the fact that the central and peripheral nervous systems of both children and adults are affected by lead exposures formerly thought to be within the safe range. In children, blood lead concentrations around 10 mg/dl are associated with disturbances in early physical and mental growth and in later intellectual functioning and academic achievement.²⁸

The limited data available are generally consistent with the hypothesis that children with greater lead burdens not only perform worse on laboratory and psychometric tests of cognitive function, but also are more frequently classified as learning disabled and make slower progress through grades. For example, Needleman's dentine lead level study associated children with dentine lead concentrations greater than

²⁷ *Ibid.*

²⁸ *Ibid*, 368.

20 parts per million with increased rates of referral for remedial academic help and with grade retention during the late elementary school years.²⁹

The impaired function of children with high lead levels, evidenced by disordered classroom behavior appears to be an early adverse effect of exposure to lead on biological functioning, cognition, and behavior. Lead exposure is associated with reduced verbal competence, increased rates of reading disabilities, frustration, and increased academic failure. Reduced verbal skills could interfere with the use of internal language to mediate behavior and to delay immediate responding. Academic failure, a demonstrated consequence of lead exposure, may also be another factor that may be an intervening variable in the causal chain between lead and delinquency. Subjects with elevated (>24 ppm) tooth lead levels during childhood had a seven fold increase in the rate of high school failure and a six fold increase in reading disability.³⁰ These conditions dim employment opportunities for adults who were once lead poisoned children.

²⁹ National Research Council, 93.

³⁰ Needleman, et al., 368.

Chapter 2:

Asthma and its Effects on Academic Performance

Asthma is one of the most common chronic childhood diseases that affect children, and it causes substantial school absenteeism. About five million children under 18 years old in the United States have asthma. The prevalence of the disease is on the rise, as are the number of hospitalizations.³¹

Potential Neuropsychological Deficits Associated with Asthma:

Children with asthma may experience problems in their adaptation to school and impediments to their learning. Although it has been found that asthma does not directly alter brain development or neuropsychological functioning, asthma symptoms may cause children to have more frequent absences from school, at the minimum. Even when attending school, children experiencing allergic or asthma symptoms may simply not feel well, may be unable to concentrate, and, consequently, may be less able to learn new skills and information. The effects of school absence are typically reversible when asthma becomes well-managed. Medications used to treat asthma and allergic conditions may occasionally impact children's ability to learn, although, for the most part, the effects are minimal.³² The more significant effects affecting academic performance for asthmatic children occur because of sleep loss and general malaise that accompany these conditions.

Studies that have employed large groups of asthmatic children and used standardized tests of educational achievement have not found decreased academic skills relative to children without asthma. In a school based study of mild to moderately ill

³¹ Bender, 204.

children with asthma, standardized achievement test scores from 255 children with asthma in Iowa were found to be no different from those of their non-asthmatic classmates. In the largest study of children with asthma to date which included 1,041 patient in eight cities, mean IQ, cognitive, and achievement test scores were normally distributed. Even among children with more severe asthma, there is no clear evidence of increased risk for learning disabilities or lagging academic skills.³³

Havard in 1975 concluded that many hyperactive, language disabled, learning disabled, lazy, minimally brain damaged, or emotionally disturbed children may, in fact, have allergy problems underlying their disability. However, these theories proposing a direct link between allergic disorder, brain function, and learning disabilities, have not been substantiated in subsequent research. There is no clear evidence that specific learning disabilities resulting from alterations in normal brain development related to asthma differ from those of other children. On average, the academic skills of children with asthma do not differ from those of other children. For most of these children, their asthma does not result in a pervasive change in cognitive abilities.³⁴

While there is no evidence of a direct link between neuropsychological development and asthma, children with these conditions may have difficulty in school for secondary reasons. These reasons include anoxic episodes resulting in brain damage, school absence, illness symptoms interfering with concentration, hearing loss, sleep loss, and side effects of asthma medications.

³² Freudenberg, et al., 523.

³³ Annet, et al, 112.

School Absenteeism:

Children with asthma miss school more often than do children without chronic illness. One study revealed that children with asthma in one school district were absent 7% of the days, while children without asthma in the same school were absent 2% of the days. Frequent school absence interrupts the process of learning and interferes with children's social interactions and participation in extracurricular activities. However, increased school absence is neither associated with decreased achievement nor increased asthma severity.³⁵

A Connecticut-based study found that in one school district the incidence of asthma or chronic bronchitis was 7.1% among kindergarten through 12th graders. Among this asthmatic group, absenteeism was increased and significantly associated with lower grades but not decreased achievement scores. The investigators, noting that the grades of children with asthma remained above average, concluded that the children with asthma in that study required no special education intervention.³⁶ These findings indicate that school absence may temporarily interrupt the acquisition of new skills and knowledge without permanently impeding academic progress.

It is typically assumed that the frequency of school absence correlates with the severity of the asthma. Surprisingly, this does not appear to be the case. Parents of children with asthma vary greatly with regard to their tendency to keep their children home from school when symptoms of asthma appear. Thus, frequency of school absence may be a reflection of parental protectiveness as much or more than asthma severity. One study of 773 children with asthma and another 773 control children found that

³⁴ Havard, 6940.

³⁵ Parcel, et al., 879.

severity of asthma was not correlated with increased school absence and concluded that school absence cannot serve as an indicator of morbidity in childhood asthma.³⁷ A survey of parents of inner-city children found that 40% reported that their children with asthma were having difficulty in their school progress due to frequent absences.³⁸ The reported findings suggest that for inner-city children with asthma school absence may be a greater difficulty than for other children. However, a subsequent study reported that low socioeconomic status did not predict absence among children with chronic illness.

Children suffering from symptoms of asthma or allergies may be well enough to attend school, yet suffer from ill feeling enough to interfere with concentration and learning. Breathing difficulties suffered by children with asthma clearly undermine their health and well-being and, even when not sufficient to mandate school absence, interfere with their school day. Fatigue, irritability, and intermittent hearing loss may accompany seasonal allergies which trigger asthma and can lead to inattentiveness in a classroom setting.

Asthma and allergic conditions may seriously interrupt sleep, resulting in fatigue, irritability, poor attention, and inability to learn effectively during the day. Some children are particularly susceptible to asthma symptoms during the night, a condition referred to as nocturnal asthma.³⁹ These children, in particular, may exhibit the effects of sleep deprivation during the day. Few controlled studies have examined the effect of asthma-related sleep loss upon children's daytime functioning. However, investigations into the impact of obstructive sleep apnea, a related condition, have been conducted.

³⁶ *Ibid*, 881.

³⁷ McCowan, et al., 310.

³⁸ Freudenberg, et al., 525.

³⁹ Martin, 6.

