Original Research

Autism Rates Associated with Nutrition and the WIC Program

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Objectives: Autism rates in the United States are increasing at a rate of 15% per year. Autistic children are diagnosed by age 3 when they have problems communicating and interacting socially. This study uses nutritional epidemiology and an ecologic study design to link the possible cause of autism to nutrition by creating autism rates for the 50 states of America and comparing them with published measures of infant nutrition such as duration of exclusive breast-feeding and participation in the Women, Infants, and Children (WIC) program. The percentage of infants with measles, mumps, and rubella (MMR) inoculations was also compared with the autism rates.

Study Design: Autism rates for each state were established. The percentage of infants who participate in the WIC program for low-income families was calculated for each of the 50 states as well as 21 New Jersey and 30 Oregon counties and compared with their autism rates. An ecologic study design with correlation coefficients is limited, but it is useful for generating hypotheses to be tested.

Results: The states with the highest WIC participation have significantly lower autism rates ($p < 0.02$). A similar pattern was observed in 21 New Jersey counties ($p < 0.02$) and 30 Oregon counties ($p < 0.05$). In contrast, there was a direct correlation with the increasing percentage of women exclusively breast-feeding from 2000–2004 ($p < 0.001$). Infants who were solely breast-fed had diets that contained less thiamine, riboflavin, and vitamin D than the minimal daily requirements (MDR). There was no correlation of MMR inoculations with the autism rate.

Conclusion: The mothers who are exclusively breast-feeding should also continue their prenatal vitamins or their equivalent and make better dietary choices. These results suggest that autism may be nutritionally related to a possible deficiency of riboflavin or the cognitive vitamins such as thiamine or vitamin D. However, due to an ecologic study design there is a potential for fallacy because individuals were not examined. The results suggest the need for a robust observational study in advance of, and to confirm the need for, an intervention study.

INTRODUCTION

Autism is described as a disease with several symptoms: poor social interaction, limited verbal and nonverbal communication, severely restricted interests, and repetitive behaviors. Autistic spectral disorder (ASD) includes autism, Asperger disorder, and pervasive developmental disorder (PDD). ASD may be caused by different disease processes or may be the result of one disease process with varying degrees of damage. It may be diagnosed in children after 14 months, but is frequently undiagnosed until age 3 when they are found to lack language and/or social skills and fail to progress.

Autism is increasing at a rate of 14% to 20% per year in the United States and Canada [1]. The Centers for Disease Control and Prevention (CDC) published a prevalence of 1 in 110 in 2009, up from 1 in 150 children in 2007. This is an 18% increase per year. Among developmental disabilities in Pennsylvania school children [2], autism increased an average of 18.9% from 2003 to 2008. In Massachusetts [3], disabilities due to autism averaged a 16.8% increase from 2002 to 2006. School boards have difficulty funding the costs associated with providing special education services. The increase must be due to environmental factors other than vaccination and is probably not genetic. The rates of autism vary widely depending on...
location and other possible risk factors such as environmental and dietary. The increase over the last 20 years is probably not the result of better diagnosis because the same diagnostic techniques have been used since 1994. Families with an autistic child incur expenses of $20,000 to $40,000 per year. A lifetime of expense may amount to as much as $3 million [4].

Publicly supported programs are often inadequate, and unreimbursed out-of-pocket medical expenses may cause family financial problems. About 80% of couples with autistic children end their marriages in divorce.

Although there have been numerous suggested causes of autism, none have been confirmed. Thimerosol, a preservative in infant preventative inoculations, was considered to be a contributor to autism. However, thimerosol has mostly been removed from the inoculations. Its removal coincided with a greater incidence of autism in the United States and Denmark.

The consensus among most autism researchers is that genetic factors predominate, thus environmental or nutritional factors are ignored. Several whole-genome scans for autism susceptibility loci have identified specific chromosomal regions, but after mapping, the underlying genes were not identified.

