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A Comparison of Anthropometric Indices of Nutritional Status in Tukanoan and Achuar Amerindians

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ABSTRACT Anthropometric data from a Tukanoan population in the Vaupes region of Colombia and an Achuar population in the Ecuadorian Amazon were compared relative to international references. The Tukanoans exploit an oligotrophic blackwater ecosystem, whereas the Achuar inhabit a resource rich *montane* ecosystem. Given this ecological distinction, three hypotheses regarding nutritional statuses were proposed: (1) Tukanoans are significantly shorter than the Achuar, indicating a greater degree of stunting; (2) Tukanoans are significantly leaner, indicating a greater degree of wasting; and (3) Tukanaons have significantly lower upper arm muscle area, indicating lower lean body mass. Z-scores for height, weight-for-height, and estimated upper arm muscle area were determined and significant nutritional stress was assumed at $z \leq -2.0$. Between population differences in z-scores for height-for-age (ZHT), weight-for-height (ZWH), and upper arm muscle area (ZUMA) were examined using analysis of variance with a subsequent Scheffe's test. Between-group differences in the frequencies of individuals with low z-scores ($z \leq -2.0$) were assessed via chi-squared analysis. Both populations showed stunting in most age groups, but neither showed low ZWH or ZUMA. Significant differences between populations were found only for ZHT in children (females 1.0–4.9 and 5.0–9.9 years, and males 5.0–9.9 years). Tukanoans have significantly higher frequencies of stunting in all age-sex groups except females and males age 30–49.9 years. There were no significant between-population differences in the frequencies of individuals with low ZWH or ZUMA. These differences in nutritional status may reflect differences in resource availability. Am. J. Hum. Biol. 13:301–309, 2001.

The Amazon rainforest of South America is a rich tapestry of ecological zones. The adaptive strategies of Amerindians living in different ecological zones has long been of interest to anthropologists (Meggers, 1971; Moran, 1993). Although traditional Amerindian subsistence systems are broadly similar in that they are based on swidden horticulture and foraging, differences in staple crop preferences and emphasis on hunting versus fishing, as well as differences in social organization have been described. The extent to which these differences are a reflection of local ecosystem constraints and resources is understood in general terms. Less well understood is how all of these differences affect nutrition and health.

This paper compares the nutritional status of Amazonian Indian populations living in two different ecosystems: the Tukanoans of Colombia, and the Achuar of Ecuador. The Tukanoans inhabit rainforests in the Vaupes region of eastern Colombia, an area defined roughly by the Rio Vaupes and its affluents. This is an area of lowland evergreen forest broken by patches of *caatinga,* scrub forest vegetation growing on sandy soils, and drained by blackwater rivers (Dufour, 1983). It is considered among the poorest of Amazonian environments because of the poor soils, relatively low above-ground plant biomass, and relatively low herbivore biomass (Moran, 1993). The Achuar inhabit the lower *montane* evergreen forests (altitude of about 700 feet) of northeastern Ecuador. These are rainforests with high species diversity and biomass of both plants and animals (Moran, 1993; Patton, 1996), and are considered a relatively resource-rich environment for native peoples. Both the Tukanoans and Achuar have subsistence systems based on a combination of swidden agriculture, with cassava as the dietary staple, foraging, hunting, and fishing (Descola, 1994; Dufour, 1983). Tukanoans are riverine-oriented, and their primary source of animal protein is fish, a dietary emphasis that prompted Jackson (1983) to

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title her ethnography *The Fish People*. Most of the Achuar, on the other hand, exploit a more inland, interfluvial ecosystem, and their main source of animal protein is the meat of game animals (Descola, 1994; Patton, 1996).

