Geographic and Nutritional Factors in Dental Caries

CARL J. WITKOP, Jr., D.D.S., M.S., LUIS BARROS, C.D., and PEGGY A. HAMILTON, B.S.

IN 1960 a nutritional survey of Chile (*1*) was conducted by the Interdepartmental Committee on Nutrition for National Defense (ICNND) in cooperation with the Chilean Armed Forces, the National Health Service of Chile, and the University of Chile (*2,3*). The survey covered four major phases: (*a*) a study of agricultural production, food technology, and food distribution; (*b*) a dietary survey of actual food intake in a sample of civilian households and military messes; (*c*) biochemical analysis of selected nutritional factors in food, water, blood, and urine, as well as genetic blood studies which included electrophoresis for abnormal hemoglobin, genotyping, and red cell enzymes; and (*d*) clinical examinations of civilians and military personnel.

Data on oral disease were obtained as an integral part of the clinical examinations. This paper reports the findings for dental caries in 1,906 Chileans and related geographic and nutritional factors studied during the nutritional survey. It also presents the hypothesis that moderate fluoride levels in domestic water supplies (0.4–0.6 part per million) may be sufficient, under the conditions observed in Chile, to give the same biological effects observed in northern communities of the United States which consume waters containing 1.0 to 1.2 ppm fluoride. Data on oral anomalies, periodontal disease, and genetic factors have been published elsewhere (*1,4*).

The authors are with the National Institute of Dental Research, Public Health Service. Dr. Witkop is chief of the Human Genetics Section, Clinical Investigations Branch, and Dr. Barros, a lieutenant in the Chilean Army Dental Service, is a visiting fellow with the section. Mrs. Hamilton is a statistician in the Laboratory of Epidemiology. This paper is the second of a series based on nutritional studies in Chile in 1960.

Because of Chile's unique geographic configuration, the survey offered the additional opportunity to observe the effect of climatic differences on a representative population sample of Chileans. For this purpose, Chile was divided into three regions, which corresponded roughly to desert, mediterranean, and temperate forest vegetation, and to climatic geographic divisions of the country. The northern region included provinces from Tarapacá to Coquimbo, the central from Aconcagua to Valdivia, and the southern from Osorno to Magallanes. Selected cities within these provinces are shown in figure 1.

A number of previous studies of the prevalence of dental caries in Chile were limited to special population segments, such as school children (*5*), rural children of the central zone (*6*), clerical workers (*7*), and a composite population (*8*). These studies are not directly comparable with the present investigation because of sample differences, and because methods other than decayed, missing, and filled (DMF) rates were used to record caries experience. However, all studies agree that a small proportion of the samples examined were caries free.

An early report by the Ministry of Health (*5*) on caries experience in 12- to 14-year-old children described a marked geographic effect in caries experience. The caries experience values were lowest in the northern provinces and highest in the central and southern provinces. Average values of caries experience by geographic region are shown in table 1. A comparison of values for the northern part of the country with the central and southern portions shows that the northern children had a 46 percent lower caries experience than the central, and a 57 percent lower caries experience than the southern children.

One of the very early national surveys of the fluoride content of domestic waters was done in Chile by Otte (*9*). This extensive study has been followed by repeated surveys (*10*) which give detailed information concerning the fluoride content of the domestic water supplies of nearly all moderate-sized Chilean communities. These reports indicate that the water supplies of northern Chile contain larger amounts of fluoride than the central and southern portions. However, the values of fluoride in parts per million range from 0.4 to 0.7 in the north and, with the exception of a few small communities not included in this study, from 0.05 to 0.4 in the central and southern communities.

Methods

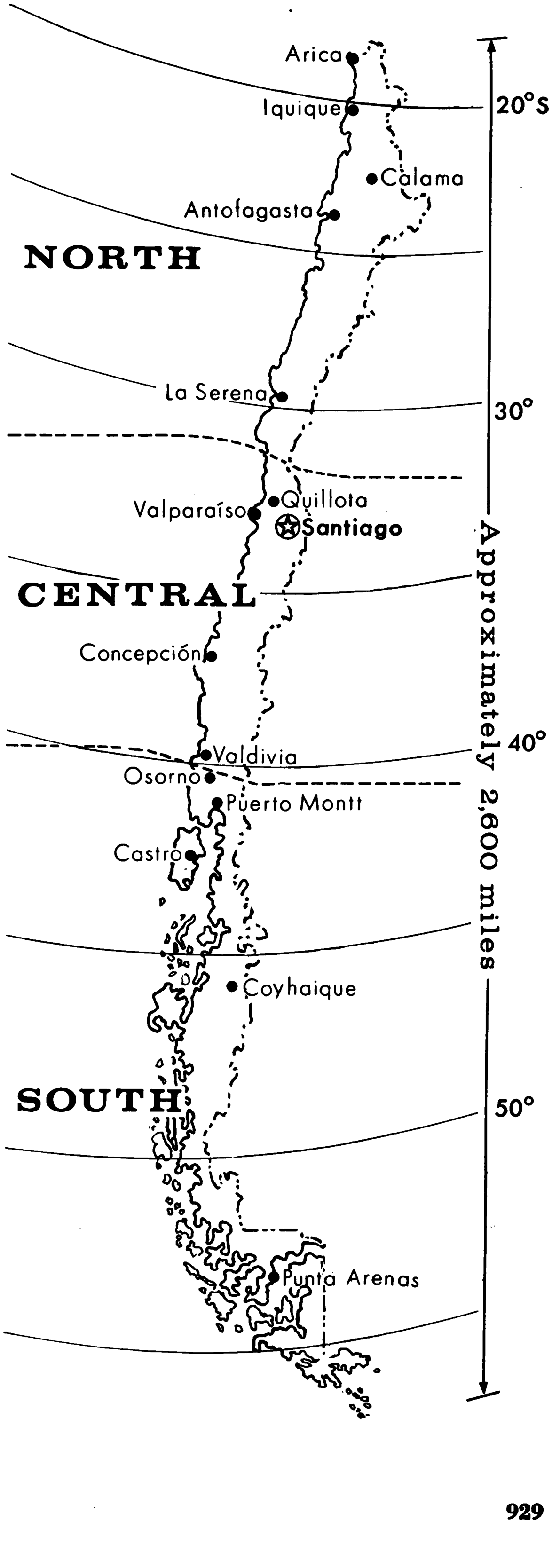
Sampling procedures. The original sample, selected in cooperation with the Institute of Economics of the University of Chile, consisted of 5,351 civilians and 4,267 military personnel.

