The Aymara of Western Bolivia: V. Growth and Development in an Hypoxic Environment[1]

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ABSTRACT

As a part of the Multinational Andean Genetic and Health Program, the Bolivian Health Survey sought to compare the anatomic, physiologic and biochemical characteristics of Aymara of the Bolivian altiplano (3700-4000 m) to those of Aymara of the Chilean altiplano (4000-4500 m). Presented here are the anthropometric age changes and differences that accompany sex, ethnicity and permanence of residence. Our objective is to assess what physical growth differences, if any, obtain among populations residing in high regions.

In height, weight and chest morphology, the two high altitude populations were more similar to each other than either was to a lowland control from the Chilean coast. The high altitude samples tended to exceed coastal controls in some of the chest measurements in spite of a generally smaller body size. This provides support for the idea that hypoxia may induce growth of anatomic features associated with oxygen transport. The two high altitude groups differed in some soft tissue measurements, and this difference was greatest among adults of the samples. These anthropometric differences probably reflect socioeconomic variation among populations at high altitude. Regional differences in environmental factors on the altiplano could influence the outcome of comparisons made between altitudes, and may account for a lack of consistent results among previous studies of the effects of hypoxia on human development.

The effect of hypoxic environment on human growth has been studied in high altitude (over 3000 m) populations in South America (Hurtado, 1932; Frisancho and Baker, 1970; Mueller et al. 1978a), Ethiopia (Clegg et al. 1972) and the Himalayan region (Pawson, 1976; Malik and Singh, 1978). A basic requirement of such studies has been to identify a control population at low altitude of similar ancestry, environmental circum-

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stances (excepting hypoxia) and historical antecedents. Also the effects of altitude on measurements of interest must be judged statistically against an appropriate error variance, usually taken to be the within-altitude variation. The latter has not really been evaluated in previous growth-hypoxia studies by comparisons of populations residing at the same altitude. This would provide baseline information on biologic variation within altitude and help us evaluate the biologic significance of changes in physical growth between altitudes. Data on high altitude populations would be particularly important, because if hypoxia has an effect on human development, patterns of growth of high altitude populations should be similar.

Frisancho et al. (1970) investigated this problem in Peruvian Quechua boys. Nuñoa boys from the south (4000 m) were taller and had greater cortical bone areas (second metacarpal) than Vicos boys from central Peru (3000 m). Frisancho et al. (1970) interpret these differences as indicating better diet and living conditions in Nuñoa. However, they point out the Nuñoa data were collected eight years after the Vicos materials. Thus, whether the observed changes are due to regional differences or to secular changes in the environment over this time period is unclear.

During the course of a multidisciplinary study of the health of the Aymara of northern Chile and western Bolivia, data were collected at various sites on both the Bolivian and Chilean altiplano region (3700-4500 m). It is the purpose of this paper to compare the physical growth of Bolivian and Chilean Aymara populations at high altitude to assess what differences, if any, obtain among populations residing in high regions.

Materials and Methods

The investigation described here is part of a larger study, the Multinational Andean Genetic and Health Program, initiated in Chile in 1973 (Schull and Rothhammer, 1977). Broadly stated, the objective of this study was to evaluate the effects of environmental differences, particularly oxygen tension, on pulmonary function, cardio-pulmonary relationships and degenerative cardiac disease in the Aymara; and to assess the genetic contribution to their anatomic, biochemical and physiologic responses.

It became apparent in the implementation of these objectives that the Chilean altiplano was somewhat different from much of that in Bolivia and Peru. It is generally higher, though possibly not significantly so from the adaptational standpoint. It is also drier, the bearing capacity of the land seems less, and the population is sparser. Cereal and potato cultivation are more limited in Chile. There are differences moreover, in settlement patterns which may influence behavior, and ultimately, disease and disability. It seemed prudent therefore to study villages in the Bolivian altiplano as well.

The Bolivian phase was conducted in April 1975 in the Departamento de Oruro in the villages of Turco (3980 m) and Toledo (3752 m). A Turco village census lists 314 persons. The town has primary and intermediate schools and a clinic staffed by a nurse. Toledo and inclusive hamlets, with a population of 7000 persons, is served by a primary, a secondary and a high school; a church with resident priest; a water supply hand drawn from a collective system of open wells; and regular truck and mail service. The two villages appear to be genetically homogeneous as measured by biochemical and immunologic genetic markers (Ferrell et al. 1978).

Residents of these communities are socio-culturally heterogeneous. Some are non-Aymara, that is, claim only Spanish or at least European antecedents; many are Aymara (see Tschopik, 1963), but more still are considered Mestizos or Cholos. The latter expressions are used indiscriminately to characterize not only individuals of mixed Indian and non-Indian ancestry, but often also upwardly socially mobile Aymara who have adopted Spanish customs, conventions and names. Thus, while the categories, Aymara and non-Aymara, have some biologic meaning, the terms Mestizo and Cholo identify a more uncertain group of individuals. Indeed, data on inherited biochemical and immunologic markers suggest the Mestizos to be appreciably more Aymara than non-Aymara (Ferrell et al. in press).