Obstructive sleep apnea syndrome refers to the cessation of breathing during sleep. For adults as well as children, obstructive sleep apnea may produce decreased attention span, intermittent hyperactivity, poor academic performance, and even developmental delay. A clinical observation study reporting on eight apneic children described serious interruption in the lives of these patients, including impairment of learning and school performance.⁴⁰

Asthma Medications:

A number of different medications have been used to treat asthma and allergic reactions through a variety of mechanisms, including fighting inflammation, opening up the airways, and impeding histamine production. Some of these medications have potential impact upon children's mood, cognition, and behavior. However, considerable misinformation about asthma and allergy medications has been proliferated. For the most part, the effects of these medications cause small changes in cognition that have little impact upon children's learning.⁴¹

Beta-antagonists, for example, provide quick relief of asthma symptoms by acting directly on the bronchial muscles to open narrowed airways. One effect of beta-antagonists such as Proventil, is increased skeletal muscle tremor and pulse rate reported in adults as well as children. A study of 20 children with asthma revealed uncompromised motor performance on tests of response speed, visual-motor control, and speed and dexterity following albuterol inhalation. Fine motor tremor of short-term duration was present. In addition, the children were found to make postural adjustments, including steadying their arms, which appeared to compensate for the stimulation

⁴⁰ Hansen and Vandenberg, 304.

⁴¹ Bender, 208.

produced by this medication. Minimal effects on cognition or performance in adults and adolescents also have been reported. Beta-antagonists are associated with muscular-skeletal tremor of short duration, but completion of more complex perceptual-motor tasks is unaffected. Thus, teachers may be aware that fine motor tasks, such as writing and drawing, may be impeded slightly in children immediately after taking their beta-antagonist inhaler, but that this side effect will diminish within 30 minutes for most children.⁴²

Corticosteroids are the single most powerful agent used to fight bronchial inflammation. Inhaled corticosteroids are frequently used during a long period of time to control inflammation. Therefore, even children who appear to have few asthma symptoms may need to maintain their relative health by using inhaled corticosteroids daily to prevent a resurgence of inflammation in the airways. Subtle neurocognitive changes have been detected in children with asthma receiving systemic steroids. Specifically, scores on a test of verbal and visual memory drop significantly during periods of high dose steroid treatment. However, these effects were absent a day after cessation of steroid treatment. Thus, available evidence indicates that systemic steroids may impede children's learning in school.⁴³ However, most children with asthma receive systemic steroids only during severe exacerbations of their illness and only for short periods of time. Consequently, the overall impact on most asthmatic children's learning is likely to be minimal.

Medications used to treat children with asthma or allergic conditions may produce occasional, specific neurocognitive, neuromotor, or behavioral changes in children.

⁴² *Ibid.*

⁴³ *Ibid*, 209.

However, the evidence supporting their safety and the absence of side effects is more convincing than any evidence of significant adverse effects. The greatest evidence for psychological side effects is found in the case of steroids, which can increase depressed and anxious feelings and interfere with children's short-term memory. For many children with asthma, these changes may be mild or may not occur at all. Furthermore, these changes have been limited to systemic steroids, which are often given only in very brief bursts and only then to children with a severe exacerbation of symptoms.⁴⁴

In conclusion, asthma and associated allergic disorders affect more than 10% of the children in the United States. When these conditions are poorly managed, they can seriously impede children's school adaptation and learning. However, neither asthma nor allergies directly alter brain development or neuropsychological functioning. Anoxia, only secondary to respiratory arrest, only rarely occurs in this population and can cause irreversible brain damage. Medications used to treat asthma and allergic conditions occasionally may impact their ability to learn. When parents inform teachers of the medications taken by their children, it is possible for teachers to be sensitive to the potential side effects and to make appropriate accommodations in the classroom.

Other secondary effects of childhood asthma may more significantly affect children's classroom learning. Specifically, sleep loss and general ill feelings may significantly diminish children's ability to concentrate. When asthma and allergies are well managed medically, these consequences can be minimized. Finally, while asthma and allergic conditions clearly result in an increase in school absence, during the long term, these absences do not result in a significant reduction in academic abilities. Thus, reasonable efforts to provide at-home work for children during prolonged absences and to

⁴⁴ Annett, 113.

provide some catch-up support upon return to the classroom should, in most cases, be sufficient to allow children with these chronic illnesses to maintain their pace with classmates.

When considering the source and solution to asthma related school problems, all the available evidence must be taken into account. Parents sometimes focus upon one potential cause of the decline in a child's school performance such as school absence and medication side effects while omitting other potential causal factors. Yet other possibilities, including the secondary effects of illness such as sleep disturbance and diminished self-esteem, may have an important role. At times, children with asthma may have learning disabilities unrelated to their illness, which would have been present if the child had never developed asthma.

While some positive changes may result from medication changes and better control of the illness, in many cases the child with asthma will require intervention, psychological or educational, that is no different than that provided to children without asthma, but with similar behavioral and learning difficulties. A multidisciplinary collaboration provides the best assessment and intervention planning and is most likely to facilitate change. Under optimal circumstances, communication between the medical care provider and the psychologist or the educational consultant can help identify those elements of the child's illness or treatment that may be contributing to school problems. It is important to determine which improvements in the child's health status may be expected and may result in improved school adaptation and also identify those elements of the child's condition that are unlikely to change and may require adjustments in the school setting.

Chapter 3:

Data and Methods

Lead Poisoning Data:

Rhode Island state law requires regular screenings of the blood of all children under the age of six for lead levels. Lead-poisoning screening data obtained from the Rhode Island Department of Health for Providence residents for children tested in 1993 to 1998 were used in this analysis. In 1993, a new law for lead testing was implemented. This law required that all medical providers test children for lead. Blood lead test data are available as far back as 1989 in Rhode Island, but beginning in 1993, the population of children tested was much more representative of the entire population. Therefore, lead tests conducted between 1993 and 1998 comprise a larger proportion of the population of children living in Providence than pre-1993 lead screenings. The total number of children under age 18 tested within the specified time frame was 31,309. Lead tests conducted in 1993 to 1996 were used for correlating with promotion to the next grade. These years represented an age group old enough to be enrolled in school resulting in a larger number of matches with promotion to the next grade. Data for blood lead tests in 1993 to 1998 were used for correlating with standardized educational test scores. Lead screenings after the year in which each test was conducted were excluded to ensure that lead levels had been measured in a student by the time he/she took the standardized test.