The civilian sample was a random selection of families from the middle- and low-economic groups, geographically distributed throughout all Chile. The ratio of rural to urban (22.6 : 77.4) closely approximated that of the general population (*1*). As entire households, including maids, were sampled, and because of the absence of some working fathers, the civilian sex distribution is not representative of Chile.

The military sample, representative of enlisted personnel of the army, air force, and navy, including recruits and cadets, was drawn from 26 geographically distributed areas. The final dental sample contained an excess of men because of the military.

Every fifth person in the original sample received a detailed medical and dental examination. A blood sample was obtained from every third person receiving a dental examination. The composition of the dental sample is shown in table 2.

Figure 1. Selected cities within geographic regions of Chile, dental survey, 1960



Dental examination. Two dentists made all the observations in this study. During an initial 3-day period, the work of both dentists was calibrated. Each examined the same group of patients until comparable observations were recorded on each patient. In addition, spot checks were made during the following 2 months to assure continued comparable observations.

Examinations were made under natural light, using portable dental chairs, small mouth mirrors, and explorers. Each dentist called his findings in a numerical code to a recorder, who wrote these findings on a McBee dental card. Recorders' entries were checked daily. Caries experience was recorded in the usual manner, using the DMF–def index. Frank loss of tooth substance was required before a lesion was designated as carious. A tooth with a filling and a separate caries lesion was counted only once, as a filled tooth. Each permanent molar was examined for signs of attrition and scored in the manner of McCombie (*11*). The periodontal index (PI) of Russell (*12*) was used to score periodontal disease. In addition, findings were recorded for gingival recession, calculus, debris, hypoplasias of enamel, fluorosis, arch shape, occlusion (Angle's classification), and oral anomalies. Findings of fluorosis were scored according to Dean's scale (*13*).

Laboratory examinations and nutritional data. Blood and urine samples were collected daily in the field. The blood samples for genetic and nutrition studies were taken from each patient in 10 cc. vacutainer tubes with EDTA anticoagulant. The blood samples and freshly voided urine samples were placed in an ice container and flown daily to the laboratories in Santiago. Nearly all samples were analyzed within 48 hours after collection. All procedures were done at the University of Chile in Santiago, with the exception of genotyping. An aliquot of blood was iced and sent by air courier to the National Institutes of Health in Bethesda, Maryland, where blood group determinations were made. All samples were typed within 1 week after collection.

Table 1. Average values of caries experience in Chilean school children aged 12–14 years, by geographic region, 1945

Region	Number examined	Mean caries experience score	Percentage difference in northern mean caries experience score compared with central and southern
Northern	6, 222	3. 79	——
Central	28, 930	7. 06	46
Southern	1, 899	8. 82	57

SOURCE: Chilean Ministry of Health (see reference 5).

Table 2. Number of persons receiving dental examinations, by sex and military status, Chile, 1960

Sample	Males	Females	Total
Military	906	0	906
Army	433	0	433
Navy	278	0	278
Air Force	195	0	195
Civilians	335	665	1, 000
Total	1, 241	665	1, 906

Water samples from 11 of the 17 cities studied were analyzed for fluoride content at the Public Health Service laboratory, Bethesda, Maryland.

One-day food consumption records for 277 Chilean families were obtained in 16 locations throughout Chile by three nutritionists from the National Health Service. Composite food aliquots from 18 families were obtained for nutritional chemical analysis.

Dental Caries

Total population. The mean number of DMF and def teeth per person by age and component for the total Chilean sample is shown in table 3 and figure 2. The DMF curve appears to be a composite of two curves broken at the 30- to 35-year age interval. It is of interest to note that this break is evident in both the military and civilians and in the male and female data (figs. 3 and 4).

Table 4 gives the mean number of DMF teeth of Chileans by age, sex, and military status, compared with Baltimore, Maryland, civilians, 1954 (*14*). These crude data indicate that Chilean and Baltimore females have about the same mean DMF rates in each age category, but the DMF rates for Chilean males are somewhat lower than the DMF rates for Baltimore males (figs. 3 and 5).

Military. Analysis of the mean number of DMF teeth per person by age shows that there were no significant differences between those in the army, navy, or air force. However, during the study it was noted that the caries experience of men at different military stations throughout the country varied considerably. When the military personnel were compared on the basis of their area of origin, a marked geographic difference was noted in caries experience (fig. 6). These data (table 5) indicate that there were statistically significantly lower DMF rates in the northern military than in the southern and central military up to the age of 35 years. Possibly the sample size and the loss of teeth from periodontal disease obliterates the caries effect beyond this age. The periodontal disease data indicate that the PI score for each age group in Chile was much higher than for corresponding age- and sex-specific intervals for North American white persons examined in Baltimore in 1954 (*1*).