Our assessment of an individual's origins was essentially sociologic; it rested entirely upon his or her patrinym and matrinym and where available, the patrinym and matrinym of his or her mother and father. The algorithm has been described elsewhere (see Schull and Rothhammer, 1977; Díaz et al. 1978). It tends to under-represent the Aymara, a number of whom will be classified as Mestizos, if their normal array of names is incomplete, or if as is frequent in Bolivia, they consciously adopt Spanish names to obscure their origins.

Residential histories were taken on each subject. Those claiming to have lived all of their lives at high altitude are designated "permanents". Those who had spent at least one year at a lower altitude (usually sea level) are designated "non-permanents". The distribution of the sample by age, sex, ethnicity and residence is given in Table 1. Most on the Bolivian altiplano are either Aymara or Mestizo, and practically all indi-

Table 1

Age, Sex, Ethnic and Residence Composition of all Individuals Seen in the Bolivian Health Survey

	Permanent residents						Non-permanent residents*					
	Males			Females			Males			Females		
Age group	A	M	NA	A	M	NA	A	M	NA	A	M	NA
0+	4	7	1	4	7	—	—	—	—	—	—	—
2+	6	15	1	5	9	—	—	—	—	1	—	—
4+	8	11	1	3	11	—	—	—	—	—	1	—
6+	10	8	—	6	13	—	—	—	—	—	—	—
8+	3	9	—	6	7	—	—	—	—	—	—	—
10+	4	9	—	7	9	1	—	—	—	—	—	—
12+	3	10	—	1	4	—	—	—	—	—	—	—
14+	1	5	—	1	5	—	—	—	—	—	—	—
16+	1	2	—	1	3	—	—	—	—	—	—	—
18+	1	2	—	—	1	—	—	—	—	—	—	—
20–29	10	9	1	18	14	1	4	1	—	3	3	—
30–39	11	10	—	11	9	1	4	3	—	2	3	—
40–49	10	5	—	10	8	—	2	1	—	1	1	1
50–59	2	4	—	9	3	—	—	1	—	—	—	—
60+	6	8	1	4	2	—	—	1	—	1	2	—
Total	80	114	5	86	105	3	10	7	0	8	10	1
Total-Sex		199			194			17			19	
Total-Residence			393						36			

*less than 100% of lifetime at altiplano
A = Aymara, M = Mestizo, NA = Non-Aymara

viduals designated as non-permanents are adults, similar to what was found on the Chilean altiplano (Mueller et al. 1978a). In tables of some of the analyses which follow sample sizes may differ from those of Table 1 because: most but not all individuals had the anthropometric examination (although they may have gone through other phases of the study), and measurements found to be outliers in a preliminary bivariate screening were set to blank.

The anthropometric examinations included: (1) weight, (2) height, (3) sitting height, (4) knee height, (5) calf circumference, (6) mid-upper arm circumference, (7) wrist breadth (bistyloid), (8) shoulder breadth (biacromial), (9, 10) chest circumference, at maximum inspiration and expiration, (11) transverse chest, (12) anterior-posterior chest, (13) sternal length, (14) head breadth, (15) head length, (16) bizygomatic diameter, and (17) bigonial diameter. Other measurements were derived from the above: (18) chest expansion is the difference between inspired and expired chest circumference. There are also two measures of shape: (19) chest shape = anterior-posterior chest/transverse chest × 100, and (20) cephalic index = head breadth/ head length × 100. The measurements were all obtained in the manner described in the International Biological Program Handbook (Weiner and Lourie, 1969, pp. 8-16) using a beam balance scale, a conventional anthropometer, a sliding caliper for chest and head measurements and a flexible steel tape. All measurements in Bolivia were taken by a single observer (F. M.). Ages are those reported to the interviewer and were not verified by reference to birth records. However, for most children, these were checked with information supplied by parents on a standard fertility history form.

Comparative data on the growth of Aymara in three altitude zones in Chile and a description of the Chilean samples have been previously published (Mueller et al. 1978a). These zones are: coast, sierra (2500-3000 m) and altiplano (4000-4500 m). In this paper we compare altiplano and coastal Chilean samples to the Bolivian one. The coastal sample is included as a lowland control.