Most children are tested for lead for the first time between eleven and thirteen months of age. If a child has a blood lead level (BLL) below 10 $\mu\text{g}/\text{dl}$ the first time he/she is tested for lead or if the BLL drops down to this level on the subsequent tests, then doctors will stop testing at 36 months of age because there is no change in risk

status. If BLLs are elevated, children are tested regularly until levels drop and in this case testing may continue well beyond 36 months of age. The regulations state that testing should occur twice before a child turns 36 months of age, at 12 months and 24 months. However, not all medical providers strictly follow the guidelines and some children are tested only once if the BLL is low. For the purposes of this analysis, one goal of which is to test for a correlation between blood-lead levels and subsequent academic performance, for children with multiple BLL measures, the highest BLL was used as the measure of the degree of lead poisoning for each child. Lead toxification causes developmental damage at different levels of exposure. The highest BLL represents the greatest risk of damage that could have occurred during a child's development. For this reason, the highest BLL was selected for the correlations. For case-control analyses, a BLL between 0 and 14 $\mu\text{g}/\text{dl}$ was considered "not lead poisoned" and 15 $\mu\text{g}/\text{dl}$ or above was considered as "lead poisoned." BLLs are available for approximately 70% of all children in Providence tested by 18 months of age. This estimate was generated by comparing Census data with lead screening records.

Asthma Data:

Data for asthma hospitalizations was obtained from Lifespan. These data included emergency room visits, and inpatient and outpatient admissions at Rhode Island and Miriam Hospitals with a primary diagnosis of asthma between January 1978 and March 2000. I used asthma records only for those born in the years of 1973 to 1994. This excludes all children under five years of age who are too young to be enrolled in at least Kindergarten or those over 20 years of age when admitted, and thus assumed to be too old to be in the educational data. The total number of children and teenagers

hospitalized for asthma is 1,705. Multiple visits to the hospital were removed from the data. These data only include asthma hospitalizations and therefore are not representative of all the asthmatics in Providence. The data do not include those asthmatics who go to private physicians for treatment and do not visit the hospital, or seldomly do. Many multiple visits by some asthmatics indicate that the hospital is being used for chronic health care and that they are not using asthma medications properly. The children visiting the hospital for asthma are thus more likely to be children who visit the clinic and lack the knowledge of proper asthma treatment and control, which may lead to more frequent visits to the hospital.

Education Measures:

Academic achievement was assessed using education data obtained by the Providence Plan from the Providence School Department and the Rhode Island Department of Education. These data included all students enrolled in the Providence Public School System from 1993 to 1998 and all students in Grades 3 and 4 from 1996 to 1999. Two educational measures were used in this analysis for testing for an association between lead poisoned and asthmatic children and educational outcomes. The measures used were:

- promotion to the next grade (from Providence School Department)
- scores on standardized tests taken in the 3rd and 4th grades in 1996 to 1999 (from Rhode Island Department of Education)

A. Promotion to the Next Grade

Data on promotion to the next grade included all grades from Half Day Kindergarten to Grade 12, with a separate category for children in special education

programs. The data covered five academic years, from 1993 to 1998. Grades 1, 7, and 9, evidence a larger number of students repeating the grade. All academic years evidence a substantial number of students repeating, as well as advancing grades. *See Appendix A

Promotion to the next grade is determined primarily by grades and attendance, although each case is considered individually. If a student is absent at least thirty days in an academic year, then the student is held back a grade. For grades, there is no set criteria. Generally, if a student fails two core classes (i.e. Language Arts, Science, Social Studies) then he/she might still pass the grade, however, if a child fails three or more core classes, he/she does not get promoted to the next grade. Elective courses do not determine promotion to the next grade. There are alternatives if a child is not making the grade. The Providence Public School System offers Project Success and special education programs. Project Success enables a student to complete credit for two grades in one academic year. If a student is not performing well in classes, then he/she is referred to a special education program, if not held back a grade.⁴⁵

B. Standardized Test Scores

The standardized tests used in this analysis cover several different academic subjects. The tests used for the correlations were for grades three and four. According to the Rhode Island Department of Education, a child must be five years of age by December 31 of the year when he/she enters Kindergarten. At grade four, a child is expected to be nine years of age, with a date of birth in 1987 for a test conducted in 1996 and a date of birth in 1988 for a test conducted in 1997. For tests conducted in 1998, a child in grade three is expected to be eight years of age with a date of birth in 1990. Finally, for tests conducted in grade three in 1999, such as the Rhode Island Writing

Assessment, a child is expected to be eight years of age with a year of birth in 1991. However, these age calculations based on grade were not the only age cohort considered in the correlations. Due to the fact that there are students who have repeated and advanced grades, the correlations were not limited to children who appeared to be of a specific age in the data. Rather, all ages were tested for correlation, except for children who were lead poisoned after the test date or visited the hospital with a primary diagnosis of asthma after the test date (determined by year).

The central purpose of the Rhode Island State Assessment Program is to measure academic achievement. This, in turn, will drive two other crucial purposes: (1) to assess student performance in order to provide information to students, families and their teachers, and (2) to inform and improve instructional programs. The tests are the following:

(1) Harcourt Brace—Rhode Island Writing and Mathematics: Grade 4, 1996 and 1997

Number of Test Takers:

1996: Writing-- 1,719 (Linear Regression Model)

Mathematics-- 1,626

1997: Writing-- 5,934

Mathematics-- 5,934

For the purposes of this analysis, the performance standards used in the correlations are not absolute values. This analysis separates scores by ranking, based on how many students performed in each category determined by the Department of Education. A low and a high score was determined by the total number of students who achieve the performance standard levels. I divided the scores approximately in half based on how many students performed in each achievement level. This analysis compares lead poisoned and non-lead poisoned children to test scores which compare, by order of ranking, how each student did relative to each other. Thus, for each test scores have separate divisions for a high or low ranking based on students achievement levels in comparison to the total population of students who took the test.

*See Appendix for Performance Standard Levels for both Department of Education and values used in this analysis

⁴⁵ Karen Basela from the Providence School Department.

The Rhode Island Writing test is a performance based test and should have performance levels. However, for the year 1996, Harcourt Brace, the test developers, did not convert the raw scores into performance levels. Therefore, the raw scores were correlated in a regression analysis. A linear regression model tests for a straight line that characterizes the relationship between BLLs and test scores. The dependent variable, the variable being predicted, is the test score. The variable being used to predict is the independent variable and in this case is the BLL. The two values for each of the data points generate a plot called a scattergram.⁴⁶ In the scattergram, the test scores are plotted on the y-axis and the BLLs are plotted on the x-axis.

*See Appendix for values

(2) New Standards—Mathematics: 1998 Grade 4

1. *Skills Standard Level*
2. *Concepts Standard Level*
3. *Problem Solving Standard Level*

Number of Test Takers: 1,897

The purpose of this test is to assess mathematical skills, concepts, problem solving and reasoning, and communication. Students' performance is measured in relation to the UU*New Standards Performance Standards*, which are aligned with the Rhode Island Mathematics Framework K-12 and with the NCTM⁴⁷ Standards.