On the basis of the lowland blackwater versus upland/*montane* ecological distinction, and the contrasting resources of the two, differences in nutritional status, as assessed anthropometrically, between the Tukanoans and Achuar were proposed. Three hypotheses were proposed and tested:

1. Tukanoans are significantly shorter than the Achuar, indicating a greater degree of stunting.
2. Tukanoans are significantly leaner, indicating a greater degree of wasting.
3. Tukanoans have significantly less estimated upper arm muscle area, indicating less overall muscularity.

METHODS

Study populations

Fieldwork by Dufour (1981) in the Vaupes region of Colombia produced a set of anthropometric data from Tukanoan Indians living in a series of villages along the rivers Cuduyari, Querari, Papuri, and Yapu. Patton (1996) provided a smaller data set of the same measurements from the village of Conambo (100% sample) along the Rio Conambo in eastern Ecuador.

At the time of Dufour's fieldwork in 1976, Tukanoan villages were small, typically about 30–100 residents, and were located along the length of the rivers separated by travel times of 30 min or more (paddle or outboard motor). Village residents lived in family units in individual houses made of wattle-daub with thatch roofs and dirt floors. Houses were clustered together in villages, often around a central plaza, and were at some distance from agricultural areas. Water for drinking and cooking was obtained from the river at least twice daily, and most was only boiled briefly before it was consumed. The very limited amount of organic refuse resulting from food processing and basketry was usually disposed of at the edge of the yard areas, which themselves were bare earth and swept clean. Human urination and defecation was restricted to areas of forest vegetation near the village but away from the river, or in the forest away from the village and the river. Many households kept dogs for hunting. A small number of households kept chickens, which were allowed free range of the village, and occasionally wild birds were kept. Pigs were not common, but were present in some villages.

At the time of Patton's fieldwork in 1993, the community of Conambo, from which all of the Achuar data were collected, had on average a population of 185 people living in 29 households. Households were distributed across 3,000 meters (straight line distance) along both banks of the Conambo River. It took about an hour to walk on the footpaths that connected the household furthest down river to the household furthest up river on the same bank, longer if one had to cross the river. Households were spread out, and with only one exception, there was no line of sight between them. Most homes had thatch roofs (two had corrugated tin) and floors made of split palm wood used in sleeping areas and in some visiting areas. Most cooking and eating areas had dirt floors. With the exception of sleeping areas, which usually had split palm wood walls for privacy, houses were not enclosed. The area immediately surrounding houses were generally cleared to bare dirt. Most households kept pets, usually different species of monkeys and birds, and raised chickens. Two households had a cow and one household had a pig, which were discouraged, sometimes unsuccessfully, from entering household compounds and the surrounding cleared areas. Each household was located by a small stream from which water was collected for cooking and making *chicha* (a sweet manioc beer). People did not drink water from the Conambo River. People defecate in the river and urinate in the river or in the forest along trails and just beyond the cleared areas surrounding their homes.

Conambo was comprised of both Achuar and Quichua speaking households. The Quichua speakers in Conambo fit Whitten's (1976) description of the Canelos Quichua. They were the last descendants of the Zaparos who, during the first half of this century, all but wiped each other out in feuds that were motivated by witchcraft accusations following an epidemic. The survivors of these "brujo" wars intermarried with Achuar who were expanding eastward to avoid the raids of the Jivaro studied by

Harner (1972) . Quichua, the Inca language, was the *lingua franca* and provided a common language for these intermarrying families. In Conambo, apart from language, there was little difference in lifestyle between Quichua and Achuar speaking households. Of the 31 households in Conambo, 16 had Achuar household heads, 5 had Quichua household heads, and 10 were intermarried households, that is, they had one Quichua and one Achuar head. Given that Quichua household heads were thought to carry roughly half Achuar genes and that the children in the intermarried households were roughly three-quarters Achuar, from a population genetics perspective the people of Conambo can be described as Achuar with some Zaparo influences. For the purposes of this study, the term Achuar refers to the entire population of Conambo. The data from the Achuar provide a means of comparison between two populations inhabiting different areas of the Amazon rainforest, and with similar, but not identical subsistence strategies.