Due to the 2- to 3-year lapse before diagnosis and no apparent common cause in the diagnosis of autism, other new approaches should be considered such as environmental or nutritional epidemiological factors. Lonsdale and Shamberger [5] have found an improvement in older children treated with a thiamine derivative. Cannell [6] has postulated that autism is linked to low levels of vitamin D. Both vitamins have been related to cognitive disorders.

Black et al. [7] found that otherwise-eligible infants not receiving WIC assistance due to access problems were underweight ($p < 0.002$) and short ($p < 0.006$) compared with WIC recipients. The unadjusted rates of perceived poor or fair health status was higher than those of WIC participants (16% vs 11%, $p < 0.01$). Due to possible links to thiamine, vitamin D, and the WIC program’s success, a nutritional origin of autism is possible.

Examination of environmental or nutritional factors in states might give direction to the cause of autism. Comparing autism rates among states might yield insight as to whether autism is an environmentally or nutritionally related disease. The CDC has issued rates for 16 states. The CDC in general calculated rates from only a few counties from each state. The data were insufficient to establish any pattern; however, autism cases were available by incidence and not by rate from another source [1]. Rates of autism by states needed to be established, and then these state rates could be compared with one another and also with other factors such as participation in the WIC program in 50 states. This program emphasizes breast-feeding and additional nutrition. Comparisons can also be made with the CDC’s infant nutrition by exclusive breast-feeding at 3, 6, and 12 months with no supplements [8]. If a link could be found, it could also establish a link with a time frame. In addition, state rates can be compared with exposure to solar irradiation, which is the main source of vitamin D.

**MATERIAL AND METHODS**

For proper comparison among states, rates needed to be established. Because the rates required a reliable count of people aged 3 to 21, the 2000 United States census was used [9]. To establish a rate, the number of cases was divided by the number of individuals aged 3 to 21 living in a particular state at the time of the 2000 census. Once all states’ autism rates were calculated, comparisons were made with per capita income, the WIC program participation percentage, percentages of breast-feeding, and solar irradiation, as well as the 4-year average percentage of children receiving their measles, mumps, and rubella (MMS) shots from 2001–2004. MMS shots have been previously linked to autism [10] because they are administered at 18 months, when autism may be diagnosed.

The WIC program is also called the Special Supplemental Nutrition Program [11]. The program is designed to teach nutrition to low-income women who are pregnant, breast-feeding, and have infants up to 1 year and other children under 5 years. The program helps women make nutritious choices. Food packages are also provided. Women who are breast-feeding can stay in the program longer than non-breast-feeding mothers. The women also receive food stamps. Participation is listed by state by the U.S. Department of Agriculture and represents 91% of eligible people for the program. To find the actual number of infants under 1 year, total participation is multiplied by 0.257 (a national constant for several years). The number of participating infants in 2004 was divided by the number of infants born that year for each state. This yields a percentage of WIC participation for that state. The results for the states were correlated to the autism rates (Fig. 1). A similar calculation was done for 21 counties of New Jersey (Fig. 2) and 30 counties of Oregon. Six counties of Oregon shared WIC offices or were too small to evaluate.

Breast-feeding is increasing in the United States and Canada, in part due to the use of breast-milk pumps to accumulate milk for later use. Total cases of autism from 2000–2004 were plotted against the percentages of mothers who were breast-feeding. This plot is in Fig. 3. This correlation as well as others were calculated from an Excel correlation coefficient program. In addition to the United States total, the CDC lists breast-feeding by state [8] and categorizes breast-feeding by ever breast-feeding, 6-month exclusive breast-feeding, and 12-month exclusive breast-feeding. There is a 3-month exclusive breast-feeding rate, but it is available only for 2004. The percentages of breast-feeding were similar from year to year, but a 4-year average was chosen to reduce variation. An example of California’s 6-month breast-feeding percentages...
Fig. 1. The autism rate from 2000–2003 [1] and the percentage of WIC participation [12] in 50 states in 2004. The correlation is $-0.37$ with a probability of $<0.02$.