Scores reflect the extent to which students accomplish tasks by using mathematical skills effectively, including the computation and symbol and manipulation skills of arithmetic and algebra as well as geometric and graphical skills; use concepts of Number and Operation, Geometry and Measurement, Function and Algebra, and Statistics and Probability to solve problems, explain those concepts to others in different ways; and use concepts and skills to formulate problems, implement solutions, justify conclusions, and make generalizations; and use the language of mathematics to describe concepts and to explain reasoning and results.

*See Appendix D for how the examination is organized

(3) New Standards—English Language Arts: Grade 4 for 1998

1. *Reading: Basic Understanding Standard Level*
2. *Reading: Analysis and Interpretation Standard Level*
3. *Writing: Standard Level*
4. *Writing: Conventions Standard Level*

Number of Test Takers: 1,815

The purpose of this test is to assess student ability to understand, draw conclusions, and make interpretations of text as a whole through reading; as

⁴⁶ Lloyd D. Fisher and Gerald van Belle, 345.

⁴⁷ National Council of Teachers of Mathematics

well as student ability to demonstrate rhetorical effectiveness in writing and use of conventions. Students' performance is measured in relation to the New Standards Performance Standards, which are aligned with Rhode Island English Language Arts Framework—Literacy for All Students.

Scores reflect the extent to which students comprehend, analyze and interpret a variety of materials of varying lengths and complexity; are able to write effectively, controlling conventions and grammar of the English language, in a variety of formats for a variety of purposes, audiences and contexts.

*See Appendix D for how the examination is organized

(4) Rhode Island Writing Assessment: Grade 3 for 1998 and 1999

Number of Test Takers:

1998: 2,157

1999: 2,309

The purpose of this test is to assess a student's ability to communicate effectively through writing in standard English in a way that models a process approach to writing. Writing assessment is a performance-based measure that attempts to match teaching and testing practices as closely as possible. It involves the collection of a writing sample under controlled circumstances. It is based on the English Language Arts Literacy Standards and measures student performance in relation to several specific standards. Scores reflect the extent to which students are able to present thoughtful ideas and develop them logically, fully and clearly; are able to present a well-organized sample of writing that uses language well; and are able to use grammar and conventions correctly in their writing.

*See Appendix D for how the examination is organized

According to Information Works published by the Rhode Island Department of Education, 84% of the students attending schools in the Providence District in the 1998-1999 academic year were enrolled in public schools. Of these, 77% were eligible for subsidized lunch programs, a free or reduced price lunch. This is an indicator of income for students whose family incomes fall below certain income poverty or near-poverty guidelines are eligible for this program. Income is a known independent variable influencing both lead poisoning and academic performance. However, in this analysis, there is no way to correct for this variable with the available data. Besides income, there

are other variables affecting academic achievement results. These variables include a non-English speaking background, educational background of parents, having special learning needs, residential mobility, length of time in the school district, and having a minority or racial group identity.⁴⁸ A majority of the students in the Providence Schools are expected to be affected by one or more of these variables based on the ethnic backgrounds of children enrolled in the Providence Public Schools. The ethnic background of the students in the 1998-1999 school year was: 45% Hispanic, 23% Black, 21% White, 10% Asian/Pacific Islander, and 1% Native American.

Methods:

Promotion to the next grade and standardized test scores, as previously described, were tested for correlation with asthmatic data and with blood lead data.

A. Lead Poisoning and Education Measures

A case-control analysis was used to correlate lead poisoning [$15+ \mu\text{g/dl}$] with promotion to the next grade and standardized test scores.⁴⁹ All students in the Providence Public Schools were matched with the lead screenings by generating the same ID code (constructed from the name and the birth date) in both data sets, as long as the academic year was equal to or greater than the year of the lead test. BLLs were used to classify exposed and unexposed populations as the independent variable. The cases are the students who repeated a grade or had low test scores and the controls are the students who advanced a grade or had high test scores. The cases and controls were arranged in a

⁴⁸ Rhode Island Board of Regents for Elementary and Secondary Education, 16.

⁴⁹ Anders Ahlbom and Staffan Norell, 50.

2X2 table with the exposed and unexposed populations and where N_1 and N_0 are the number of cases and controls.

	Exposed	Unexposed	All
Cases	a	b	N_1
Controls	c	d	N_0
All	a + c	b + d	N

The odds ratio is the outcome in the exposed group divided by the odds of the outcome in the unexposed group. The calculation of the odds ratio applies the following formula:

$$\text{Odds Ratio} = (a/b)/(c/d)$$

Or, as in Table 1, Odds Ratio = (Lead Poisoned Repeat / Non-Lead Poisoned Repeat) / (Lead Poisoned Advance / Non-Lead Poisoned Advance)

The variance for the corresponding logarithm is:

$$\text{Var}[\ln(\text{Odds Ratio})] = 1/a + 1/b + 1/c + 1/d$$

A general formula for the 95% confidence interval for the odds ratio can be calculated as follows, if the number of observations is reasonably large so that the normal distribution approximation can be applied. Thus, the confidence interval becomes:

$$e^{\ln(\text{Odds Ratio}) \pm 1.96(\text{square root of variance})}$$

If the proportion of cases exposed is sufficiently higher than the proportion of controls exposed, there appears to be an association between exposure and disease. This general formula for the confidence interval for the odds ratio is based on the normal distribution. The constant, e, and the natural logarithm are involved in this formula because the distribution of possible values of the relative risk is highly asymmetric: the

relative risk cannot be less than zero but has no upper limit. This asymmetry limits the applicability of the normal distribution, which is symmetric.⁵⁰

B. Asthma Hospitalizations and Education Measures

A cohort analysis based on cumulative incidence was used to correlate asthma hospitalizations with promotion to the next grade and standardized test scores.⁵¹ The cumulative incidence among the asthmatics and non-asthmatics was estimated. This exposure categorization is dichotomous with asthmatic and non-asthmatic categories. All members of the population not identified by hospital visits as asthmatic were categorized as non-asthmatics. Thus, this cohort includes a larger number of children than is considered in the case-control analysis. All hospital visits were matched as long as the hospitalization date was before or at the same time as the academic year and the year of the test. The cases are the students who repeated a grade or had low test scores and the controls are the students who advanced a grade or had high test scores. Data are arranged in a 2X2 table as follows:

	Exposed	Unexposed	All
Repeat	A ₁	A ₀	A
Advance	N ₁ - A ₁	N ₀ - A ₀	N - A
All	N ₁	N ₀	N

The calculation of the odds ratio applies the following formula:

$$\text{Odds Ratio} = (A_1/N_1) / (A_0/N_0)$$

Or, as in Table 2, Odds Ratio= (Asthmatics Repeat/ All Asthmatics)/
(Non-Asthmatics Repeat/ All Non-Asthmatics)

⁵⁰ Ahlbom and Norell, 71.

⁵¹ Ahlbom and Norell, 47.

