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Minerals in the Hair and Nutrient Intake of Autistic Children

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The concentrations of calcium, magnesium, zinc, copper, lead, and cadmium were determined in scalp hair samples from a group of 12 autistic children and a group of 12 nonautistic control children. The only statistically significant difference between median concentrations of minerals in the hair from the two groups was a 62% decrease in the concentration of cadmium in the hair of autistic children. This decrease was probably not physiologically significant. The nutrient intake of autistic children as a group was found to be adequate and typical of well-fed American children. It was concluded that the children in neither the autistic nor the nonautistic control group showed evidence of toxicity or deficiency of the minerals or nutrients studied, but because of food idiosyncracies nutrient intake should be monitored.

INTRODUCTION

The etiology of early childhood autism is largely unknown. Abnormal mineral metabolism can cause a variety of illnesses (Underwood, 1977), and scalp hair has been proposed as a convenient sampling tissue for determining the exposure of patients to certain minerals (Valkovic, 1977). Thus, one purpose of the study presented below was to determine if concentrations of certain minerals in the hair of autistic children were different from those in nonautistic control children.

Several studies have measured nutritional factors in the etiology and treatment of autism, although nutritional therapy is generally not accepted in the treatment of autism (Goodwin, Cowen, & Goodwin, 1971; McCarthy & Coleman, 1979; Moss & Boverman, 1978; O'Banion, Armstrong, Cummings, & Stange, 1978; Rimland, 1973; Rimland, Callaway, & Dreyfus, 1978).

Common in the description of the behavior of autistic children is the notation of food idiosyncrasies, specific food preferences, sensitivity to food texture, and physical illnesses secondary to malnutrition (Ritvo & Freeman, 1977; Wing, 1976). DeMyer, Ward, and Lintzenich (1968) reported that autistic children consumed less energy than normal children. However, to our knowledge, there have been no published quantitative measurements of the combined micronutrient and macronutrient intake of autistic patients. Thus, the other purposes of the study presented below were to provide a quantitative evaluation of the nutrient intake of autistic children, and to determine if their diets were adequate and similar to the nutrient intake of normal children.

METHOD

Subjects and Procedure

A total of 24 children were investigated. The mean age of the non-autistic children who served as controls was 8.4 ± .6 years, and the mean age of the 12 autistic children was 8.0 ± .8 years. Both the normal and autistic children were from middle-class urban families, and the children were not institutionalized. Children were classified as autistic using the definition of the National Society for Autistic Children (Ritvo & Freeman, 1977). After informed consent, a sample of scalp hair was collected. Hair samples were washed by rinsing in absolute ethanol at room temperature for 2 minutes, rinsing in .1 M EDTA at 60°C for 2 minutes, rinsing in distilled water, and then drying at 50°C for approximately 30 minutes. Twenty (20)- to 100-mg samples were dissolved in 10 ml concentrated HNO_3 with heating. Calcium, zinc, magnesium, copper, lead, and cadmium were determined by atomic absorption spectroscopy (Emmel, Sotera, & Stux, 1977), and results were expressed as ppm dry weight. Because hair mineral values were asymmetrically distributed with positive skewing, data were expressed as the median ± standard error of the median:

$$S_{mdn} = \frac{1.253 \cdot \text{standard deviation}}{\text{sample size}}$$

A number of hair samples from the autistic children were below the detection limit of .2 ppm Cd. For these samples, a value of .2 ppm Cd was used to calculate statistical values.

The parents or guardians of the children were also instructed to keep a 3-day written record of all foods and beverages actually consumed by the children. Vitamin and mineral supplements were not recorded. The nutrient intake of the children was calculated by the use of a computer program (Shearer, Elmer, Brown, & Wyss, 1980). Student's *t* test was used to test for statistical differences between means. When variances were not homogeneously distributed, the nonparametric Mann-Whitney U test was used (Downie & Heath, 1974).