Civilians. The mean number of DMF and def teeth per person by age and sex in the civilian sample, shown in table 6 and figure 4, indicates that for most age intervals statistically significant sex differences exist. However, 38.8 percent of the females were from the northern four provinces where very mild fluorosis was present, while only 32.8 percent of the males were from this region. No correction was made in figure 4 for this excess of northern females with low DMF rates. If this excess of northern females is excluded, the sex differences are greater than indicated by the graph. The male civilian sample was too small to analyze for regional differences. The apparent difference between the DMF rates of Chilean males and Baltimore males disappears when the northern males living in a fluoride area are eliminated from the sample. The female sample shows statistically significantly lower DMF rates for the northern females than for the central and southern females up to the age of 40 years (table 7).

Fluorosis

Among the various factors to be considered when comparing the crude Chilean data with the Baltimore data is that 29.9 percent of persons in the Chilean sample were from the four northern provinces where fluorosis was prevalent (table 8), while fluorosis in the Baltimore sample was negligible.

The community dental fluorosis index is a better indicator of total fluoride exposure than the prevalence of fluorosis. Ideally, children from 12 to 14 years of age should be examined. Children younger than 12 years of age will have some unerupted teeth, while in persons older than 14 years of age, the surface characteris-

Table 3. Mean number of DMF teeth per person in total Chilean sample, by age group

Age group	Mean age	Number	Mean number of permanent teeth—				Mean DMF	SE	Mean def	SE
			Decayed	Missing	Extraction indicated	Filled				
0–4	3. 3	27							2. 4	0. 487
5–9	7. 1	163	0. 5	0. 0	0. 1	0. 1	0. 7	0. 100	4. 7	. 309
10–14	11. 8	191	1. 4	. 4	. 3	. 7	2. 8	. 229	1. 1	. 139
15–19	17. 9	351	2. 8	2. 2	1. 5	1. 8	8. 2	. 293		
20–24	21. 8	257	2. 3	4. 6	1. 2	2. 5	10. 5	. 333		
25–29	26. 9	233	2. 2	7. 0	1. 3	2. 6	13. 1	. 405		
30–34	31. 8	200	2. 0	8. 7	1. 8	2. 2	14. 7	. 450		
35–39	37. 2	146	1. 9	8. 6	1. 8	1. 8	14. 1	. 519		
40–44	41. 7	120	1. 9	10. 2	1. 9	1. 6	15. 6	. 594		
45–49	46. 7	91	1. 7	13. 3	1. 8	1. 3	18. 0	. 709		
50–54	52. 4	41	1. 0	16. 0	1. 4	1. 2	19. 5	. 999		
55–59	57. 0	27	. 8	20. 1	1. 7	. 4	23. 0	. 547		
60 and over	68. 2	59	. 7	19. 3	1. 3	1. 0	22. 3	. 832		
Total	26. 4	1, 906	1. 9	6. 0	1. 3	1. 7	10. 8	. 181	. 5	. 043

tics of fluorosis become increasingy obliterated by attrition with advancing age. Table 9 compares the fluorosis index for 12- to 14-year-old children by region. Only one case was seen which we classified as moderate, and none was severe. The higher community fluorosis index of the northern portion of the country is accompanied by a mean DMF rate which is 59.1 percent lower than the DMF rates of the central and southern children.

The results of the analysis of water samples for fluoride and those previously reported for Chilean domestic waters are given in table 10. These values show that the fluoride content is highest in the northern communities. However, the values reported here are lower than those usually accepted in the United States as necessary to give a maximum biological effect, as measured by the community fluorosis index and low DMF rates.

Nutritional Findings

The nutritional findings summarized here were compiled from the reports of the Agriculture and Food Supply Survey, the Military Dietary Survey, and the Dietary Survey of Chilean Families (*1*). These studies comprised some of the special investigations of the ICNND survey of Chile in 1960, and they were