Results and Discussion

The effects of ethnicity (Aymara = +1, Mestizo = 0, non-Aymara = −1) and residence (permanent = 1, non-permanent = 0) were tested in Bolivia on representative measurements (weight, height and head breadth) by analysis of variance (ANOVA). Age and age^2 were covariates for which the measurements were adjusted prior to the ANOVA. Sexes were tested separately. Neither ethnicity nor residence registered significant effects on the measurements, nor were there any significant two-way interactions (ethnicity × residence). These results are consistent with those reported earlier for Chile (Mueller et al. 1978a, 1979). For the analyses which follow, ethnic and residence groups were combined.

Growth curves of various body measurements in the three populations are shown in Figures 1 through 3 along with adult measurements. Mean weights and heights per age group and sex in Bolivia are also given in Table 2. Some generalizations emerge from inspection of these curves.

In general, growth is similar in the two high altitude populations, and distinct from the coast. Possible exceptions are body weight (in males only) and transverse chest and arm circumference in both sexes, in which the Chilean altiplano children are intermediate between coast and Bolivian altiplano. It is difficult to assign these differences to the effects of hypoxia, for we would expect in that case for Bolivia to be intermediate to the coastal and altiplano Chilean samples, as Turco and Toledo in Bolivia are slightly lower than the Chilean altiplano. The exceptional measurements are those which include a substantial soft tissue component, suggesting that short term changes—possibly nutritional or public health related ones—have occurred on the Chilean altiplano in recent years that have not occurred in Bolivia.

Generally, the pattern of growth among these populations is also reflected in the measurements of adults, suggesting that this is a result of environmental factors to which the children are exposed during the developmental period. This is again particularly evident in weight and transverse or circumferential measurements.

Growth retardation at high altitude is apparent in the following measurements: weight, height, transverse chest and arm circumference. On the other hand, high altitude children exceed the coastal ones in anterior-posterior chest at most ages (Figure 2), a trend not evident in adults. This particular measurement is difficult to plumb in adults as it is one that continues to increase with age after 20 years in this and other cross-sectional samples irrespective of altitude (Lasker, 1953). Why this is so is not entirely clear, although a shrinking vertebral column or deposition of inner fat could conceivably lead to a more prominent sternum with aging. Such factors could obscure altitude differences among adults.

As Hurtado (1932) and we have reported earlier (Mueller et al. 1978a), high altitude Andean children have rounder chests (Figure 2, bottom) starting from an early age. This appears related to retardation in the transverse diameter and, to a lesser extent, the acceleration of anterior-

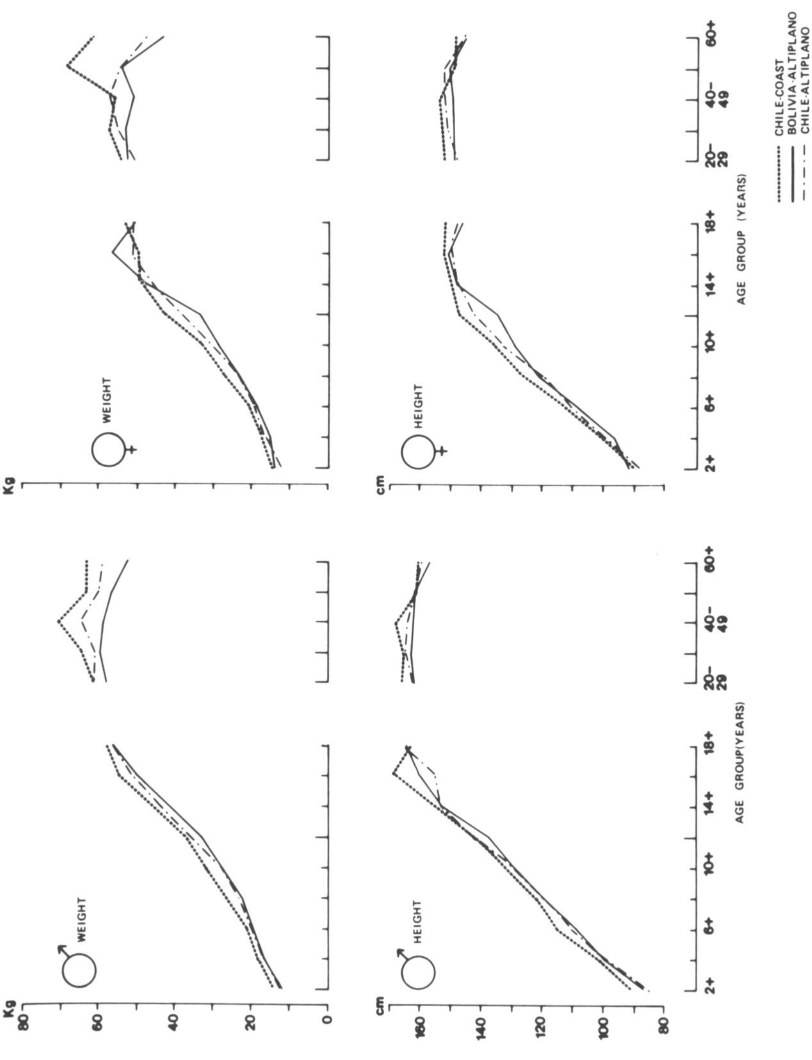

FIG. 1. Mean weights and heights by age group and sex in altiplano (Bolivia-Chile) and coastal (Chile) samples.