RESULTS

The median concentrations of four essential minerals (calcium, zinc, magnesium, and copper) and two toxic trace minerals (cadmium and lead) in the scalp hair from control and autistic children are presented in Table I. Mineral concentrations in the hair from the control children showed the following order of concentrations: Ca > Zn > Mg > Cu > Pb > Cd. Median concentrations for minerals in all groups ranged from a high of 175 ppm Zn in the autistic group to a low of .5 ppm Cd in the autistic group. The median concentrations of calcium, zinc, magnesium, copper, and lead in the hair from autistic children were not statistically different ($p > .05$) from the median levels of those minerals in the hair from control children. Values for both groups also fell within typical values for normal patients reported in the literature. However, the median concentration of cadmium in the hair from the autistic children, .5 ppm, was significantly lower than the concentration of cadmium in the hair of control children, 1.3 ppm. In fact, the levels of cadmium in the hair of 5 of the 12 autistic children were

Table I. Mineral Concentrations in the Hair of Autistic Children

Mineral	Control	Autistic
	ppm	
Calcium	160 ± 127[a]	68 ± 96
Zinc	158 ± 57	175 ± 73
Magnesium	74 ± 67	63 ± 29
Copper	10 ± 4	11 ± 22
Lead	4.7 ± 3.4	3.5 ± 3.3
Cadmium	1.3 ± .5	.5 ± .4[b]

[a]Median ± standard error. There were 12 children each in the control and autistic groups.
[b]The median concentration of cadmium in hair from autistic children was significantly lower than the median cadmium concentration in control group at $p < .05$. There were no other statistically significant differences between groups.

below the detection limit of our analytical method for cadmium, while this never occurred in the hair samples from the control children.

There was wide individual variance in hair mineral concentrations as reflected in the rather high standard errors of the median concentrations in Table I. The individual concentrations of the homeostatically controlled essential minerals, calcium, zinc, magnesium, and copper, tended to be grouped together for most patients while one or two patients