Fig. 2. The autism rate in 2004 in New Jersey [1] and the percentage of WIC participation. The correlation is $-0.49$ with a probability of $<0.02$. 
was 46.7%, 47.4%, 49.3%, and 52.9%. No year-by-year trends were noted. The 6-month period is considered the most significant, because after 6 months, the infants are introduced to types of nutrition other than breast-feeding.

The percentages of mothers breast-feeding “ever,” 3, 6, and 12 months exclusively were correlated to the autism rates from 2001 to 2004 as well as to the autism rates from 1992 to 2003 [1]. The correlation coefficient and probabilities of significance were calculated for each of the breast-feeding variables and are listed in Table 1.

Another autism rate was published in 2006 for each of the states [1]. The data were expressed as the number of autism cases in relation to the number of school children at risk for each state, for example, 1 in 82 or 1 in 200. The reciprocal of these rates was also correlated to the same duration of breast-feeding listed in Table 2. These results are listed in Table 2.

The states and their autism rates were also compared with the per capita income by state in 2000 [9] and the solar radiation [12]. The amount of yearly average solar exposure for the 50 states was calculated and then matched to the autism rates calculated for the 50 states. Five states not included in that study were derived from a later publication [13,14]. The correlation is 0.982 with a probability of <0.001.

The percentages of mothers breast-feeding “ever,” 3, 6, and 12 months exclusively were correlated to the autism rates from 2001 to 2004 as well as to the autism rates from 1992 to 2003 [1]. The correlation coefficient and probabilities of significance were calculated for each of the breast-feeding variables and are listed in Table 1.

Table 1. Correlation Coefficients and Probability of Significance between Breast-Feeding Percentages in 50 States for 2001–2004 for Various Lengths of Breast-Feeding [9] and the Autism Rates Calculated from the 2000 Census and the Autism Incidence for 2000–2003 and 1992–2003 [1]*

| Duration of Breast-Feeding Exclusively (mo) | Correlations | Probabilities |
|--------------------------------------------|--------------|---------------|
|                                            | 2000–2003    | 2000–2003     |
|                                            | 2003          | 1992–2003     |
|                                            | 2003          | 1992–2003     |
| Ever                                       | 0.274         | <0.05         | <0.05         |
| 3                                          | 0.156         | NS            | NS            |
| 6                                          | 0.299         | <0.05         | <0.02         |
| 12                                         | 0.271         | NS            | <0.02         |

NS = not significant.

* The exclusive 3-month breast-feeding rate was only available for 2004.

Average yearly percentage of children receiving MMR shots in each state from 2001 to 2004 was compared with the states’ autism rates [10].

When it was observed that there was an ecological link of breast-feeding to autism (Fig. 2), comparisons of thiamine, riboflavin, and vitamin D levels in breast milk were made with those of cows’ milk. Breast milk had markedly lower amounts of the three vitamins [15]. The amounts of thiamine and riboflavin in cows’ milk were also derived from the National Dairy Council [15].

RESULTS

The 4-year autism rates from 2000 to 2003 varied widely among the 50 states (Fig. 1). The highest state rates per 10,000 were found in Massachusetts (254); Minnesota (213); and Oregon (152). The three lowest rates were found in Mississippi (29); Montana (31); and Oklahoma (31). The median autism rate in the United States in this study was 72 per 10,000.

Per capita income [10] correlated to autism ($r = -0.54, p < 0.001$). Those with greater income should be able to purchase more nutritious food and afford better health care. This correlation may indicate other unrelated factors or a lack of nutrition education. These mothers may rely totally on breast-feeding for infant nutrition. Low-income, frequently single mothers who are trained in breast-feeding and nutrition are provided with nutritious food and food stamps by the WIC program are less likely to have children with autism. In this study WIC children are considerably less likely to have autism than non-WIC children (Fig. 1) ($p < 0.02$). If the states were divided into those above and below a 100 rate, there were 11 states above and 39 below 100. When compared with the WIC data, the 39 states with lower rates correlated at $r = -0.51$ or $p < 0.001$. However, the states with over a 100 rate had a correlation of $-0.22$, which is not significant. The difference may be due to better diagnostic ability in the 11 states.
However, the higher group has a higher per capita income per state. This would eliminate many potential WIC recipients as a result of the federal limit for WIC eligibility.