Anthropometry

Measurements of height, weight, triceps skinfold, and arm circumference were taken in both populations following standard protocols. All measurements of Tukanoans were taken by a single individual (D.L.D.) in 1976. Height was measured to the nearest 0.1 cm using a free-standing Holtain anthropometer. Weight was measured in kilograms on a calibrated platform spring scale (±0.25 kg) with subjects lightly clothed. Weights of infants and young children were obtained by weighing the mother holding the child and then subtracting the mother's weight. Triceps skinfold was measured in millimeters with a Lange caliper, and arm circumference was measured in centimeters with a flexible steel tape. Two individuals (J.Q.P. and a field assistant) did the measurements of the Achuar in 1993. Height was measured to the nearest 0.05 cm with a Martin anthropometer. Body weight of children ≤4 years of age was taken with a Pesola hanging spring scale accurate to ±0.05 kg, and that of older children and adults with a higher-capacity Pesola hanging spring scale accurate to ±0.5 kg. Children and adults were lightly clothed. Triceps skinfold was taken with a Holtain skinfold caliper, and upper arm circumference was measured with a plastic measuring tape.

Age was estimated based on birth or baptism certificates when available for both Tukanoans and Achuar. However, for the majority of children no documentation was available and age was estimated on the basis of relative birth order in relation to known ages of siblings or other village children, and dentition. For older individuals age estimates were based on approximate age at the time of specific historical events. For example, a statement such as "I was as big as my grandson [pointing out the child] when the war with Peru broke out" was translated to "approximately 8 years old in 1938."

Height-for-age was used as an index of linear growth, and low z-scores (≤–2) are assumed to indicate stunting (Gorstein et al., 1994). Weight-for-height was used as an indicator of relative fatness/thinness, and low z-scores (≤–2) are assumed to represent wasting (Gorstein et al., 1994). Estimated upper arm muscle area (UMA), calculated from triceps skinfold and arm circumference (Frisancho, 1990), was used as an index of protein reserves, and low z-scores (≤–2) were assumed to represent risk of malnutrition (Frisancho, 1990).

Data analysis

Data for height-for-age, weight-for-height, and UMA were transformed into z-scores (ZHT, ZWH, and ZUMA, respectively) using the NCHS reference values presented in Frisancho (1990). The z-scores provide a scale by which the estimated nutritional status of individuals of different ages and sexes can be compared. By convention, nutritional stress was assumed at two standard deviations below the reference population (z = –2.0). Mean z-scores and standard errors of all variables were calculated for each sex by age group in each population. The Tukanoans and Achuar were compared by sex and age group: 1.0–4.9, 5.0–9.9, 10.0–17.9, 18.0–29.9, 30.0–49.9, and 50.0+ years.

Sex-specific one-way analysis of variance (ANOVA) was performed to determine differences in z-scores between the Tukanoan and Achuar. Assumptions of normality, homoscedasticity, and independence were reasonably well met. Scheffe's multiple comparison was utilized to control for type I errors in testing pair-wise differences be-

TABLE 1. Anthropometric characteristics of Tukanoan and Achuar Amerindians by population, sex, and age group