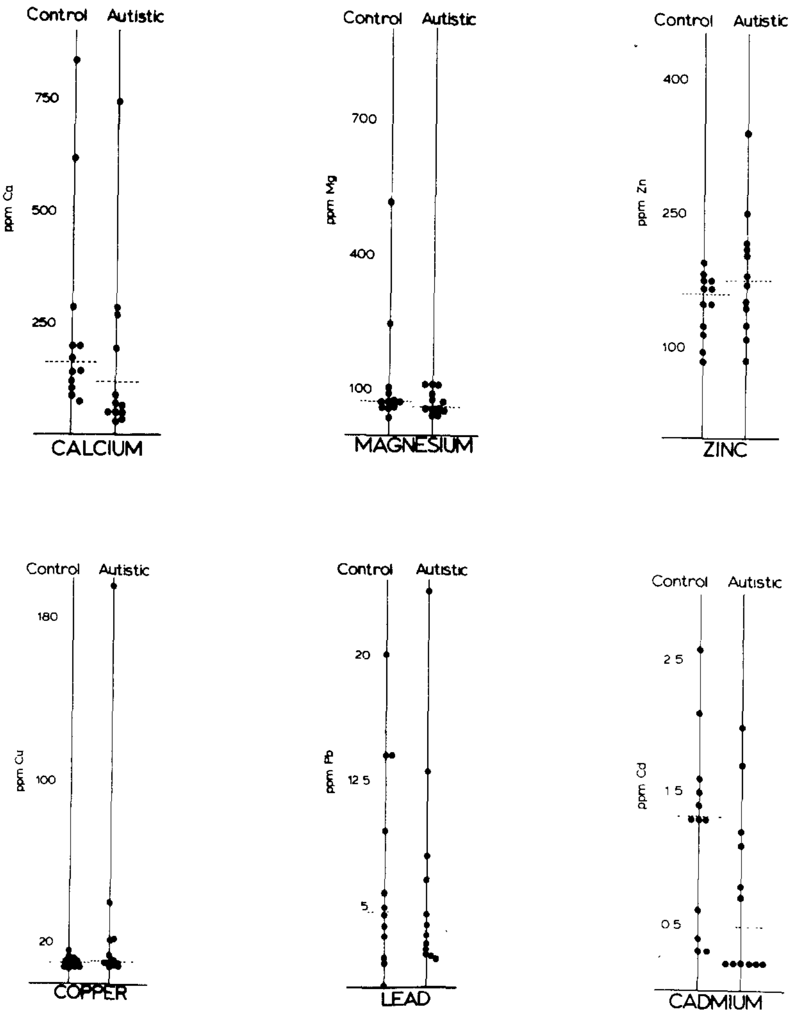

Fig. 1. Concentrations of minerals in the hair from individual autistic and control children. Dotted line indicates the group median.

in each group showed unusually high hair mineral levels. For example, one patient in the control group exhibited a hair calcium level of 835 ppm while the median for this group was 160 ppm; a child in the autistic group showed a hair copper level of 196 ppm while the median level was 11 ppm. There was no obvious explanation for these high values. About an equal number of patients in the control and autistic groups exhibited unusually high trace mineral levels. An individual showing a high value for one mineral was usually not high in another. Neither age nor unusual hair color (red or blond) explained the high hair mineral concentrations.

The mean daily intake of 12 nutrients from foods and beverages actually consumed by the autistic and control children in the present study is shown in Table II. Autistic children consumed significantly lower amounts of calcium and riboflavin than the control children. The mean daily intake of calcium by the autistic children, 782 mg, was 32% lower than the intake of calcium by the control children, 1,151 mg. The mean daily intake of riboflavin by the autistic children, 1.4 mg, was 26% lower than the riboflavin intake of the control children, 1.9 mg. Dietary intake of all other nutrients, including carbohydrates, fats, and proteins, and major vitamins and minerals, was not significantly different between the autistic and control groups.

Table II. Mean Daily Nutrient Intake from Foods and Beverages and Percentage of Recommended Intake Levels in Autistic and Control Children

	Control (10)		Autistic (12)	
Nutrient (RDA)	Absolute value	% RDA	Absolute value	% RDA
Energy (2,400 kcal)	1,871 ± 90[a]	84 ± 5	1,899 ± 122	92 ± 6
Protein (34 gm)	73 ± 4	221 ± 12	68 ± 5	201 ± 11
Fat (93 gm)[b]	80 ± 5	93 ± 6	79 ± 6	97 ± 7
Carbohydrate (283 gm)[c]	232 ± 15	88 ± 6	236 ± 16	97 ± 8
Niacin (preformed, 16 mg)	15 ± 1	101 ± 9	15 ± 2	108 ± 10
Thiamin (1.2 mg)	1.2 ± .1	102 ± 10	1.1 ± .1	103 ± 7
Riboflavin (1.4 mg)	1.9 ± .2	147 ± 14	1.4 ± .1[d]	116 ± 9
Ascorbate (45 mg)	83 ± 13	185 ± 28	65 ± 14	140 ± 29
Vitamin A (700 I.U.)	7,257 ± 2,653	224 ± 80	5,303 ± 473	172 ± 16
Calcium (800 mg)	1,151 ± 114	144 ± 14	782 ± 81[d]	92 ± 10[e]
Phosphorus (800 mg)	1,340 ± 87	167 ± 11	1,166 ± 101	136 ± 11
Iron (10 mg)	10.1 ± .4	101 ± 4	12.0 ± 1.3	106 ± 7

[a]Mean ± standard error.
[b]Calculated as 35% of the RDA for energy.
[c]Calculated as 53% of the RDA for energy.
[d]Mean of the autistic group was significantly lower than the mean of the control group at $p < .05$.
[e]Mean of the autistic group was statistically lower than the control group at $p < .05$. The absolute value (1,151 mg Ca) for daily calcium intake by the control group was significantly higher than the RDA for calcium.