Figure 2. Mean number DMF teeth per person in total Chilean sample, by age group

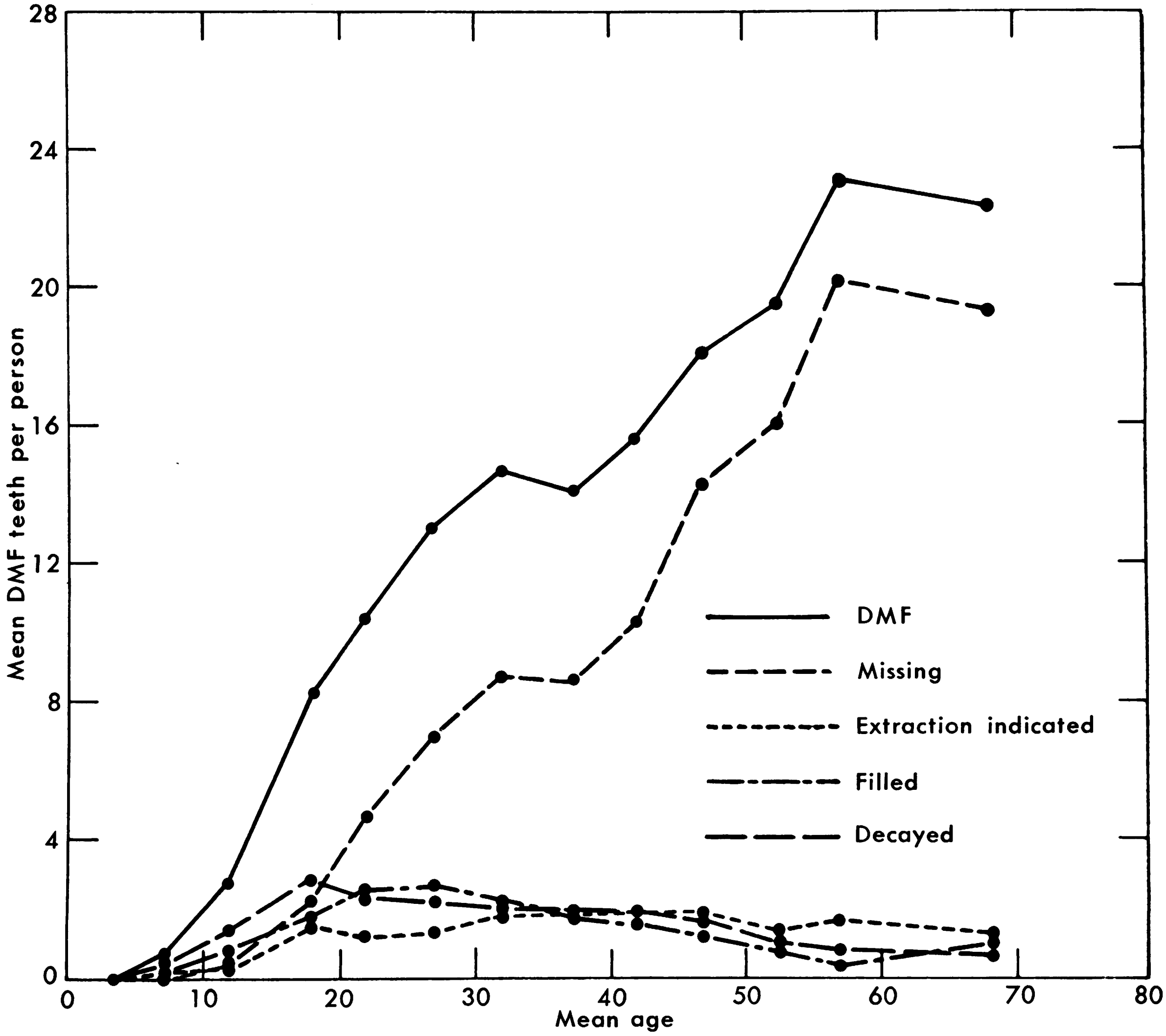


Table 4. Comparison of dental survey findings in Chile, 1960, and Baltimore, Maryland, 1954

Age group	Chile									Baltimore					
	Military males			Civilian males			Civilian females			White males			White females		
	Number	Mean DMF	SE	Number	Mean DMF	SE	Number	Mean DMF	SE	Number	Mean DMF	SE	Number	Mean DMF	SE
15–19	263	8.1	0.327	25	8.2	1.411	65	8.4	0.675	36	11.9	0.944	28	11.9	0.951
20–24	200	10.2	.357	16	9.1	1.156	41	12.8	.989	34	12.9	1.094	56	13.6	.849
25–29	160	12.4	.465	7	10.7	1.426	66	15.5	.800	76	14.0	.702	109	14.6	.537
30–34	110	13.4	.594	19	14.4	1.238	71	16.6	.821	102	14.2	.579	129	16.2	.541
35–39	78	13.1	.694	20	12.5	1.101	48	16.3	.936	141	15.7	.493	136	17.2	.528
40–44	59	15.0	.783	15	12.3	1.655	46	17.5	.987	121	17.9	.616	113	17.3	.513
45 and over	36	16.8	1.157	56	17.8	.942	126	22.1	.514	363	21.0	.367	423	21.9	.284

Table 5. Mean number DMF teeth per person in Chilean military services, by age group and area of origin

Age group	Northern military				Central military				Southern military				Variance ratio	*P*
	Mean age	Number	Mean DMF	SE	Mean age	Number	Mean DMF	SE	Mean age	Number	Mean DMF	SE		
10–19	18.4	77	6.0	0.606	18.3	166	9.1	0.392	17.9	18	8.4	1.194	9.890	<.01
20–24	22.2	37	8.8	.889	21.7	140	10.9	.416	21.3	23	8.3	.934	4.430	>.01
25–29	27.1	21	9.3	1.450	26.9	118	12.6	.548	27.1	19	13.8	.759	3.672	<.05
30–34	31.4	29	10.6	.998	31.4	66	15.0	.777	32.3	15	11.9	1.358	6.299	<.01
35–39	36.9	13	11.2	1.721	37.1	53	13.6	.849	37.2	12	12.8	1.709	.818	(1)
40–44	41.7	14	13.5	1.557	41.6	42	15.3	.950	41.0	3	18.0	2.646	.859	(1)
45 and over	49.2	9	18.2	2.465	47.6	25	15.9	1.380	53.5	2	21.5	3.500	.859	(1)
Total	26.1	200	8.9	.451	26.6	610	12.0	.244	26.9	92	11.1	.575	18.721	<.01

[1] Not significant.