In another study 21 New Jersey counties (Fig. 2) in 2004 WIC children also had significantly less autism ($p < 0.02$). In 30 counties of Oregon the WIC children also had significantly less autism in 2010 ($r = -0.39, p < 0.05$).

In contrast, the correlation in the United States shown in Fig. 3 between the average percentage of breast-feeding at 6 months from 2000 to 2004 and the incidence of autism is $r = 0.982, p < 0.001$.

Even though the databases were derived in slightly different ways, similar results were found in Tables 1 and 2. A positive correlation was found between 6 months of exclusive breast-feeding and the autism rates for 2000 to 2003. Those infants exclusively breast-fed for 1 year also had higher correlations. The 2004 exclusive breast-feeding for 3 months did not show a correlation.

Both thiamine and riboflavin are important vitamins for brain development. Cows’ milk was more than adequate in thiamine, riboflavin, and vitamin D at the four ages studied. Deficiencies of thiamine and riboflavin could cause serious metabolic problems.

**DISCUSSION**

The results of the epidemiological study show direct ecological statistical links between autism and infant nutrition. Low-income mothers who qualify for the WIC program seem to have an important vitamin source for their infants. Breast-feeding in combination with nutritious food lowers autism risk. However, the longer the duration of exclusive breast-feeding, the greater the correlation with autism. Already at 3 months a positive nonsignificant mathematical correlation is starting. The new mother who chooses to nurse her infant should continue her prenatal vitamins or take nursing vitamins to maintain the vitamin levels of her breast milk. A diet containing wheat bread, cereal, or other B-vitamin-rich food is desirable. The infant can also be supplemented with vitamin drops containing thiamine and other vitamins.

Many related nutritional concerns arise for new mothers after childbirth: the mother would like to return to her original shape and body weight as soon as possible; as a nation, there is a tendency toward high-calorie, high-fat, and low-vitamin diets that lead to obesity; food available for purchase in the United States and easy for a busy new mother to prepare is usually refined with lesser vitamin content; prenatal vitamins are discontinued at birth because they are by definition “prenatal”; thiamine seems to be chronically low in breast milk; and finally, the MDR increases in lactating women from 1.1 to 1.4 mg for thiamine and from 1.1 to 1.6 mg for riboflavin.

The goal that 75% of mothers exclusively breast-feed for 6 months should include a recommendation to continue vitamin supplementation. In addition, the suggestion of the American Academy of Pediatrics and the Canadian Paediatric Society that breast milk is the only food necessary for babies should include a recommendation to also continue prenatal or other suitable vitamins during the nursing period. Low-income mothers who qualify for the free milk formula under the WIC program seem to have an important vitamin source for their infants.

Thiamine deficiencies have rarely been reported in the United States and Canada except as a result of alcoholism. Studies show that rat pups suckling from thiamine-deficient dams have evidence of memory deficits [16]. Thiamine deficiency also causes cerebellar damage in animals and may be related to the cerebellar swelling seen in autistic children. Data from a series of 126 autistic children aged 2 to 16 in southwest France showed a higher population of macrocephaly (head circumference >97th centile) [17]. Macrocephaly is one of the most consistent physical findings reported in autistic individuals. Macrocephaly is not usually present at birth.

Flavin adenine dinucleotide stimulates erythrocyte glutathione reductase, which is needed to convert oxidized glutathione to reduced glutathione (GSH). GSH is known to prevent oxidative stress. James et al. [18] has found lower levels of GSH in the plasma of autistic children.

Unlike other vitamins, the majority of human vitamin D comes from sunlight and skin production rather than oral intake. Vitamin D from sunlight or supplements is metabolized by the liver to 25-hydroxyvitamin D, which is the main circulating form of vitamin D. Circulating 25-hydroxyvitamin D is further changed to calcitrol, which is a neurosteroid that acts as a receptor molecule found in brain cells and controls brain cell growth. Non-Hispanic blacks in this study who breast-feed at about the same level as whites have children with about the same autism rates as those of whites. If vitamin D production was blocked by dark skin, a much greater autism rate would be expected. The mathematical correlation between solar energy and autism in 50 states was not significant ($r = 0.110$). Vitamin D is probably not a factor in autism. However, there are inherent weaknesses in ecological designs such that cause and effect are not possible to determine. In addition, there was no correlation between MMR shots and the autism rates.