		Tukanoan						Achuar					
		Females			Males			Females			Males		
Measure	Age, years	n	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD
Weight, kg	1.0–4.9	63	11.2	2.5	61	11.7	2.4	17	12.5	3.0	12	12.4	2.1
	5.0–9.9	106	19.3	3.8	96	20.1	3.9	16	19.4	2.3	19	21.5	4.7
	10.0–17.9	76	37.9	10.8	102	34.8	10.2	21	38.2	9.8	14	41.7	11.8
	18.0–29.9	72	51.1	5.3	74	59.8	5.4	16	52.9	5.2	14	61.4	4.7
	30.0–49.9	79	51.0	7.0	98	59.6	7.4	13	53.2	6.0	10	60.6	7.6
	50.0+	34	44.8	5.9	28	57.0	6.8	3	45.4	4.0	8	57.3	7.9
Height, cm	1.0–4.9	42	87.3	8.1	42	86.1	8.9	17	87.9	10.7	12	85.3	8.8
	5.0–9.9	106	108.6	10.0	96	108.4	8.6	16	110.2	6.2	19	113.8	8.9
	10.0–17.9	76	135.9	10.9	102	135.8	13.7	21	138.9	9.2	14	144.2	12.1
	18.0–29.9	72	146.1	4.2	74	156.6	4.7	16	147.3	5.4	14	158.7	4.5
	30.0–49.9	79	146.6	5.0	98	157.0	5.3	13	148.2	5.6	11	159.4	6.0
	50.0+	34	145.1	5.0	28	155.6	4.0	3	143.4	5.2	8	155.2	5.4
Weight/height, kg/cm	1.0–4.9	42	0.14	0.02	61	0.14	0.01	17	0.14	0.02	12	0.14	0.01
	5.0–9.9	106	0.18	0.02	96	0.18	0.02	16	0.18	0.01	19	0.19	0.03
	10.0–17.9	76	0.28	0.06	102	0.25	0.05	21	0.27	0.05	14	0.28	0.06
	18.0–29.9	72	0.35	0.03	74	0.38	0.03	16	0.36	0.04	14	0.39	0.02
	30.0–49.9	79	0.35	0.04	98	0.38	0.04	13	0.36	0.03	10	0.38	0.04
	50.0+	34	0.31	0.03	28	0.37	0.04	3	0.32	0.02	8	0.37	0.04
UMA, cm^2	1.0–4.9	42	14.9	6.4	39	13.8	2.2	11	13.9	3.2	8	13.4	1.3
	5.0–9.9	103	19.3	3.8	96	19.5	3.4	4	16.2	2.0	4	21.1	7.3
	10.0–17.9	76	32.9	9.0	102	32.9	9.0	7	33.6	5.4	4	41.1	14.6
	18.0–29.9	72	42.0	5.6	74	54.1	9.0	15	42.3	3.4	14	54.2	9.0
	30.0–49.9	79	42.2	8.0	98	58.0	8.3	13	44.4	4.0	11	56.5	5.9
	50.0+	33	39.3	7.3	28	51.8	8.7	2	38.7	1.4	7	54.1	9.0

tween populations in each age-group (Zar, 1996). A 95% significance level ($\alpha = 0.05$) was used.

In addition to the comparison of mean z-scores, chi-square analysis was used to compare the frequencies of stunted individuals within each age group between the two populations. Yates' correction was utilized in cases where observed frequencies were below five. A 95% significance level was also assumed for this analysis.

All data analysis and hypothesis testing were conducted accordingly using SAS version 612.

RESULTS

Descriptive statistics for height, weight-for-height, and UMA by sex and age within each population are given in Table 1. Trends in z-scores by age and sex are shown in Figure 1. ZHT for the Tukanoans is below −2.0 for all age-groups, whereas ZHT for the Achuar is above −2.0, except for females ages ≥10.0 years and males ≥18.0 years. Means for ZWH are between 0.7 and −1.0 in both populations, and mean ZUMA are between 1.4 and −0.7.

The results of the ANOVA for ZHT indicate significantly lower z-scores for Tukanoan than Achuar females ($F = 9.92, P = 0.0001$) and males ($F = 5.12, P = 0.0001$). Scheffe's multiple comparison indicates that significant between-population differences exist only between females 1.0–4.9 years (mean difference = 1.7 ± 1.4) and 5.0–9.9 years (mean difference = 1.6 ± 1.2), and males ages 5.0–9.9 years (difference in means = 1.21 ± 1.20). In all cases, Tukanoan children are shorter (Fig. 1). In contrast, there are no statistically significant differences between Tukanoans and Achuar in either ZWH or ZUMA.