With the incidence rate as the basis for the relative risk, the variance for the corresponding logarithm is:

$$\text{Var}[\ln(\text{Odds Ratio})] = \frac{N_1 - A_1}{N_1 A_1} + \frac{N_0 - A_0}{N_0 A_0}$$

Thus, the confidence interval becomes: $e^{\ln(\text{Odds Ratio}) \pm 1.96(\text{square root of variance})}$ ⁵²

Chapter 4:

Results

I. Lead Results:

Case-Control Analysis:

TABLE 1

**Blood Lead Levels and Promotion to the Next Grade for 1993-1998 Academic Years
Kindergarten through Grade 12:**

	Lead Poisoned*	Not Lead Poisoned	All
Repeat	483	1,494	1,977
Advance	4,449	22,616	27,065
All	4,932	24,100	29,042

[*Lead Poisoning = 15+ µg/dl]

Interpretation of Odds Ratio:

Children who have been lead poisoned are 1.6 times more likely to repeat a grade than are children who have not been lead poisoned.

Since the proportion of cases exposed is higher than the proportion of controls exposed, there appears to be an association between repeating a grade and lead poisoning.

95% CI [1.5, 1.8]

Our best estimate of this odds ratio is 1.6 and we are 95% confident that the true value falls between 1.5 and 1.8.

Summary of Lead Results:

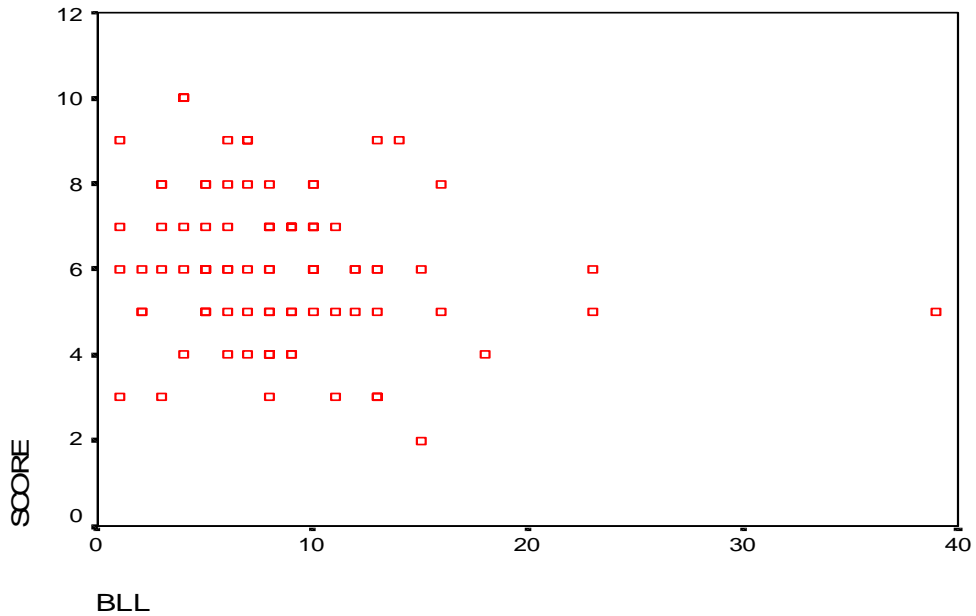
Test:	Year of Test:	Grade:	Odds Ratio:	95% CI: Lower Bound	95% CI: Upper Bound	Cases:	Controls:
ELA Reading: Understn.	1998	4	1.6	1	2.5	195	373
ELA Reading: Analysis	1998	4	2	1.3	3.2	214	354
ELA Writing Std. Level	1998	4	1.4	0.9	2	234	334
ELA Writing Convention	1998	4	1.5	1	2.4	267	301
Math: Concepts	1998	4	1.3	0.7	1.8	425	144
Math: Skills	1998	4	1.6	1	2.5	171	398

⁵² *Ibid*, 73.

Math: Problem Solving	1998	4	4.8	1.2	20	516	53
Math	1996	4	0.74	-	-	58	44
Writing	1998	3	1.5	1	2.3	740	187
Writing	1999	3	2.1	1.5	3	750	367

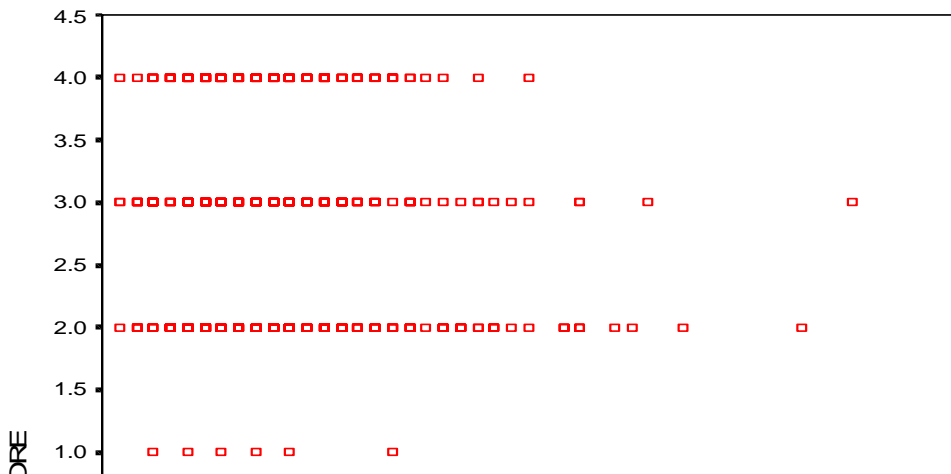
Linear Regression Models:

Test: 1996 Writing-- Grade 4 and BLLs (Raw Scores)



The points on the scattergram show a negatively sloping line although the model does not indicate a strong linear relationship. The regression coefficients are: $\beta_0 = 6.5$ and $\beta_1 = -0.005$ hence the regression function (in the form $y = \beta_0 + \beta_1 x$) can be stated: test score = $6.5 - 0.005(\text{BLL})$. This indicates that there is no strong relationship between test scores and BLLs.

Test: 1998 English Language Arts: Reading: Analysis and Interpretation-- Grade 4 and BLLs



II. Asthma Results:

Cohort Design—Cumulative Incidence:

TABLE 2
Hospitalizations and Promotion to the Next Grade for 1993-1998 Academic Years
Half Day Kindergarten through Grade 12:

	Asthmatics	Non-Asthmatics	All
Repeat	152	8,760	8,912
Advance	1,583	119,368	120,951
All	1,735	128,128	129,863

Interpretation of Odds Ratio:

Asthmatic children who have visited the hospital are 1.3 times more likely to repeat a grade than are children who are not asthmatics.

95% CI [1.1, 1.5]

Our best estimate of this odds ratio is 1.3 and we are 95% confident that the true value falls between 1.1 and 1.5.