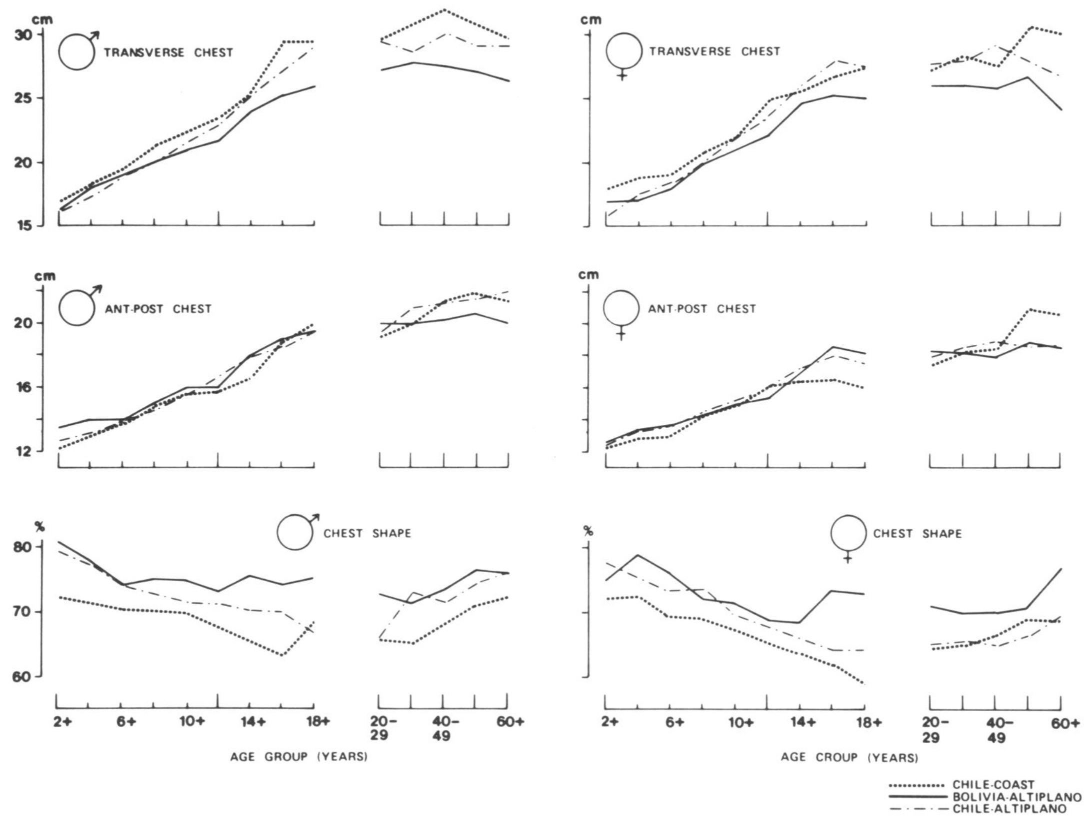

FIG. 2. Mean transverse chest, anterior-posterior chest and chest shape index by age group and sex in altiplano (Bolivia-Chile) and coastal (Chile) samples.

