Hair Element Content of Native American Indian Children

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The nutritional status of Native American Indian children has received little examination. This study examined the hair element content of Northern Arapahoe children living on the Wind River Reservation in central Wyoming. Scalp hair has been proposed as a convenient sampling tissue for screening an individual's burden of certain nutrient minerals and heavy metals (Laker, 1982; Passwater & Cranton, 1983).

The Northern Arapahoe population at Wind River Reservation is approximately 3,500, and the limited tribal income is derived primarily from deposits of oil and gas. Rates of unemployment and underemployment are high (a 1975 Bureau of Indian Affairs report indicated that of an available labour force of 1,125 the unemployment rate was 48 percent). The vast majority of families live at a subsistence level, and under nutrition and malnutrition are a concern of public health officials.

Educational levels among the Arapahoes lag behind those of Wyoming residents; for Wind River Indians in 1980 the United States Census indicates a median of 10.3 years of schooling. By the sixth grade the average Arapahoe child is two years behind non-Indian Wyoming children in measures of academic achievement, and the school dropout rate for Arapahoe children is approximately 50%.

The first purpose of this research was to determine if concentrations of certain minerals and metals in the hair of Arapahoe children were different from a control group. The control group consisted of Caucasian children in Wyoming. The second purpose was to determine the relative importance of each mineral and metal to the discrimination of the two groups.

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Method

Subjects

The population sample of 120 subjects consisted of sixty-four Arapahoe children randomly drawn from an elementary school on the Wind River Reservation and 56 Caucasian children randomly drawn from an elementary school in Laramie, Wyoming. The mean age of the Indian children was 7.26 years, while the Caucasian children's mean age was 10.53 ($p = .01$). Thirty-three of the Indian subjects and twenty-nine of the Caucasian subjects were male ($p = ns$). The mean social class of the Indian group was 4.15 (Hollingshead & Redlich, 1958) compared to a mean social class of 2.34 in the control group ($p = .001$). Two of the Indian children were reported to engage in pica, the behavioural habit of ingesting inedible materials, such as paper or plaster, while one of the controls had a history of pica. Pica has been shown to substantially contribute to increased metal burdens.

Classification of Hair Element Levels

In this study mineral and metal levels were determined via hair samples and atomic absorption spectroscopy. Trace elements are accumulated in hair at concentrations that are generally higher than those present in blood serum, provide a continuous record of nutrient mineral status and exposure to heavy metal pollutants, and may serve as a probe of physiologic functions (Bland, 1979; Passwater & Cranton, 1983). Scalp hair has several characteristics of an ideal tissue for epidemiologic study in that it is painlessly removed, normally discarded, easily collected, and its contents can be analyzed relatively easily.

After obtaining parental permission children were asked to submit a small sample of hair (about 400 mg) for trace mineral analysis. Hair samples were collected from the nape of the child's neck, as close to the

scalp as possible, by the researcher using stainless steel scissors. The hair samples were then submitted to Doctors Data, Inc., a clinically licensed laboratory in West Chicago, Illinois, where they were analyzed with three instruments: the atomic absorption spectrophotometer, the graphite furnace, and the induction coupled plasma torch, to determine seven toxic metal levels and 16 nutrient mineral levels. The seven toxic metal levels tested for were lead, arsenic, cadmium, mercury, aluminum, nickel, and beryllium. The 16 nutrient mineral levels tested for were calcium, magnesium, sodium, potassium, copper, zinc, iron, manganese, chromium, phosphorus, selenium, molybdenum, silicon, lithium, cobalt, and vanadium.

Precise laboratory techniques are used by Doctor's Data, Inc., to assure reliability of results and to meet reproducibility requirements. These include:

1. About 0.5 g of washed hair was wet digested. The wash consisted of alternate water, 1% triton-X 100 and acetone treatment with air drying at 70 degrees.
2. A control sample was run from the initial steps through the entire procedure to assure reproducibility of methods.
3. At least one of every ten tests was a standard. Working standards are made to assure proper values.
4. The in-house spiked pool was completely remade and analyzed daily as every 50th specimen as part of the quality control procedure.
5. Temperature and humidity were controlled to assure reliability and consistency of the testing instruments.

Results

The two groups of children were compared for hair element concentrations. As shown in Table 1, the Indian children's mean hair concentrations of magnesium, copper, zinc, iron, molybdenum, silicon, mercury, and beryllium were considerably below those of the control group, while the Indian children's mean hair concentrations of sodium, potassium, phosphorus, cobalt, lithium, selenium, lead, and arsenic were above those of the control group.