The frequency of individuals with low z-scores (−2.0) for height-for-age is significantly greater among Tukanoans than Achuar for individuals less than 30 years of age (Fig. 2). There were no significant between-population differences in the frequency of individuals with low z-scores for weight-for-height or UMA.

DISCUSSION

Results support a modified version of the first hypothesis, i.e., Tukanoans are significantly shorter than the Achuar. Means for ZHT of Tukanoans are lower than those of the Achuar in all age groups except the oldest. However, the differences are only statistically significant for children less than 10 years of age.

The greater prevalence of stunting among

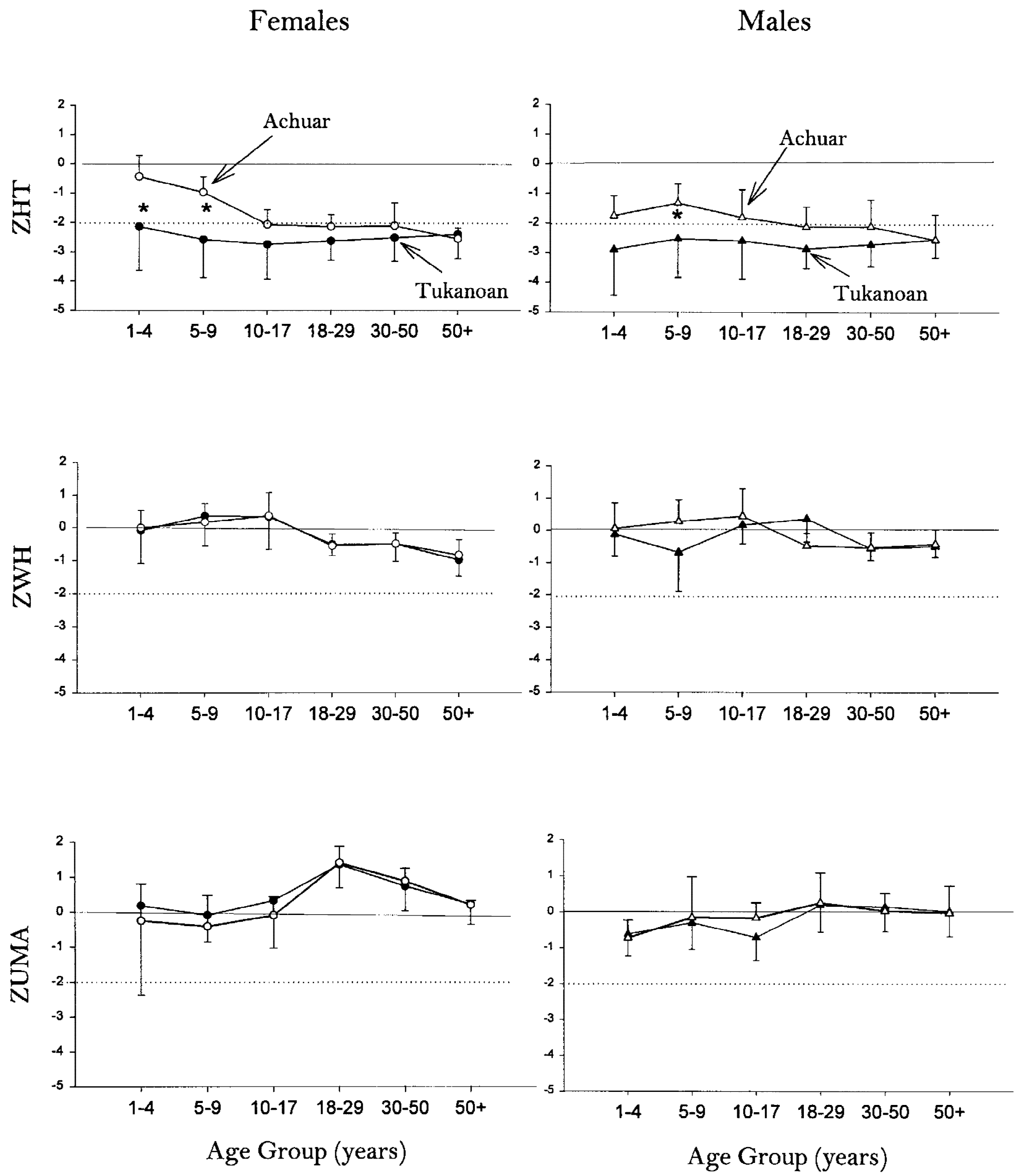

Fig. 1. Mean z-scores for height (ZHT), weight-for-height (ZWH), and upper arm muscle area (ZUMA) by age-group for Tukanoan and Achuar females, and Tukanoan and Achuar males; *significant between-population differences by sex ($P < 0.05$, one-way ANOVA, Scheffe's multiple comparison test).

Tukanoans is consistent with the first hypothesis. Both populations, however, have high percentages of stunted individuals, which is also consistent with studies of other Amazonian Indians (Dufour, 1992). Indeed, Stinson (1990) emphasized that Amazonian Indians are among the shortest peoples in the world, and questioned the extent to which there might be a genetic component to shortness in stature. Whether