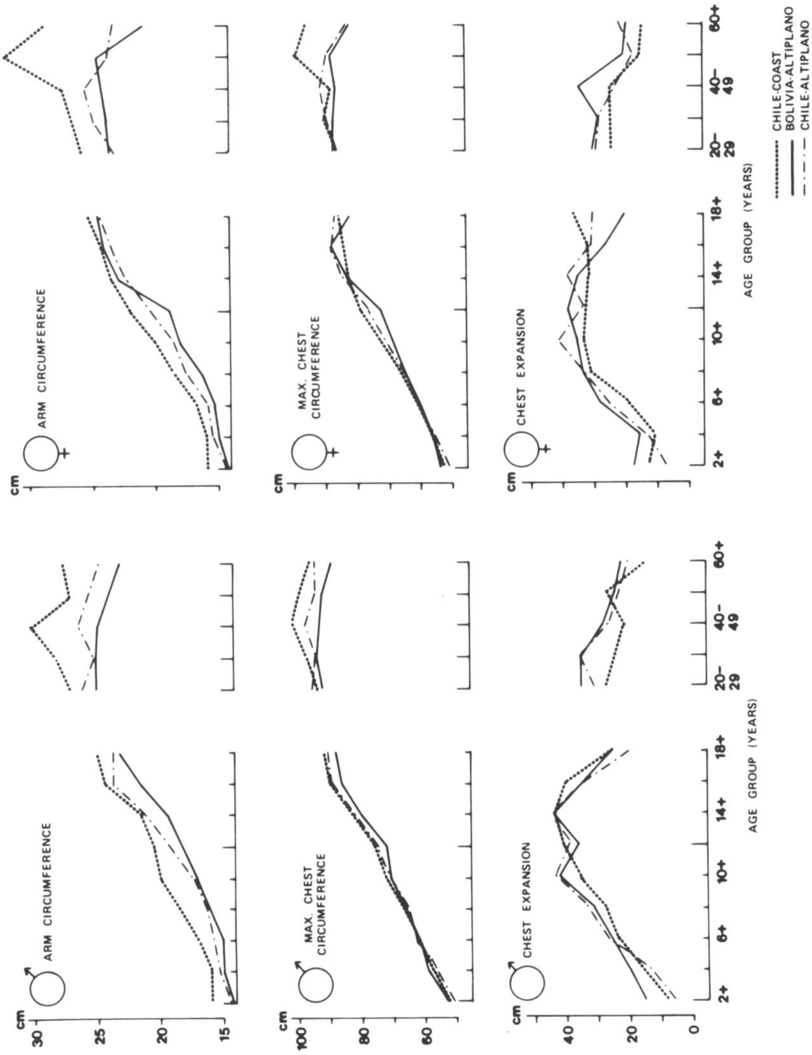

FIG. 3. Mean arm and maximum chest circumferences and chest expansion by age group and sex in altiplano (Bolivia-Chile) and coastal (Chile) samples.

Table 2

Mean Weight (kg) and Height (cm) with Standard Deviations (SD) by Age Group in the Bolivian Altiplano Sample

	Weight (kg)						Height (cm)					
	Males			Females			Males			Females		
Age group	x̄	SD	n	x̄	SD	n	x̄	SD	n	x̄	SD	n
2–3	12.0	3.1	2	13.6	2.5	2	87.2	6.4	2	91.5	7.1	2
4–5	16.4	1.5	17	15.5	2.5	10	99.5	4.9	17	96.7	6.9	10
6–7	19.3	2.6	18	18.8	2.3	19	108.9	5.5	18	108.4	6.5	19
8–9	22.5	2.8	12	23.7	2.9	13	119.5	6.6	12	121.2	4.2	13
10–11	27.4	3.7	13	28.4	3.0	17	129.2	5.4	13	129.3	4.6	17
12–13	32.8	6.2	13	33.0	6.0	5	137.5	10.1	13	134.7	4.9	5
14–15	42.4	4.3	6	47.7	6.6	6	153.4	8.3	6	148.0	2.1	6
16–17	50.4	4.4	3	56.3	9.1	4	160.0	5.3	3	150.5	3.6	4
18–19	56.0	2.9	3	50.0	0.0	1	164.4	7.6	3	146.3	0.0	1
20–29	58.1	6.3	25	52.4	6.4	39	162.0	6.5	25	149.0	4.0	39
30–39	59.4	6.2	28	52.7	8.3	25	162.9	3.9	28	149.2	4.9	25
40–49	58.4	6.5	18	50.9	8.3	21	162.2	6.0	18	149.5	4.9	21
50–59	56.2	5.6	7	53.9	15.4	11	160.8	5.0	7	150.4	4.7	11
60+	52.2	6.6	16	43.3	6.9	9	156.6	5.1	16	145.1	7.0	9

posterior diameter growth at high altitudes. Such shape changes appear to be associated with a more efficient breathing rate in preadults as determined by standard lung function tests (Mueller et al. 1978b), although the cause of this association is unclear.

In Figure 3 it is notable that there are no altitude differences in the maximum chest circumferences in spite of the high altitude populations having considerably less muscle and fat tissue in the arm (Figure 3, top). We say muscle and fat, as boney breadths in the arm were not different between altitudes in Chile (Mueller et al. 1978a). This suggests that while the high altitude children may not have absolutely larger chests, their chests are larger relative to the soft tissue they possess. In other words, the functional portion of the chest circumference appears larger at high altitude, presumably reflecting increased growth of the lung. This is indeed suggested by the growth curve for chest expansion (Figure 3, bottom) (maximum chest circumference minus the minimum chest circumference). Chest expansion at most ages is smallest in coastal children and adults. Some cross-over is apparent at adolescence, although samples are smaller at these age groups. Greater mobility of the chest and accelerated growth of the lungs could contribute to more expansive chests at high altitude. Chest expansion appears related to the vital capacity (FVC) and could thus be considered an adaptive feature (Mueller et al. 1978c).