**CONCLUSION**

There is an inverse relationship between the WIC program, which emphasizes breast-feeding and good nutrition, and the autism rate. In contrast, exclusive breast-feeding shows a direct epidemiological relationship to autism. The continual infant diets containing low thiamine and riboflavin should be examined by the CDC, the Canadian Paediatric Society, and the American Academy of Pediatrics. Autism could be the...
result of a thiamine or riboflavin deficiency, which is correctable and preventable. A robust observational study in advance to confirm the need for an interventional study is necessary. However, it would seem prudent to allow all parents to follow a program similar to the WIC program or a health program that emphasizes adequate vitamins and nutrition and nutrition education.

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REFERENCES

1. Fighting Autism: Accessed at: http://www.fightingautism.org/idea/index
2. Accessed at: http://penndata.hbg.psu.edu/
3. Massachusetts Department of Education: Prevalence estimates of autism and autism spectral disorder in Massachusetts. Accessed at: http://www.afamaaction.org/PDF/autism_report2005.pdf
4. Ganz ML: The lifetime distribution of the incremental societal costs of autism. Arch Pediatr Adolesc Med 161:343–349, 2007.
5. Lonsdale D, Shamberger RJ: Treatment of autism spectrum children with thiamine tetrahydrofurfuryl disulfide. A pilot study. Neuro Endocrinol Lett 23:303–308, 2002.
6. Cannell JJ: Autism and vitamin D. Med Hypotheses 70:750–759, 2008.
7. Black MM, Cutts DB, Frank DA, Geppert J, Skalicky A, Levenson S, Casey PH, Berkowitz C, Zaldwar N, Cook JT, Myers AF, Herren T: Special Supplementation Nutrition Program for women and children. Participation and infants’ growth and health: a multisite surveillance study. Pediatrics 114:169–176, 2004.
8. Department of Health and Human Services: “Breast Feeding and Statistics. National Immunization Survey.” Centers for Disease Control and Prevention, 2000–2004.
9. United States Census 2000. Washington, DC: U.S. Department of Commerce, 2000.
10. Vaccines @ Immunizations. MMR Vaccination. CDC Department of Health and Human Services.
11. U.S. Department of Agriculture, Food and Nutrition Program. WIC Program: total participation. Annual state level data 2004–2008. Accessed at: http://www.fns.usda.gov/wic/
12. Garland CF, Garland FC: Do sunlight and vitamin D reduce the likelihood of colon cancer? Int J Epidemiol 9:227–231, 1980.
13. U.S. Department of Commerce: “Maps of Annual Mean Daily Solar Radiation for the United States.” Washington, DC: US Government Printing Office, 1974.
14. Hanson RL: Evapotransposition and droughts. In Paulson RW, Chase EB, Roberts RS, Moody DW: “Compilers National Water Survey 1988–89 Hydraulic Events and Floods and Droughts: US Geological Survey Water Survey Water Supply 2375.” Washington DC: US Government Printing Office, pp 99–104, 1991.
15. U.S. Department of Agriculture: Accessed at: http://www.ars.usda.gov/nutrient data
16. Bell JM, Stewart CN: Effects of fetal and early thiamine deficiency on avoidance learning in rats. J Nutr 109:1577–1583, 1979.
17. Fombonne E, Roke B, Claverie J, Courty S, Fremolle J: Microcephaly and macrocephaly in autism. J Autism Dev Disord 29:113–119, 1999.
18. James SJ, Melnyk S, Jernigan S, Blossom S, Pavliv O, Gaynor DW: Cellular and mitochondrial glutathione redox imbalances in lymphoblastoid cells derived from children with autism. FASEB J 23:2374–2383, 2009.

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