Table 6. Mean number DMF and def teeth per person in Chilean civilian sample, by age and sex

Age group	Males						Females						Student's *t* test	*P*
	Mean age	Number	Mean DMF	SE	Mean def	SE	Mean age	Number	Mean DMF	SE	Mean def	SE		
0–4	3.7	13	------	------	2.2	0.545	3.2	14	------	------	2.1	0.810	------	------
5–9	7.3	70	0.7	0.146	5.2	.499	7.0	93	0.8	0.137	4.3	.388	0.50	>.60
10–14	11.6	94	2.4	.261	1.5	.228	11.9	95	3.2	.364	.7	.158	1.79	<.10
15–19	16.2	25	8.2	1.411	------	------	16.9	65	8.4	.675	------	------	.13	<.90
20–24	21.6	16	9.1	1.120	------	------	21.9	41	12.6	.989	------	------	2.48	>.01
25–29	26.6	7	10.7	1.426	------	------	27.0	66	15.5	.800	------	------	2.94	<.01
30–34	32.6	19	14.4	1.238	------	------	32.0	71	16.6	.821	------	------	1.48	<.20
35–39	36.9	20	12.5	1.101	------	------	37.4	48	16.3	.936	------	------	2.63	>.01
40–44	42.0	15	12.3	1.655	------	------	41.7	46	17.5	.987	------	------	2.70	<.01
45–49	46.8	14	14.4	1.354	------	------	46.8	49	20.0	.961	------	------	3.37	<.01
50 and over	63.3	42	18.9	1.128	------	------	60.0	77	23.5	.526	------	------	3.70	<.01
Total	23.5	335	7.2	.430	1.6	.165	27.7	665	12.1	.364	.8	.084	8.69	<.01

carried out concurrently with the dental examination by other team members.

Sugar and sugar-product consumption per person per day varied from 37 gm. in the south to 47 gm. in the central region to 61 gm. in the north, with La Serena reporting the highest consumption, 82 gm. This constituted about 4.3 percent of the total Chilean civilian diet. Ten military messes were surveyed in a like manner. Sugar comprised about 50 gm. per man per day, or about 2.7 percent of the total diet by weight.

Figure 3. Mean number DMF teeth in Chilean civilian and military males, 1960, and Baltimore, Maryland, white males, 1954, by age group

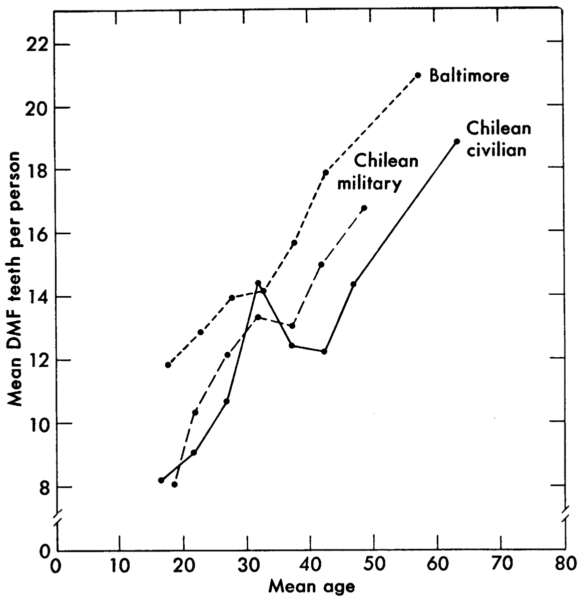


Figure 4. Mean number DMF teeth per person in total Chilean civilian sample, by sex and age group

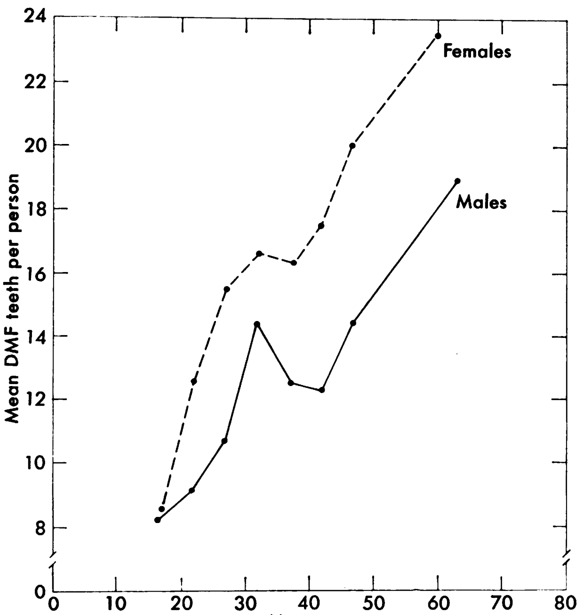


Figure 5. Mean number DMF teeth per person in females, Chile, 1960, and Baltimore, Maryland, 1954, by age group

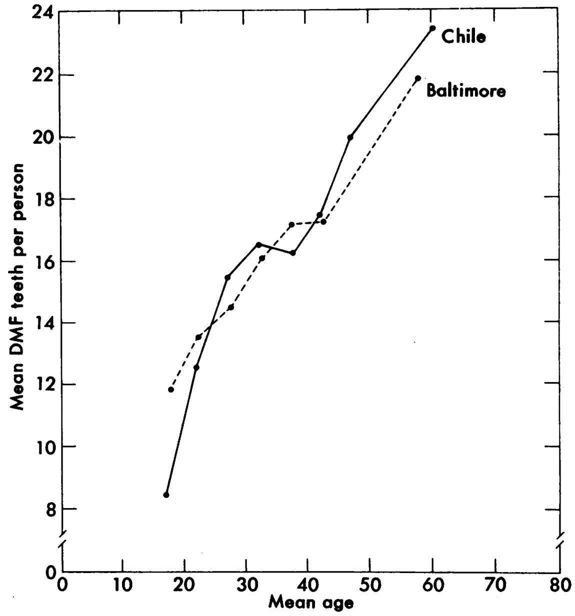


Figure 6. Mean number DMF teeth per person in Chilean military sample, by age group and area of origin