The data were analyzed with the Mest for two independent samples design of SPSS (Nie, Hull, Jenkins, Steinbrenner, and Bent, 1976) yielding significant *t* values for magnesium (*t* = -2.72, 118, p. > .05), sodium (*t* = 2.84, 118, p. >.01), potassium(*t* = 2.94, 118, p. > 01), copper (*t* = -6.83, 118, p. > .001), zinc (*t* = -2.79, 118, p. > .05), iron (*t* = -2.59, 118, p. > .05), chromium (*t* = -6.51, 118, p. > .001), cobalt (*t* = 8.09, 118, p. > .001), lithium (*t* = 10.68, 118, p. > .001), molybdenum (*t* = -8.15, 118, p. >.001), phosphorus (*t* = 10.32, 118, p. >.001), selenium(*t* = 8.54, 118, p. > .001), silicon (*t* = -11.95, 118, p. > .001), vanadium (*t* = 3.20, 118, p. > .01), lead (*t* = 2.48, 118, p. > .05), arsenic (*t* = 6.12, 118, p. > .001), mercury (*t* = -5.56, 118, p. > .001), and beryllium (*t* = -7.74, 118, p. > .001).

Also as shown in Table 1, the Indian group's mean hair concentrations of magnesium, copper, zinc, chromium, and silicon were below the theoretical normal range (± 1SD) established by Doctors Data, Inc. (1987), while the Indian group's mean hair concentrations of sodium and vanadium were above the normal range. The Caucasian children were below the theoretical normal range of chromium and above the normal range for molybdenum. Both groups' hair concentrations of the seven toxic metals were below the accepted upper limits established by the laboratory.

A stepwise discriminant analysis was then performed using a program from SPSS (Nie et al, 1976). The stepwise method using Wilks Lambda was employed to ascertain the relative contributions of the 23 hair elements to the separation of the groups.

The combination of silicon, cobalt, phosphorus, mercury, molybdenum, lithium, arsenic, chromium, beryllium, zinc, nickel, selenium, potassium, and vanadium in order of entry into the discriminant function significantly separated the Northern Arapahoe and Caucasian groups (F14, 105, = 105.76, p. > .001). Each of the 14 hair elements contributed significantly over and above the previously entered elements to the discrimination between the groups at the .001 level of confidence (F = 142.81, 156.45, 151.88, 142.62, 137.02, 143.57, 142.04, 146.06, 144.70, 135.74, 126.97, 120.12, 112.60, and 105.76, respectively). Overall, the 14 hair elements accounted for 94% of the variance of the two groups with silicon being the largest contributor, accounting for 55%. The standardized canonical

TABLE 1

Results of Trace Mineral Mean Analysis Mean ± S.D.

Trace Mineral	Indian Group (ppm)	Caucasian Group (ppm)	Normal Range[a] (ppm)
Calcium	538.60 ± 476.06	683.67 ± 639.72	343.00 - 780.00
Magnesium	31.78 ± 30.65*	59.80 ± 75.71	36.00 - 142.00
Sodium	147.53 ± 208.95**	56.05 ± 127.98	19.00 - 123.00
Potassium	47.01 ± 53.72**	22.60 ± 33.21	10.00 - 84.00
Copper	11.51 ± 9.52***	33.41 ± 23.54	13.00 - 63.00
Zinc	117.09 ± 44.42**	138.80 ± 40.35	123.00 - 172.00
Iron	11.31 ± 5.59*	13.91 ± 5.35	7.68 - 23.00
Manganese	0.78 ± .59	0.52 ± 1.31	0.35 - 1.96
Chromium	0.29 ± .08***	0.44 ± 0.16	0.63 - 1.10
Cobalt	0.28 ± .07***	0.16 ± 0.08	0.139 - 0.352
Lithium	0.10 ± .03***	0.04 ± 0.27	0.007 - 0.459
Molybdenum	1.01 ± .45***	2.15 ± 1.01	0.25 - 1.65
Phosphorous	141.45 ± 16.09***	111.37 ± 15.73	102.00 - 178.00
Selenium	0.43 ± .12***	0.24 ± 0.11	0.16 - 0.88
Silicon	5.03 ± 1.34***	8.28 ± 1.63	5.14 - 10.00
Vanadium	0.24 ± .05**	0.20 ± 0.07	0.016 - 0.214
Lead	7.01 ± 3.52*	5.57 ± 2.72	15.00[b]
Arsenic	3.43 ± 1.18***	2.18 ± 1.02	7.00[b]
Mercury	0.69 ± .28***	1.03 ± 0.37	2.50[b]
Cadmium	0.51 ± .32	0.49 ± 0.34	1.00[b]
Aluminum	8.12 ± 3.68	9.28 ± 5.13	30.00[b]
Nickel	1.00 ± 1.11	1.00 ± 0.52	2.20[b]
Beryllium	0.03 ± .01***	0.05 ± 0.01	0.01[b]

a Theoretical Normal Range (± 1SD) established by Doctor's Data, Inc., (1987).
b Normally tolerated limit (+ 1SD) established by Doctor's Data, Inc., (1987).
* $p < .05$
** $p<.01$
*** $p<.001$

discriminant functions revealed that molybdenum (.68), silicon (.59), cobalt (.-59), and arsenic (.-59) were the most important to the discrimination of the two groups.