Taken together these curves seem to indicate that hypoxia induces differential growth: acceleration of anatomical features related to oxygen transport (chest) and diminution of linear and soft tissue measurements. However the latter seem to vary among high altitude populations suggesting differences in socioeconomic and related factors among populations that inhabit the altiplano.

The dependence of some measurements on age in Bolivian and Chilean altiplano children is shown in Table 3. Regression coefficients are shown for two analyses: one in which age is the only independent variable and a second in which both age and age^2 are independent variables. Age^2 is included here to test for possible non-linear trends of the measurement with age. Table 3 shows that including both age and age^2 in the regression equation improves the fit (over age alone) by only a small amount (0-5%). There do not seem to be striking or systematic differences in the regressions of height or weight on age between the two populations. However, maximum chest circumference and transverse chest seem to increase at a faster rate with age in Chile. One is tempted to ascribe adaptational significance to this difference as Chileans live at a somewhat higher altitude. But no such growth rate differences were apparent between altitudes in the Chilean sample (Mueller et al. 1978a).

Table 3

Dependency of Representative Body Measurements on Age and Age² in Children from the Bolivian and Chilean Altiplanos. Regression Coefficients are Shown with their Standard Errors and Proportion of the Variation (R^2) Explained by the Independent Variables

	Bolivia (3700–4000 m)			Chile (4000–4500 m)		
Measurement	Age $b \pm SE_b$	Age^2 $b \pm SE_b$	R^2	Age $b \pm SE_b$	Age^2 $b \pm SE_b$	R^2
Males						
Weight (dKg)	26.64 ± 1.19**	–	.86	26.66 ± 0.95**	–	.87
	−4.74 ± 4.86	1.62 ± 0.25**	.91	4.79 ± 3.68	1.20 ± 0.20**	.91
Height (mm)	51.49 ± 1.69**	–	.92	53.19 ± 1.45**	–	.92
	51.18 ± 8.62**	0.02 ± 0.44	.92	69.80 ± 6.31**	−0.91 ± 0.34*	.93
Maximum chest	21.48 ± 0.90**	–	.87	25.97 ± 0.81**	–	.90
circumference (mm)	10.82 ± 4.49*	0.55 ± 0.27*	.88	23.52 ± 3.64**	0.14 ± 0.19	.90
Transverse	6.02 ± 0.30**	–	.83	7.88 ± 0.30**	–	.86
chest (mm)	3.24 ± 1.51*	0.14 ± 0.08	.84	5.35 ± 1.32**	0.14 ± 0.07	.86
Anterior-posterior	3.84 ± 0.30**	–	.67	4.19 ± 0.24**	–	.73
chest (mm)	0.67 ± 1.49	0.16 ± 0.08*	.69	2.22 ± 1.06*	0.11 ± 0.06	.74
Females						
Weight (dKg)	27.78 ± 1.53**	–	.83	28.50 ± 1.03**	–	.87
	−8.29 ± 6.48	2.01 ± 0.35**	.88	–	1.65 ± 0.05**	.90
Height (mm)	48.52 ± 1.96**	–	.90	52.97 ± 1.38**	–	.93
	69.05 ± 9.82**	−1.15 ± 0.54*	.91	72.60 ± 7.20**	−1.14 ± 0.41*	.93
Maximum chest	23.92 ± 1.13**	–	.86	27.37 ± 0.87**	–	.90
circumference (mm)	7.29 ± 5.46	0.93 ± 0.30**	.88	20.96 ± 4.65**	0.37 ± 0.26	.90
Transverse	6.75 ± 0.41**	–	.79	8.29 ± 0.35**	–	.84
chest (mm)	4.49 ± 2.10*	0.12 ± 0.12	.80	3.90 ± 1.76	0.25 ± 0.10*	.85
anterior-posterior	3.39 ± 0.36**	–	.57	3.87 ± 0.27**	–	.64
chest (mm)	−0.92 ± 1.78	0.24 ± 0.10*	.59	2.42 ± 1.46	0.08 ± 0.08	.64

*$P < 0.05$

Age changes in adults (not shown) are similar in the two samples and except for body weight, which increased on the coast over the adult age groups considered, are similar to those observed in other rural adult samples from Latin America (Lasker, 1953; Himes and Mueller, 1977).

The following measurements declined significantly with age in adult Bolivians: weight (1-1.5 kg per decade), height and sitting height (6-12 mm per decade) and chest expansion (3 mm per decade). The decline of stature is related to shrinkage of the intervertebral disks or postural changes with age, as the deficit was reflected in sitting height but not knee height, a long bone measurement.