Summary of Asthma Results:

Test:	Year of Test:	Grade:	Odds Ratio:	95% CI: Lower Bound	95% CI: Upper Bound	Cases:	Controls:
ELA Reading: Understn.	1998	4	1.4	1	1.9	576	1228
ELA Reading: Analysis	1998	4	1.4	1.1	1.9	630	1174
ELA Writing Std. Level	1998	4	1.6	1.3	2	732	1072
ELA Writing Convention	1998	4	1.3	1	1.7	799	1005
Math: Concepts	1998	4	1.04	0.9	1.2	1403	482
Math: Skills	1998	4	0.95	0.63	1.42	591	1294
Math: Problem Solving	1998	4	1.04	0.97	1.1	1687	198

In this study, I do not establish a causal relationship between lead poisoning/asthma and educational success measures. I establish that some educational success measures have significant negative correlations with lead poisoning and asthma. There are confounders such as income level and parents' education which are not corrected for in this analysis. These variables are known to influence a student's academic achievement. Reading to young children at home, for example, and participation in pre-school programs are two factors which make a difference in reading achievement and overall success in school. Extensions of this study should attempt to control for socio-economic status. For correlations with standardized test scores, I suggest linear regression models in order to define the relationship between individual blood lead levels and test scores. Students' enrollment in subsidized lunch programs might be used as a control, although this may not be effective due to the fact that 77% of the children in Providence public schools receive a free or reduced-price lunch. Parent education, language proficiency, family structure, and the community's socioeconomic status are strong predictors of student academic achievement and in the future, may be accounted for if the data are available.

Appendix A

I. Lead Results by Standardized Test Scores

Test: 1998 New Standards English Language Arts, Grade 4
(31% matches)

Reading: Basic Understanding Standard Level

	Lead Poisoned	Not Lead Poisoned	All
Low Scores	38	157	195
High Scores	51	322	373
All	89	479	568

Interpretation of Odds Ratio:

Children who have been lead poisoned are 1.6 times more likely to receive a low score than are children who have not been lead poisoned.

95% CI [1,2.5]

Our best estimate of this odds ratio is 1.6 and we are 95% confident that the true value falls between 1 and 2.5.

Reading: Analysis and Interpretation Standard Level

	Lead Poisoned	Not Lead Poisoned	All
Low Scores	46	168	214
High Scores	43	311	354
All	89	479	568

Interpretation of Odds Ratio:

Children who have been lead poisoned are 2 times more likely to receive a low score than are children who have not been lead poisoned.

95% CI [1.3, 3.2]

Our best estimate of this odds ratio is 2 and we are 95% confident that the true value falls between 1.3 and 3.2.

Writing Standard Level

	Lead Poisoned	Not Lead Poisoned	All
Low Scores	43	191	234
High Scores	46	288	334
All	89	479	568

Interpretation of Odds Ratio:

Children who have been lead poisoned are 1.4 times more likely to receive a low score than are children who have not been lead poisoned.

95% CI [0.9, 2]

Our best estimate of this odds ratio is 1.4 and we are 95% confident that the true value falls between 0.9 and 2.

Writing: Conventions Standard Level

	Lead Poisoned	Not Lead Poisoned	All
Low Scores	49	218	267
High Scores	40	261	301
All	89	479	568

Interpretation of Odds Ratio:

Children who have been lead poisoned are 1.5 times more likely to receive a low score than are children who have not been lead poisoned.

95% CI [1, 2.4]

Our best estimate of this odds ratio is 1.5 and we are 95% confident that the true value falls between 1 and 2.4.

Test: 1998 New Standards Math, Grade 4
(30% matches)

Concepts Standard Level

	Lead Poisoned	Not Lead Poisoned	All
Low Scores	65	360	425
High Scores	18	126	144
All	83	486	569

Interpretation of Odds Ratio:

Children who have been lead poisoned are 1.3 times more likely to receive a low score than are children who have not been lead poisoned.

95% CI [0.7, 1.8]

Our best estimate of this odds ratio is 1.3 and we are 95% confident that the true value falls between 0.7 and 1.8.

Skills Standard Level

	Lead Poisoned	Not Lead Poisoned	All
Low Scores	32	139	171
High Scores	51	347	398
All	83	486	569

Interpretation of Odds Ratio:

Children who have been lead poisoned are 1.6 times more likely to receive a low score than are children who have not been lead poisoned.

95% CI [1, 2.5]

Our best estimate of this odds ratio is 1.6 and we are 95% confident that the true value falls between 1 and 2.5.

Problem Solving Standard Level

	Lead Poisoned	Not Lead Poisoned	All
Low Scores	81	435	516
High Scores	2	51	53
All	83	486	569

95% CI [1.2,20]

Test: 1996 Mathematics Grade 4

(6% matches)

	Lead Poisoned	Not Lead Poisoned	All
Low Scores	5	53	58
High Scores	5	39	44
All	10	92	102

Odds Ratio: 0.74*

**A less than 1 odds ratio is due to the low number of lead poisoned and non-lead poisoned children matched in this test.*

Test: 1998 Writing Grade 3

(43% matches)

	Lead Poisoned	Not Lead Poisoned	All
Low Scores	145	595	740
High Scores	26	161	187
All	171	756	927

Interpretation of Odds Ratio:

Children who have been lead poisoned are 1.5 times more likely to receive a low score than are children who have not been lead poisoned.

95% CI [1,2.3]

Our best estimate of this odds ratio is 1.5 and we are 95% confident that the true value falls between 1 and 2.3.

Test: 1999 Writing, Grade 3
(48% matches)

	Lead Poisoned	Not Lead Poisoned	All
Low Scores	161	589	750
High Scores	43	324	367
All	204	913	1117

Interpretation of Odds Ratio:

Children who have been lead poisoned are 2.1 times more likely to receive a low score than are children who have not been lead poisoned.

95% CI [1.5, 3]

Our best estimate of this odds ratio is 2.1 and we are 95% confident that the true value falls between 1.5 and 3.