On the basis of the discriminant function 100% of the Northern Arapahoe children and Caucasian children were correctly classified. The percentages are optimistic however, since the function was applied to the data that produced it. A cross-validation of the discriminant function is expected to result in somewhat smaller percentages.

Discussion

The value of the present study is that it presents the baseline concentrations of hair elements in Native American Indian children. The literature on the subject contains a lack of data for direct comparison.

Although the number of Indian subjects in the present study was small, there were several interesting findings. First, the Indian children were more than one standard deviation below laboratory norms for hair concentrations of the nutrients magnesium, copper, zinc, chromium, and silicon.

The essentiality of these nutrients in humans is well documented (Underwood, 1977) and deficiencies in zinc and chromium have been linked to learning and behaviour problems in children. An insufficiency of chromium has been observed to produce glucose intolerance and neuropathy (Jeejeebhoy et al, 1977), while behavioural manifestations of zinc deficiency in children have been described as follows: moodiness, depression, irritability (Moynahan, 1976), antagonism, temper tantrums, and learning problems (Kronick, 1975). In a review of 51 studies low hair chromium and low hair zinc levels were found to correlate with childhood learning/behaviour problems (Rimland and Larsen, 1983).

Second, the Indian sample was more than one standard deviation above laboratory norms for hair concentrations of sodium. Previous research has linked elevated hair sodium levels to protein deficiency in children (Bowen, 1972), although hair sodium in itself cannot be used to determine protein deficiency. Elevated hair sodium along with other element abnormalities allowed researchers to separate learning disabled children from normal children with 98% accuracy (Phil, Drake, and Vrana, 1980).

Although the Indian children's mean hair-lead and hair-arsenic concentrations were below the accepted upper limits established by the laboratory, the mean concentrations of these metals were significantly higher than those in the control group. Increased low lead and low arsenic levels and their synergistic interaction have been linked to decrements in intelligence, academic achievement, and behaviour (Marlowe & Moon, 1987; Marlowe et al, 1985; Moon, Marlowe, Stellern, & Errera, 1985; Thatcher, Lester, McAlaster, & Horst, 1982). The toxicity of low level metal exposure is potentiated in the absence of adequate intake of nutrients such as magnesium, zinc, and copper (Mahaffey, 1980), and as mentioned, the Indian group's hair concentrations of magnesium, zinc, and copper were considerably below laboratory norms.

While the depressed educational attainment of children on the Wind River Reservation is due to a multiplicity of cultural and social factors unexamined here, the role of inadequate nutrition should not be minimized. The first of each month Arapahoe families wait in line at the post office to receive their per capita checks from the tribal oil and gas leases. The entire amount is usually spent within the week, and families (particularly those with no employed members) may then resort to pawning property or asking merchants for credit. Arapahoes also count on a system of institutionalized sharing. People with money or food are expected to share with relatives or friends upon request. Nevertheless, toward the end of the month many households do not have adequate food supplies and children's nutritional needs go unmet.

Prior to summarizing the findings, it must be reiterated that hair element analysis is only a screening test and not a precise method of determining what is occurring in the body. Suspicions raised on hair analysis must always be confirmed by more precise and scientifically validated forms of testing before an exact diagnosis can be made.

Twenty-two hair elements were examined here. According to Passwater and Cranton's (1983) review of the literature, hair elements of proven clinical significance determined here are calcium, magnesium, zinc, copper, chromium, lead, cadmium, mercury, and nickel. Hair elements suggested to have possible clinical significance are sodium and potassium, while the other hair elements determined here have an unknown clinical significance because of an absence of scientific data.

In summary, a discriminant function analysis revealed that by using 14 hair elements subjects could be classified as Indian or non-Indian with 100% accuracy. Overall, the 14 elements accounted for 94% of the variance in the two groups. This information is simply presented to encourage others to examine the nutritional status of Native American Indian children, who because of their disadvantaged backgrounds are at high risk for poor nutrition and concomitant learning problems.

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