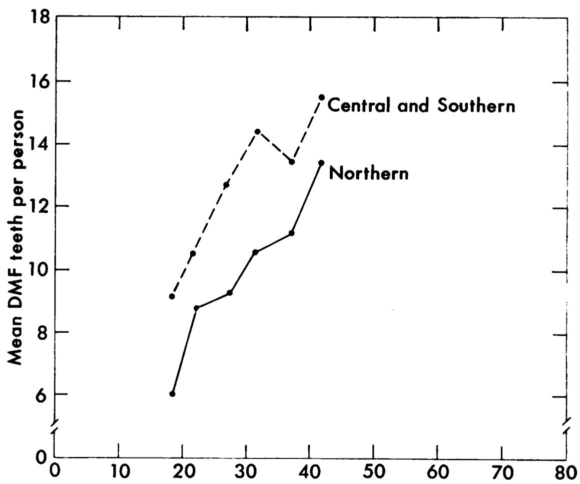


Table 7. Mean number DMF teeth per person in Chilean females, by age and geographic location

Age group	Northern				Central				Southern				Variance ratio	P
	Number	Mean age	Mean DMF	SE	Number	Mean age	Mean DMF	SE	Number	Mean age	Mean DMF	SE		
0–9	52	6. 4	0. 3	0. 137	41	6. 6	0. 9	0. 232	14	7. 0	1. 1	0. 329	3. 831	<. 05
10–19	59	14. 1	2. 8	. 537	70	13. 8	7. 0	. 583	31	13. 9	6. 3	. 730	13. 520	<. 01
20–29	33	24. 9	11. 1	. 975	55	25. 1	16. 2	. 796	19	25. 0	15. 3	1. 904	7. 334	<. 01
30–39	46	34. 2	14. 7	. 943	60	34. 0	18. 1	. 767	13	34. 9	15. 3	2. 538	3. 774	<. 05
40–49	39	44. 4	17. 4	1. 218	40	44. 5	19. 9	. 971	16	43. 9	19. 3	1. 493	1. 449	(1)
50 and over	29	62. 3	23. 2	1. 050	39	58. 0	23. 9	. 600	9	60. 9	22. 6	1. 577	. 397	(1)
Total	258	27.	9. 9	. 586	305	28. 5	13. 9	. 520	102	26. 3	11. 9	. 899	12. 589	<. 01

[1] Not significant.

Special studies of infants less than 3 years of age indicated that infants are nursed by the mother for an average of about 6 months. After that, they are weaned onto cow's milk (depending on location), evaporated milk or special Nestlé's milk products (infrequent), or powdered milk, provided by the National Milk Program, which is the most commonly used form of milk.

Studies on milk production and milk processing show an unequal distribution of fresh milk in the three geographic regions of Chile. Nearly all milk consumed in the northern provinces is in the form of dried milk that must be reconstituted with domestic water. A greater proportion of fresh milk is consumed in the central and southern portions of the country. However, the National Milk Program distributes powdered milk throughout Chile on the basis of 2 kg. per month (providing 20 liters of milk per month) to babies under 2 years old, children over 2 years until school age, if recommended by the social welfare worker, pregnant women, nursing mothers, and tuberculosis patients.

Table 8. Prevalence of dental fluorosis in Chilean civilian and military samples, by area of origin

Area	Number examined	Number with fluorosis	Percent with fluorosis
Civilians:			
Northern	368	82	22. 3
Central	473	9	1. 9
Southern	159	0	0
Military:			
Northern	200	24	12. 0
Central	610	11	1. 8
Southern	92	0	0
Not known or not Chile	4	0	0
Total	1, 906	126	6. 6

Household checks indicate that in many cases the milk issued for babies is distributed to other children in the family. For Chile as a whole, milk consumption in all forms is much too low for optimal child development. Other beverages such as wine, beer, cocoa, and maté contribute a minute fraction of the total daily fluid intake for children through 10 years of age. Soft drinks are consumed, but represent less than half that consumed by U.S. children.

Blood Studies

Blood types were determined for 617 persons who had dental examinations (table 11). There were no significant differences in blood group distributions for sex, age, geographic location, or military status. When blood type was compared for persons with low, medium, or high caries experience, there were no significant differences from the expected distribution.

Discussion

The essential problem presented by these data relates to significant geographic differences in caries experience. These differences have been shown to exist in various subportions of the data, such as for children, females, and the military. Furthermore, we have some indication that the regional caries experience differences noted in this study reflect essentially the same pattern described in the Chilean Ministry of Health Study of 1945 (*5*). The higher numerical caries experience values in the Ministry of Health study compared with this study are partially ascribable to different scoring and examining methods. The dietary study of regional differences in sugar intake correlated with the regional DMF rates in a direction opposite to that expected if sugar could account for higher rates in the central and southern regions. A strong correlation exists between the community fluorosis index, the DMF rates, and fluoride in the domestic waters on a regional basis. However, the fluoride content of the domestic waters of northern Chilean cities varies from 0.4 to 0.6 ppm, with 0.5 ppm as the weighted regional average for the population in this study. These levels appear to be insufficient to provide the sole source of fluoride to account for the biological effects observed, if U.S. standards are accepted. Before drawing such a conclusion, we must consider that northern Chile differs from northern United States in at least two major factors, temperature and milk consumption, that influence total daily water intake, and hence the total daily amount of fluoride ingested.