II. Promotion to the Next Grade and Lead Screenings Data

Providence Public School System Enrollment (1993-1998)

Academic Year	Number of Students
1993-1994	23,904
1994-1995	24,173
1995-1996	25,398
1996-1997	25,723
1997-1998	26,164

1993-1994 Academic Year Promotion to the Next Grade for all Students Enrolled in the Providence Public School System

Grade	Number of Students Repeat	Number of Students Advance
0	29	29
1	139	1761
2	56	1830
3	28	1622
4	22	1579
5	19	1567
6	48	1485
7	153	1380
8	54	1265
9	214	1312
10	99	1308
11	65	999
12	77	879
14	Not Available	1

**1994-1995 Academic Year Promotion to the Next Grade for all Students Enrolled in
the Providence Public School System**

Grade	Number of Students Repeat	Number of Students Advance
0	23	22
1	121	1687
2	89	1806
3	36	1686
4	32	1520
5	15	1475
6	45	1484
7	139	1404
8	73	1252
9	223	1214
10	157	1142
11	77	1001
12	32	776
14	Not Available	11

**1995-1996 Academic Year Promotion to the Next Grade for all Students Enrolled in
the Providence Public School System**

Grade	Number of Students Repeat	Number of Students Advance
0	39	225
1	160	1820
2	120	1913
3	48	1879
4	45	1757
5	33	1576
6	60	1526
7	154	1415
8	68	1394
9	304	1376
10	120	1233
11	63	1093
12	28	944
14	1	28

1996-1997 Academic Year Promotion to the Next Grade for all Students Enrolled in the Providence Public School System

Grade	Number of Students Repeat	Number of Students Advance
0	98	53
1	157	1809
2	130	2142
3	68	1988
4	52	1924
5	40	1812
6	59	1601
7	212	1579
8	70	1436
9	342	1503
10	189	1427
11	86	1144
12	27	1004
14	7	63

1997-1998 Academic Year Promotion to the Next Grade for all Students Enrolled in the Providence Public School System

Grade	Number of Students Repeat	Number of Students Advance
0	33	16
1	141	1793
2	106	1948
3	77	2103
4	65	1955
5	50	1815
6	75	1729
7	211	1495
8	107	1439
9	335	1435
10	150	1352
11	110	1236
12	49	996
14	23	56

1993 Lead Screenings and Promotion to the Next Grade by Academic Year:

	1993-1994		1994-1995		1995-1996		1996-1997		1997-1998	
BLL (µg/dl)	0-14	15-81	0-14	15-81	0-14	15-81	0-14	15-81	0-14	15-81
Repeat	70	21	67	27	96	38	99	50	106	48
Advance	630	137	811	217	1458	402	1849	559	2374	648
Left	59	13	109	18	150	37	174	44	235	56

1994 Lead Screenings and Promotion to the Next Grade by Academic Year:

BLL (µg/dl)	1993-1994		1994-1995		1995-1996		1996-1997		1997-1998	
	0-14	15-81	0-14	15-81	0-14	15-81	0-14	15-81	0-14	15-81
Repeat	51	11	62	17	75	23	109	39	106	49
Advance	344	47	703	117	1363	244	1816	357	2300	498
Left	33	4	98	12	154	19	193	39	261	44

1995 Lead Screenings and Promotion to the Next Grade by Academic Year:

BLL (µg/dl)	1993-1994		1994-1995		1995-1996		1996-1997		1997-1998	
	0-14	15-81	0-14	15-81	0-14	15-81	0-14	15-81	0-14	15-81
Repeat			63	10	79	19	126	31	137	34
Advance			424	47	1170	136	1751	226	2291	329
Left			42	4	143	19	198	26	286	36

1996 Lead Screenings and Promotion to the Next Grade by Academic Year:

BLL (µg/dl)	1993-1994		1994-1995		1995-1996		1996-1997		1997-1998	
	0-14	15-81	0-14	15-81	0-14	15-81	0-14	15-81	0-14	15-81
Repeat					39	11	90	20	119	35
Advance					500	67	1135	169	1697	249
Left					48	7	133	14	242	29

Total Sums for 1993-1996 Lead Screening and 1993-1998 Academic Years

Total Sum:	Lead Poisoned	Not Lead Poisoned
Repeat	483	1,494
Advance	4,449	22,616

Appendix B

I. Asthma Results by Standardized Test Scores

Case Cohort Analysis:

Test: 1998 New Standards English Language Arts, Grade 4

Reading: Basic Understanding Standard Level

	Asthmatics	Non-Asthmatics	All
Low Scores	25	551	576
High Scores	32	1196	1228
All	57	1747	1804

Interpretation of Odds Ratio:

Asthmatic children who have visited the hospital are 1.4 times more likely to receive a low test score than are children who are not asthmatics.

95% CI [1, 1.9]

Our best estimate of this odds ratio is 1.4 but we are 95% confident that the true value falls between 1 and 1.9.

Reading: Analysis and Interpretation Standard Level

	Asthmatics	Non-Asthmatics	All
Low Scores	27	603	630
High Scores	30	1144	1174
All	57	1747	1804

Interpretation of Odds Ratio:

Asthmatic children who have visited the hospital are 1.4 times more likely to receive a low test score than are children who are not asthmatics.

95% CI [1.1, 1.9]

Our best estimate of this odds ratio is 1.4 but we are 95% confident that the true value falls between 1.1 and 1.9.

Writing Standard Level

	Asthmatics	Non-Asthmatics	All
Low Scores	36	696	732
High Scores	21	1051	1072
All	57	1747	1804

Interpretation of Odds Ratio:

Asthmatic children who have visited the hospital are 1.6 times more likely to receive a low test score than are children who are not asthmatics.

95% CI [1.3, 2]

Our best estimate of this odds ratio is 1.6 but we are 95% confident that the true value falls between 1.3 and 2.

Writing: Conventions Standard Level

	Asthmatics	Non-Asthmatics	All
Low Scores	31	768	799
High Scores	26	979	1005
All	57	1747	1804

Interpretation of Odds Ratio:

Asthmatic children who have visited the hospital are 1.3 times more likely to receive a low test score than are children who are not asthmatics.

95% CI [1, 1.7]

Our best estimate of this odds ratio is 1.3 but we are 95% confident that the true value falls between 1.3 and 2.

Test: 1998 New Standards Math, Grade 4

Concepts Standard Level

	Asthmatics	Non-Asthmatics	All
Low Scores	44	1359	1403
High Scores	13	469	482
All	57	1828	1885

Interpretation of Odds Ratio:

Asthmatic children who have visited the hospital are 1.4 times more likely to receive a low test score than are children who are not asthmatics.

95% CI [0.9, 1.2]

Our best estimate of this odds ratio is 1.4 and we are 95% confident that the true value falls between 0.9 and 1.2.

Skills Standard Level

	Asthmatics	Non-Asthmatics	All
Low Scores	17	574	591
High Scores	40	1254	1294
All	57	1828	1885

Odds Ratio: 0.95*

**A less than 1 odds ratio is due to the low number of asthmatic and non-asthmatic children matched in this test.*

Problem Solving Standard Level

	Asthmatics	Non-Asthmatics	All
Low Scores	53	1634	1687
High Scores	4	194	198
All	57	1828	1885

Interpretation of Odds Ratio:

Asthmatic children who have visited the hospital are 1.04 times more likely to receive a low test score than are children who are not asthmatics.

95% CI[0.97, 1.1]

Our best estimate of this odds ratio is 1.04 but we are 95% confident that the true value falls between 0.97 and 1.1.