So far we have looked at selected measurements—those of general body size, composition and chest development. In Table 4 are given the means and standard deviations for all 17 measurements and the three derived indices, comparing Bolivia and Chile altiplano samples. Means were adjusted by linear regression to age nine in children and age 44 in adults. These ages are close to the mean ages of the Bolivia and Chile samples. The statistical significance of differences in these means were evaluated by t-test assuming equality of variances. The validity of this assumption is seen in Table 4, as standard deviations are similar in both populations.

The two populations of preadults do not differ significantly in weight, height, sitting height or knee height. Although there are statistically significant differences in some body dimensions between children of the two populations, an overall trend is lacking. In both sexes, Chilean children tend to have larger limb circumferences, broader transverse chests and longer heads. But Bolivian children have broader shoulders, longer sternums and somewhat broader heads and faces. The chest shape index also indicates significantly rounder chests in Bolivian children. Differences are small in magnitude, amounting to less than one-half centimeter for most of these measurements.

Differences between these two high altitude populations are greater in adults, especially males, and follow the pattern already seen in children: Some measurements are greater in Chile than Bolivia, others vice versa. For example, in addition to the measurements previously mentioned, Chilean adults exceed their Bolivian peers in weight, height, anterior-posterior chest (males) and chest circumference (both sexes). To the measurements already noted to be larger in preadult Bolivians, we may add wrist breadth (females) and chest expansion in which Bolivian adults exceed their Chilean counterparts.

In evaluating the true significance of the differences which we have noted, some consideration should be given to the effect caused by the

Table 4

Anthropometric Means and Residual Standard Deviations (SD) in Bolivia (3752–3980 m) and Chile (4000–4500 m). Measurements Are Adjusted to Age 9 in Children and Age 44 in Adults

	Males					Females				
	Bolivia (N = 84[a],85,86[b])		Chile (N = 116)			Bolivia (N = 70[a],73)		Chile (N = 117)		
Measurement	$\bar{x}$	SD	$\bar{x}$	SD	t	$\bar{x}$	SD	$\bar{x}$	SD	t
Children										
Weight (dKg)	259.9	40.5	268.8	38.7	1.57	266.2	41.2	276.8	39.8	1.74
Height (mm)	1216.9	57.8	1229.6	59.3	1.51	1218.2	52.9	1232.9	53.3	1.83
Sitting height (mm)	663.6	27.7	669.3	29.7	1.38	663.4	33.0	669.1	30.0	1.21
Knee height (mm)	356.7	22.0	358.3	21.0	0.52	357.9	21.0	359.2	21.5	0.40
Calf circumference (mm)	240.1	14.7	245.2	14.4	2.45*	244.1	15.3	247.1	15.4	1.29
Arm circumference (mm)	166.4	13.5	172.4	13.7	3.06**	173.0	14.3	179.9	16.1	2.96**
Wrist breadth (mm)	44.2	2.6	43.8	2.6	1.07	43.4	2.0	43.0	2.2	1.24
Shoulder breadth (mm)	241.3	14.8	235.0	14.8	2.97**	243.1	14.8	238.1	17.2	2.02*
Chest circumference (inspired) (mm)	672.9	31.2	674.7	33.2	0.39	665.0	30.6	672.6	33.6	1.57
Chest circumference (expired) (mm)	642.0	32.6	643.6	33.0	0.34	634.2	33.3	643.2	34.8	1.76
Chest expansion (mm)	30.8	10.2	31.1	16.6	0.15	30.9	10.8	29.6	15.6	0.62
Transverse chest (mm)	203.7	10.4	207.2	12.2	2.14**	201.6	11.2	208.9	12.9	3.99**
Anterior-posterior chest (mm)	152.8	10.3	150.8	9.8	1.40	146.6	9.8	148.2	10.5	1.05
Sternal length (mm)	153.4	11.1	148.0	12.0	3.25**	149.0	11.1	143.8	12.1	2.97**
Chest shape (%)	75.3	4.7	73.3	5.1	2.85**	73.1	5.3	71.6	4.8	2.01*
Head breadth (mm)	141.4	5.2	140.2	5.5	1.56	139.1	4.7	137.2	4.5	2.78**
Head length (mm)	171.7	5.8	175.0	5.3	4.19**	170.2	5.4	171.1	5.9	1.06
Bizygomatic breadth (mm)	123.6	4.3	123.0	4.2	0.99	121.8	4.2	122.1	4.2	0.48
Bigonial breadth (mm)	91.4	4.2	89.1	4.2	3.84**	88.9	4.7	88.0	4.1	1.39
Cephalic index (%)	82.4	3.9	80.2	4.2	3.79**	81.8	3.7	80.3	3.6	2.76**