Initial studies on the relationship between the fluoride content of domestic water, the prevalence and severity of fluorosis (*13*, *15*), and the prevalence of dental caries (*16*) were conducted in communities largely in the northern portions of the United States with mean annual temperatures of approximately 50° F. Here it was found that water supplies must contain from 1.0 to 1.2 ppm fluoride to give a community fluorosis index up to 0.4 and to give the maximum protection against dental caries; that is, 60 percent fewer DMF teeth than communities with no fluoride.

Table 10. Fluoride content of Chilean water samples, 1960, and values previously reported by Chilean Ministry of Health

Location	Fluoride levels (ppm)	
	Previously reported	Public Health Service, 1960
Arica	0. 3–. 6	0. 59
Iquique	. 3–. 6	. 52
Calama	----------	. 46
Antofagasta	. 2–. 6	. 26
La Serena	. 6–. 7	[1] . 41
Quillota	. 05–. 4	. 29
Valparaíso	. 1–. 4	----------
Santiago	. 4	. 11
Concepción	. 2	. 10
Valdivia	. 3	. 33
Osorno	. 1–. 2	----------
Puerto Montt	. 2	. 17
Castro	. 1	----------
Coyhaique	. 05	----------
Punta Arenas	. 4	. 39

[1] Value for tapwater; raw water, 0.36.

A number of studies (*17–23*) have reported fluorosis and low dental caries rates in populations consuming water with low fluoride concentrations. This phenomenon has been observed in such widespread geographic locations as Ethiopia, Thailand, Peru, Formosa, and Chile. In some of these studies, regions or communities have been observed where the amount and severity of fluorosis and the low caries rates were of a magnitude expected in a northern U.S. population consuming water with 1.0–1.2 ppm fluoride. However, these communities were ingesting waters with much lower amounts of fluoride, that is, 0.35–0.70 ppm.

Even before fluoridation became a public health measure, Arnold (*24*) postulated that climate should influence water intake and, therefore, total fluoride ingestion. Galagan and coworkers (*25–28*) have made a series of extensive

Table 9. Mean number of DMF teeth and fluorosis index, Chilean children aged 12–14 years, by region

Region	Number	Mean DMF	SE	Fluorosis index	Student's *t* test	*P*	Percentage difference in mean DMF
Northern	37	1. 81	0. 335	0. 58	4. 687	<0. 001	59. 1
Central and southern	70	4. 43	. 447	0			

studies on water consumption in populations living under different climatic conditions and consuming water with different concentrations of fluoride. The distribution of types of fluid consumed in two of the communities studied is shown in table 12. These investigations showed that temperature was the most important element of climatic environment affecting water consumption.

Galagan and Vermillion (*28*) have proposed the following formula to allow for the effect of temperature on the optimum fluoride levels in domestic waters of the United States:

$$\text{ppm}=\frac{0.34}{E}$$

$$E=-0.038+0.0062T,$$

where E is the estimated water consumption in ounces per pound of body weight and T is the mean maximum temperature in degrees Fahrenheit.

Application of this formula to various communities in the United States gives estimates very close to observed conditions. However, this formula was derived from a study of U.S. children, who consume about 44 percent of their daily fluid intake as milk (table 12). Milk contains negligible amounts of fluoride (*29*). Assuming that children drink the same amount of fluid per pound of body weight in all populations, Galagan and Vermillion's formula should be corrected when it is applied to populations such as that of northern Chile, where

Table 12. Percentage distribution of ounces of each kind of fluid consumed, Antioch and Brentwood, Calif.[1]

Kind of fluid consumed	Antioch	Brentwood
All fluids	[2]100. 0	[3]100. 0
Drinking water	33. 8	36. 4
Water-based beverages	9. 6	11. 2
Milk	47. 9	39. 9
Carbonated beverages	3. 0	3. 6
Other fluids	5. 7	8. 9

[1] During 1,539 child-days in Antioch and 681 in Brentwood.
[2] 61,810 ounces.
[3] 27,044 ounces.

NOTE: Table reproduced with permission of the authors (see reference 27).

fresh milk comprises only a minute amount of the total fluid intake. The U.S. values in parts per million fluoride would be about 44 percent too high for communities where fresh milk is not used. If these assumptions are correct, we propose that a more generally applicable formula would be:

$$\text{ppm}=\frac{0.34}{E}$$

$$E=\frac{(-0.038+0.0062T)\ W}{0.56},$$

where W is the proportion of domestic water in the total daily fluid intake of the average child through 10 years of age in the average community studied. Essentially, W should include

Table 11. Blood type distributions in persons with low, medium, and high DMF experience

Blood type	Mean number DMF teeth: 0–7, Number observed	0–7, Number expected	8–15, Number observed	8–15, Number expected	16–28, Number observed	16–28, Number expected	Total	Percent
AB*	3	3	3	2. 7	2	2. 2	8	1. 30
A_1	54	51. 7	47	46. 9	36	38. 4	137	22. 21
A_2	13	13. 3	14	12. 0	8	9. 8	35	5. 67
B	22	24. 2	23	21. 9	19	18. 0	64	10. 37
O	141	140. 8	124	127. 5	108	104. 6	373	60. 45
Total	233	233. 0	211	211. 0	173	173. 0	617	100. 00

* Not considered in χ^2 calculation.