II. Asthma and Promotion to the Next Grade Data

Asthma Hospitalizations and Promotion to the Next Grade

Academic Year	Total Population Asthmatics	Repeated a Grade	Advanced a Grade	Left the Providence Public School System
1993-1994	168	29	123	16
1994-1995	266	28	167	71
1995-1996	332	23	253	56
1996-1997	428	25	330	73
1997-1998	541	47	418	76
TOTAL	1735	152	1291	292

Students Enrolled in Providence Public School System and Promotion to the Next Grade

Academic Year	Total Student Population	Repeated a Grade	Advanced a Grade	Left the Providence Public School System
1993-1994	21,997	2,124	17,203	2,670
1994-1995	23,856	2,042	16,744	5,070
1995-1996	24,188	1,568	18,353	4,267
1996-1997	25,339	1,597	19,477	4,265
1997-1998	25,723	1,581	19,391	4,751
TOTAL	121,103	8,912	91,168	21,023

Asthmatics and Non-Asthmatics

Total Sum Repeats	Total Sum Advance
9,064	92,459

Appendix C

Harcourt Brace—Rhode Island Writing and Mathematics:

Performance Standard Levels*

Value	Field Description
1	Considerably Below Proficient Performance
2	Below Proficient Performance
3	Proficient Performance
4	Exemplary Performance

* For 1996 Mathematics Grade 4, 1997 Mathematics Grade 4, and 1997 Writing Grade 4

1997 Writing Grade 4:

Low Score	High Score
1	2-4

Value	Number of Students
1	3513
2	1863
3	243
4	3

1997 Mathematics Grade 4:

Low Score	High Score
1	2-4

Value	Number of Students
1	4479
2	849
3	165
4	15

1996 Mathematics Grade 4:

Low Score	High Score
131-235	239-311

Scores were assigned and divided by 10 for a percentile rank.

Score	Percentile Rank	Number of Students
131	13%	15
161	16%	36
182	18%	57
195	20%	80
205	20%	96
213	21%	117
219	22%	119
225	23%	117
230	23%	124
235	24%	125
239	24%	120
243	24%	85
246	25%	93
250	25%	87
253	25%	63
255	26%	54
258	26%	46
261	26%	41
264	26%	38
267	27%	33
270	27%	17
274	27%	21
277	28%	16
281	28%	6
286	29%	6
290	29%	3
296	30%	6
302	30%	4
311	31%	1

1996 Writing Grade 4:

Values for Regression Analysis:

Value	Number of Students
2	29
3	51
4	156
5	224
6	481
7	294
8	215
9	104

10	33
11	15
12	2
98	1
99	114

98= Off –Topic
99= No Response

New Standards—Mathematics:

1. Concepts Standard Level
2. Skills Standard Level
3. Problem Solving Standard Level

Performance Standard Levels

Value	Field Description
1	Little Evidence of Achievement
2	Below the Standard
3	Nearly Achieved the Standard
4	Achieved the Standard
5	Achieved the Standard with Honors
8	<i>Testing Incomplete</i>
9	<i>Did Not Attempt</i>

1998 Grade 4

Low Score	High Score
1-2	3-5

(1) Concepts Standard Level

Value	Number of Students
1	40
2	1372
3	423
4	59
5	3
8	80
9	36

(2) Skills Standard Level

Value	Number of Students
1	35
2	559
3	777
4	456
5	70
8	80
9	36

(3) Problem Solving Standard Level

Value	Number of Students
1	320
2	1378
3	157
4	39
5	3
8	80
9	36

New Standards—English Language Arts:

1. **Reading: Basic Understanding Standard Level**
2. **Reading: Analysis and Interpretation Standard Level**
3. **Writing: Standard Level**
4. **Writing: Conventions Standard Level**

Performance Standard Levels

Value	Field Description
1	Little Evidence of Achievement
2	Below the Standard
3	Nearly Achieved the Standard
4	Achieved the Standard
5	Achieved the Standard with Honors
8	<i>Testing Incomplete</i>
9	<i>Did Not Attempt</i>

1998 Grade 4

Low Score	High Score
1-2	3-5

(1) Reading: Basic Understanding Standard Level

Value	Number of Students
1	31
2	547
3	466
4	723
5	48
8	64
9	21

(2) Reading: Analysis and Interpretation Standard Level

Value	Number of Students
1	18
2	615
3	694
4	486
5	2
8	64
9	21

(3) Writing Standard Level

Value	Number of Students
1	26
2	709
3	687
4	386
5	7
8	64
9	21

(4) Writing: Conventions Standard Level

Value	Number of Students
1	13
2	790
3	607
4	402
5	3
8	64
9	21

Rhode Island Writing Assessment:

Value	Field Description
1	Little Evidence of Achievement
2	Below the Standard
3	Nearly Achieved the Standard
4	Achieved the Standard
5	Achieved the Standard with Honors

1998 Grade 3

Low Score	High Score
1	2-5

Value	Number of Students
1	1683
2	431
3	43
4	0

1999 Grade 3

Low Score	High Score
1-2	3-5

Value	Number of Students
1	637
2	923
3	610
4	133
5	6

Appendix D

Test Organization

New Standards Mathematics Reference Examination:

There are three test sessions and each session is administered on a separate day, for a minimum of 55 minutes of testing time each day. Schedule testing periods of at least 70 minutes each day.

- Session 1: 20 multiple choice items and several short and medium tasks
- Session 2: Various combinations of short, medium and long tasks. The combinations of types of tasks vary by grade level and test form; some forms do not include short tasks in this section.
- Session 3: Various combinations of short, medium, and long tasks. The combinations of types of tasks vary by grade level and test form.

New Standards English Language Arts Reference Examination:

There are three test sessions and each session is administered on a separate day, for a minimum of 55 minutes testing time each day. Schedule testing periods of at least 70 minutes each day.

- Session 1: Writing-- Students provide a response to an “on-demand” independent writing prompt.
- Session 2: Reading and Writing-- Students read an extended literature passage and provide responses in three short open-ended answers and a fourth extended, open-ended response.
- Session 3: Reading Comprehension and Editing-- Students respond to text, in multiple-choice format, for understanding, inference and analysis, and recognition of English language conventions.

Rhode Island Writing Assessment:

The assessment involves a writing assignment administered over two consecutive days. On the first day, students receive a handout providing a writing prompt. Students compose first drafts with 45 minutes allowed for directions, prewriting and drafting. Forty minutes of this time is for actual writing. On the second day, students answer a series of revision questions designed to help them revise their first drafts. A total of 45 minutes is allocated for the second day. Finally, students use a short checklist of editing questions about punctuation, spelling and mechanics. In March 2000, a grade 11 writing assessment is being introduced which is completed in a single day (including revisions) with 75 minutes of writing time.

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