Nutrient intake by the autistic and control children was also expressed as percent of the recommended daily allowance (RDA) in the United States (National Research Council, 1980) (Table II). The relative level of calcium intake of the autistic group, 92% of the RDA, was lower than the relative calcium intake of the control group, 144% of the RDA. The absolute level of calcium consumed by the control group, 1,151 mg, was higher than the RDA for calcium, 800 mg. There were no other statistically significant differences for the intake of nutrients expressed as % RDA between the autistic and control children or between the absolute levels of nutrient intake by the groups and the RDAs.

Foods consumed by the autistic and control children were categorized according to the USDA food groups (U.S. Department of Agriculture, 1965), and servings from these groups were averaged over a 3-day period (Table III). Autistic children consumed significantly fewer servings from the milk group, 1.9 servings per day, than the control children, 3.3 servings. Although not statistically significant, the 1.9 servings from the milk group consumed by the autistic children was more than 1 serving below the baseline recommendation of 3 servings for preadolescent children. There were no other statistically significant differences between consumption of servings from the food groups and autistic and control groups, or between the baseline food group recommendations and the mean number of servings consumed by these children. Both autistic and control children consumed an average of more than 2 servings above the baseline recommendations for the bread-cereal group set at 4 servings per day.

The intake of sugar by the autistic and control children was also categorized (Table IV). There were no statistically significant differences in sugar intake between the autistic and normal children when the results were expressed as percent of the total calories consumed as sugar, number

Table III. Servings of Food Groups Consumed by Autistic and Control Children

Food groups	Recommended	Control (10)	Autistic (12)
	← Servings per day →		
Milk	3	3.3 ± .4[a]	1.9 ± .3[b]
Meat	2	1.8 ± .2	2.0 ± .2
Vegetables/Fruit	4	3.6 ± .5	4.1 ± .6
Vitamin C	1	1.5 ± .3	.7 ± .2
Vitamin A	0.5	.5 ± .3	.3 ± .1
Bread-Cereal	4	6.3 ± .6	6.2 ± .5

[a]Mean ± standard error.
[b]Mean of autistic group was significantly lower than the mean of the control group at $p < .05$.

Table IV. Sugar Intake and Exposure to Sugary Foods in Autistic and Control Children

Sugar intake	Control (10)	Autistic (12)
% calories from sugar	17.4 ± 1.7[a]	18.6 ± 2.8
Exposures (N per day)	5.0 ± .5	4.5 ± .4
Daily intake (teaspoons)	16.2 ± 1.9	18.1 ± 3.1

[a] Mean ± standard error (there were no statistically significant differences between the means of the control and autistic groups).

of sugar exposures per day, or teaspoons of sugar per day. Approximately 17-19% of the total caloric intake of the autistic and normal children was consumed as simple sugars. This sugar was consumed with an average frequency of about five exposures per day, resulting in a mean total sugar intake of 16-18 teaspoons per day. In some cases sugary snacks were used as teaching prompters for the autistic children, and in this situation our data probably underestimated the sugar exposure.

DISCUSSION

The value of the study above is that it presents the baseline concentrations of some essential and toxic minerals in the hair of autistic children. The literature on this subject contains a lack of data for direct comparison. Pihl and Parkes (1977) measured the concentrations of 14 minerals in the hair from a group of 22 normal children and from a group of 31 "learning-disabled" children, which may or may not have included autistic children. Among other changes, cadmium and lead were significantly increased in the hair of the learning-disabled children while calcium, magnesium, and copper levels were unchanged. Mahanand, Wypych, and Calcagno (1976, pp. 73-76) reported that zinc, but not copper, levels in the serum of autistic children were significantly increased compared to control patients.