NOTE: $\chi^2=1.45$; $P=<0.95$.

corrections for any fluoride-containing fluid. However, it is proposed that, for practical purposes, in most populations it can be estimated by subtracting the proportion of milk (M) from the total fluid intake:

$$W = 1 - M.$$

Table 13 shows the mean maximum annual temperature of various Chilean communities averaged over the number of years they have been recorded (*30,31*). The estimated optimum parts per million fluoride in the drinking water, using the temperature and milk correction formula are shown in table 13. Temperature and milk corrections have been calculated for the northern towns only, because we have evidence that fresh milk constitutes only a negligible portion of the total fluid intake of children of this region. If the proposed formula is essentially correct, the amounts of fluoride present in the drinking waters of northern Chile appear adequate to account for the biological effects observed (table 13). Other dietary sources of fluoride probably contribute to the individual variations seen; however, these data strongly suggest that waterborne fluoride is the major significant source of the observed effects.

While these data have been considered for the northern region of Chile as a whole, variations exist from town to town which would make future local studies desirable. Time did not permit detailed studies of the water supplies and water histories of each community. However, the relatively low fluoride content of 0.26 ppm found in Antofagasta in 1960 may not represent the amount of fluoride that was in the water supply 6 to 15 years earlier. The fluorosis index seen in the children of Antofagasta in 1960 leads us to suspect that the water supply has been changed from a higher to a lower fluoride-containing source. We are informed that all water used in Antofagasta comes by pipeline from a source in the Andes Mountains. An abandoned pipe paralleled the one in use in 1960.

The water supply of La Serena includes a number of well sources. We suspect that these sources vary in the amount of fluoride and would contribute variations in the total domestic waterborne fluorides, depending on pumping variations.

When both temperature and milk consumption differences are taken into account for many previously reported studies where low fluoride values, by U.S. standards, are present in domestic waters, the observed concentrations of waterborne fluoride are sufficient to account for the biological effects reported. One possible major source of error that could be encountered if this corrected formula is applied to previously reported studies is the community fluorosis index. In some studies the index has been underestimated by using populations other than children aged 12 to 14 years. We also recognize the tendency by inexperienced investigators to include many nonfluoride hypocalcifications and hypoplasias of enamel, resulting in an overscoring of the index. Even after considering the corrections suggested here, there are several studies which give some evidence for a nonwater source of fluoride. Perhaps the Tristan

Table 13. Calculated optimum domestic water fluoride levels corrected for mean maximum temperature and milk consumption for cities in northern Chile

City	5-year average mean maximum temperature	Fluoride levels in the water supply (ppm)			
		Previously reported	Observed, 1960	Calculated optimum	Optimum level for similar U.S. city
Arica	72.0	0.3–.6	0.59	0.47	0.83
Iquique	70.9	.3–.6	.52	.47	.85
Antofagasta	69.0	.2–.6	.26	.49	.91
Calama	77.9	----------	.46	.43	.76
La Serena	66.3	.6–.7	.41	.51	.91

da Cunha (*22*) and the Pescadores (*20*) studies are the best examples.

Whatever the sources of the fluorosis and low caries rates in northern Chile, conditions here closely approach the optimum expected from fluoride in domestic waters. Waters of central and southern Chile are deficient in fluoride.

Summary

A dental survey of 1,906 Chileans (1,000 civilians and 906 military personnel) geographically distributed throughout Chile revealed significant regional (north, central, and south) differences in caries experience. There was an unexpected negative correlation between regional decayed, missing, and filled rates and regional sugar consumption, but an expected strong negative correlation with fluoride in domestic waters. Persons from northern Chile exhibited low DMF rates and mild fluorosis, characteristic of communities of northern United States consuming water with from 1.0 to 1.2 ppm fluoride. Water analysis indicates that these waters contain from 0.4 to 0.6 ppm fluoride. It is postulated that this amount of fluoride is sufficient, under conditions prevailing in northern Chile, to account for the biological effects seen because of higher ingestion of water per child per day, compared with northern United States. Assuming that Chilean and North American children drink the same amount of fluid per pound of body weight under similar conditions, at least two factors, temperature and milk, could account for higher water consumption. Because milk is deficient in fluoride and because optimum fluoride levels in the United States have been calculated in populations (0 to 10 years of age) consuming about 44 percent of their fluid intake as milk, it is postulated that the requirement for fluoride in parts per million in domestic waters in populations not consuming milk is lower. A tentative milk correction factor applied to Galagan and Vermillion's (*28*) temperature correction formula is proposed:

$$\text{optimum fluoride in ppm} = \frac{0.34}{E}$$

$$E = \frac{(-0.038 + 0.0062T)\ W}{0.56},$$

where E is the estimated water consumption in ounces per pound of body weight and W is the average proportion of domestic water in the total daily fluid intake of children 0 to 10 years of age in the community under study.

A major assumption is inherent in this proposed revision of the temperature formula—that Chilean and North American children of comparable ages under identical conditions would have the same requirements for total fluid per pound of body weight. Future studies should be designed to test the variables affecting water consumption in populations such as northern Chile.

Comparison of ABO blood groups and persons with low, medium, and high caries experience did not show any significant deviations from the expected distribution ($P < .95$).

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Study of Environment and Cancer

An extensive study of environmental factors and the variations in cancer mortality rates in 20 election districts in Washington County, Md., found no specific environment-cancer correlations, according to the National Cancer Institute, Public Health Service.

The soil, rocks, water, air, and vegetation in the districts were analyzed, and mortality records for all types of cancer for the past 30 years, as well as new data on cancer morbidity, were collected. Contrary to previous impressions, the variation in mortality rates from one district to another was attributable to chance and could not be correlated with specific environmental conditions.

In other studies of possible environment-cancer relationships, the National Cancer Institute is investigating the clustering of cases in families or geographic areas.