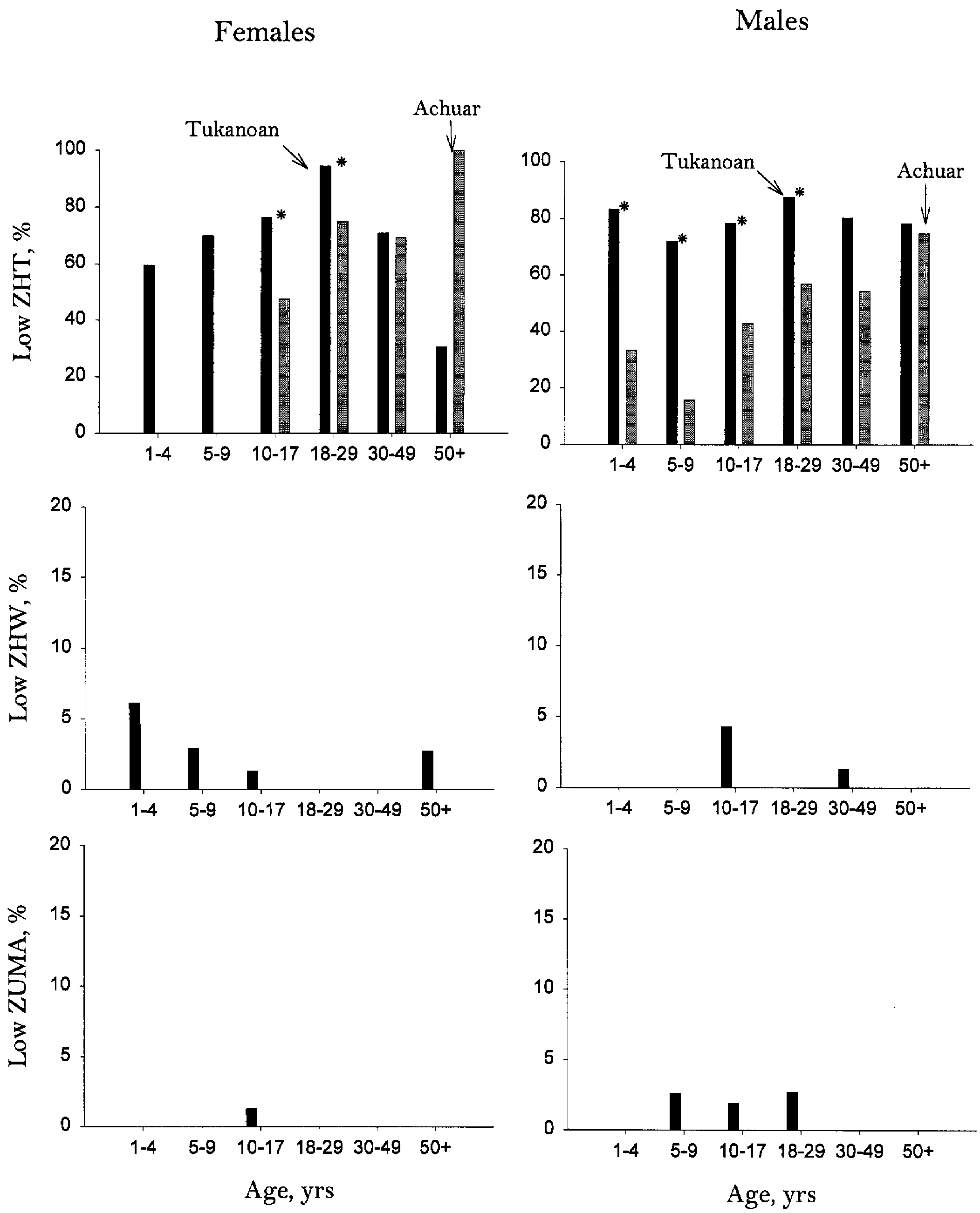

Fig. 2. Percentage of each age-sex group with z-scores of ≤−2 by population; *significant between-population differences ($P < 0.05$, chi square).

there might also be a thermoregulatory component is not known. Insufficient attention has been devoted to this question.

Current consensus is that stunting indicates long-term nutritional inadequacy coupled with infectious disease (WHO, 1995). The nutritional adequacy of the Tukanoan diet has been evaluated but that of

TABLE 2. Mean daily per capita energy and protein production by Tukanoan (n = 4) and Achuar (n = 6) households

	Energy, kcal		Protein, g	
Source	Tukanoan	Achuar	Tukanoan	Achuar
Gardens	2245	2680	14	24
Hunting/ fishing	221	728	33	81
Other	76	3	–	–
Totals	2542	3408	50	105

the Achuar has not. The diet of Tukanoan adults living at Yapu is about 81% carbohydrates, 11% protein, and 8% fat (Dufour, 1992). Most (83%) of the food energy is from horticulture, and the remainder from fishing, gathering, and hunting (Dufour, 1983). The energy and protein intakes of adults are adequate for their body size and level of physical activity (Dufour, 1983, 1984). The dietary intakes of children have not been estimated, and hence the adequacy of the Tukanoan diet for young children, where growth stunting actually occurs (Martorell et al., 1975), is not known. However, because the diet is so low in fat, it may be difficult for children to eat enough food to satisfy energy needs (Dufour, 1992).

Although dietary intake data are not available for the Achuar, household food production has been reported by Descola (1994) and can provide an approximate measure of household food availability. The Achuar subsistence system provides an average of 3,408 kcal of energy (70% from horticulture), and 105 g protein (81 g animal protein) per capita per day (Table 2). The data may be suspect, because the study did not follow standard procedures for estimation of household food production, and the sample size was small. Ross (1976) reported daily per capita values of 3257 kcal of energy and 107.7 g protein for Achuar living in Peru. Achuar in Conambo say that there is less game on the Peruvian side, so that the data of Ross may have a bias toward lower estimates. Thus, given that the studies reported comparable numbers, and in the absence of data to the contrary, the data of Descola are considered here.