Although the number of autistic children in the present study was somewhat small, our data showed no significant changes in the concentrations of four essential minerals, calcium, magnesium, copper, and zinc, in the hair of autistic children compared to controls. Of the toxic trace elements studied, cadmium and lead, only the concentration of cadmium was significantly altered in the hair of autistic children. The levels of cadmium were actually 62% lower in the autistic children compared to the control children. Health concern about cadmium is actually directed toward its detrimental effects since there appears to be no homeostatic control of this element in the animal body (Underwood, 1977, pp. 243-257). One of the better known conditions caused by excess cadmium intake in man is itai-itai disease, observed in Japan (Friberg, Piscator, Nordberg, & Kjellstrom, 1974, pp. 137-196). There is no evidence that cadmium is an essential nutrient for man. Thus, it is doubtful that the lowered levels of cadmium observed in the hair of autistic children were of physiological significance to these children.

The use of hair as a diagnostic tool for assessing mineral nutriture should be viewed with caution since a number of factors influence normal hair mineral levels (Valkovic, 1977). These factors include distance from the scalp at which the hair was sampled, age and sex of patient, and treatment of the hair before sampling. It is often difficult to assign normal cutoff values in hair for the diagnosis of mineral deficiencies and toxicities. However, levels of lead in the hair have been related to the prior presence of lead in blood (Valkovic, 1977), and two previous reports indicated elevated blood lead in autistic children (Campbell, Petti, Green, Cohen, Geniesser, & David, 1980; Cohen, Johnson, & Caparulo, 1976). Average hair lead levels were not elevated in the autistic children in the present study. Correlations between blood lead and hair lead levels were not made, but future studies should be performed to do this.

Contrary to expected results based on food idiosyncrasies in autistic children (Ritvo & Freeman, 1977; Wing, 1976) and the report of lower energy intake of autistic children (DeMyer et al., 1968), our results showed that the nutrient intake of autistic children as a group was quite good. Both autistic and normal groups consumed a diet typical of well-fed American children. The average caloric intake of both groups was approximately 1,900 calories. Approximately 15% of the calories were derived from protein, 37% from fats, and 48% from carbohydrates. When the nutrient intake data were expressed as absolute amounts of nutrients or as percent of the RDA, there were no statistically significant differences in the mean levels of intake of carbohydrates, fats, proteins, niacin, thiamin, ascorbate, vitamin A, phosphorus, or iron consumed by the autistic and control children.

The only statistically significant differences in nutrient intake between these children were the significantly lower intakes of calcium and riboflavin by the autistic group as compared to the control children. This was due to the fact that the autistic children consumed fewer servings of food items from the milk group than the control children. Foods in the milk group are generally the most common sources of calcium and riboflavin. Ideally, intake of food items from the milk group should be improved in the autistic children to the three recommended servings per day. However, lower intake levels of calcium and riboflavin and the decreased number of servings from the milk group in the autistic children were probably not physiologically important. Differences in calcium and riboflavin intake between these two groups of children were due to calcium and riboflavin intake above RDA levels in the control group. Calcium and riboflavin intakes in the autistic group were not significantly below the RDA levels. Furthermore, the nutrient data presented above do not take into account the fact that some of the children may have consumed vitamin and mineral preparations that supply additional calcium and riboflavin.

Sugar intake was fairly high in both autistic and control groups, averaging 85 grams (17 teaspoons) or sugar per day or 18% of the total calories. Our analysis estimated total simple sugars as either natural sugars present in foods, such as glucose and fructose in fruits, or as refined sugars, such as sucrose and corn syrup in snack foods (Shearer, DeSart, Isman, Sanzi-Schaedel, & Pickles, 1980). The estimated average refined sugar intake in 1971 for all persons in the U.S. was 126 grams per day (Page & Friend, 1974), indicating that sugar intake by the autistic and control children in our study was fairly typical.

The overall general nutritional adequacy and typical nature of the foods and snacks eaten by the autistic children were a surprising outcome of the present study. Autism is a severely debilitating emotional disorder (Ritvo & Freeman, 1977). Caution should be exercised when applying these conclusions based on group averages to individual autistic patients. These children do have definite food preferences and idiosyncrasies, and the probability of nutritional problems occurring in the individual patient, as compared to normal children, is increased and should be monitored.

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