Measurement	Males					Females				
	Bolivia (N = 94[a],95)		Chile (N = 70)			Bolivia (N = 106[a], 108, 109[b])		Chile (N = 90)		
	x̄	SD	x̄	SD	t	x̄	SD	x̄	SD	t
Adults										
Weight (dKg)	571.0	64.2	611.1	71.8	3.50**	508.8	86.6	528.2	80.1	1.62
Height (mm)	1609.0	53.8	1629.2	45.3	2.54*	1488.4	47.4	1499.0	50.9	1.51
Sitting height (mm)	854.1	30.7	857.8	24.7	0.83	790.9	27.6	799.0	28.1	2.03*
Knee height (mm)	483.7	24.4	486.2	20.7	0.69	443.0	20.1	439.2	20.9	1.30
Calf circumference (mm)	324.4	21.5	335.2	23.5	3.06*	318.8	21.8	307.3	22.4	3.63**
Arm circumference (mm)	243.5	18.2	254.6	19.1	3.78**	233.3	26.4	240.1	23.4	1.89
Wrist breadth (mm)	57.7	2.9	57.5	2.8	0.44	52.0	2.6	50.6	2.5	3.82**
Shoulder breadth (mm)	327.3	16.3	328.5	15.9	0.47	301.0	14.8	295.2	14.0	2.80**
Chest circumference (inspired) (mm)	918.3	50.6	949.1	51.5	3.83**	859.5	57.1	880.0	58.4	2.48*
Chest circumference (expired) (mm)	888.4	50.5	923.5	51.9	4.36**	832.3	58.1	855.9	60.7	2.78**
Chest expansion (mm)	30.0	11.1	26.4	12.3	1.97*	27.0	11.7	23.5	12.3	2.05*
Transverse chest (mm)	272.8	16.7	291.7	17.3	7.08**	257.5	18.7	279.1	20.4	7.75**
Anterior-posterior chest (mm)	195.8	16.1	210.2	16.2	5.66**	182.7	15.4	184.2	13.9	0.71
Sternal length (mm)	219.0	13.9	220.2	11.9	0.58	197.6	15.7	188.9	15.5	3.90**
Chest shape (%)	73.7	6.5	72.2	5.7	1.54	71.5	6.8	66.2	4.9	6.19**
Head breadth (mm)	146.5	4.8	148.1	4.8	2.12*	142.9	4.5	144.0	4.6	1.69
Head length (mm)	186.0	5.9	189.4	6.1	3.62**	178.9	5.1	179.3	5.0	0.55
Bizygomatic breadth (mm)	141.9	5.0	143.5	4.1	2.19*	134.4	4.7	135.4	4.7	1.49
Bigonial breadth (mm)	105.6	6.0	105.6	6.3	0.02	98.8	4.5	97.2	5.4	2.27*
Cephalic index (%)	78.8	3.2	78.3	3.5	0.95	80.0	3.2	80.1	3.0	0.23

[a] Weight through shoulder breadth.
[b] Chest expansion, chest shape and cephalic index.
*$p < 0.05$
**$p < 0.01$

inclusion of related individuals in our sample. Chakraborty (1978) has shown that in the same population, apparent significant differences in gene frequencies at several enzyme and blood group loci disappear when a correction is made for the number of independent individuals in the sample. He notes that such a correction does not usually affect the mean of the measurement under consideration, but does result in an increased variance. Since the t-test depends upon an estimate of the variance, such an increase would reduce the number of significant differences between the two altiplano populations.

To generalize, there appear to be few striking or consistent differences in growing children between Aymara populations of the Bolivian and Chilean altiplano regions. The greatest differences, with few exceptions, are in measurements with some soft tissue component (circumferences and transverse body dimensions). In these, the Chileans tend to exceed the Bolivians, especially among adults. Since altitude differences are negligible between these populations, these differences likely reflect improvements in socioeconomic factors in recent years on the Chilean altiplano which have not occurred in Bolivia. Previous studies of growth and development in populations residing at or above 3000 m altitude have been equivocal with regard to demonstration of consistent effects of hypoxia on growth. In some studies high altitude children are taller and heavier than lowland children (Clegg et al. 1972; Frisancho et al. 1975). In others, growth appears similar between high and low altitude groups (Hoff, 1974; Pawson, 1976), and in still others, hypoxia is said to retard statural growth (Frisancho and Baker, 1970; Haas, 1976; Beall et al. 1977). Some of this lack of consistency could reflect differences in the degree to which other factors varying with altitude have been held constant. Comparing Bolivian and Chilean altiplano Aymara populations, we see significant differences in soft tissue measurements. Were we to take the Coastal Chilean sample and compare it to a high altitude sample, we would get somewhat different results, depending on whether we had the Bolivians or the Chileans as our high altitude control. Regional differences in environmental factors at high altitude can influence the outcome of comparisons made between populations living at different altitudes. This could explain the lack of consistent findings among previous studies of the effects of hypoxia on human development.

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