Data on Tukanoan household food production indicate that the Tukanoan subsistence system provides 2,542 kcal of energy (83% from horticulture) and 50 g protein (35 g animal protein) per capita per day (Dufour, 1983). The data suggest lower household energy and protein availability for Tukanoans. These data compare reasonably well to dietary data based on weighed foods of adults measured during two seasons (May–June and November–January) for a total of 18 man- and 23 woman-days. The weighed dietary intake data indicate that adults consumed an average 2,790 ± 464 kcal of food energy and 77 ± 52 g protein (55 ± 34 g animal protein) per day (Dufour, 1987, and unpublished). The adult energy intake values are slightly higher than the per capita values obtained from household level data, but are sufficiently close to suggest the household data are reasonably accurate. The absolute value for protein intake, however, is somewhat higher than that for per capita household availability. This difference is probably not statistically significant given the high standard deviation for individual protein intake, which reflects high day-to-day variability in protein availability and intake.

The higher animal protein availability in Achuar households supports the ethnographic observations of both Descola (1994) and Patton (1996), who found that the Achuar ate meat every day in substantial amounts. In comparison, Tukanoan adults consume animal protein on only 83% of all days (Dufour, 1987). The fact that the animal protein in the Tukanoan diet is principally from fish is not relevant because the meat of fish and terrestrial vertebrates (or game animals) is generally comparable in meeting nutritional requirements. The differences between the Achuar and Tukanoan diets are more related to quantity and frequency of consumption.

If it can be assumed that the differences in animal protein availability between Achuar and Tukanoan households translate to actual differences in children's diets, then Achuar children have a higher-quality diet. This difference in the overall quality of the diets may help explain the difference in stunting because higher-quality diets, i.e., those with more animal protein, are associated with better growth and greater height-for-age in young children (Allen, 1994). The mechanisms are not well understood, but the higher micronutrient content of high-quality diets rather than high protein content per se may be important (Allen, 1994).

It is not suggested that animal protein is "limiting" in either population because there is no evidence to this effect. Thus, differences in diet quality may explain some of the differences in child growth between the Achuar and Tukanoans.

The between-population difference in household availability of animal protein reflects both foraging efforts and local animal biomass. Assuming foraging efforts are similar in the two populations, the greater availability of animal protein in Achuar households suggests that the *montane* ecosystem is relatively richer in animal biomass resources for native populations.

The frequency and severity of infectious disease is also a significant factor in limiting child growth, and as much as one-third of the faltering in linear growth in children can be attributed to illness and diarrheal diseases (Martorell et al., 1975; Allen, 1994). The impact of infectious disease on the growth of Tukanoan and Achuar children is not known. However, parasitic infections were ubiquitous among both the Achuar and Tukanoans. Other infectious diseases and diarrheal diseases were also common among Tukanoans, who did not have consistent access to medical care in the 1970s. The Achuar were in a similar position in the 1990s. Therefore, infectious disease may have negatively impacted the growth of children in both populations, but there is no way of distinguishing if one population was more affected than the other.

Data do not support the second hypothesis dealing with fatness/thinness and frequency of wasting. There are no statistically significant differences in the means for ZWH between the two populations, and there is little evidence of wasting in Tukanoans, and none in the Achuar. This indicates good current nutritional status, i.e., adequate food intake and absence of major disease problems (WHO, 1995).

In addition, data do not support the third hypothesis regarding lean body mass. Neither population shows low means for ZUMA, indicating generally muscular people with adequate lean body mass (Frisancho, 1990). Women in both populations show a peak in ZUMA scores at ages 18–29 years. This is probably an artifact of the inappropriateness of the reference values, which are based on generally sedentary American women; in contrast, Tukanoan and Achuar women do physical work.

Although data indicate a greater degree of growth stunting in the Tukanoans than the Achuar, there are several reasons to be cautious in interpreting this difference. First, there are considerably less data for the Achuar, and the numbers for some age groups are extremely small. Second, many of the ages are estimates. This was more of a problem among the Tukanoans because the measurements were done earlier in time, when birth and baptismal records were less readily available. Thus, there may be some error in individual ages. The age estimates are probably most accurate for the young adults (ages 18.0–29.9 years) in both populations, and in this age group there are no statistically significant differences between the two populations. Third, measurements on the Achuar were taken 15 years after those on the Tukanoans. Thus, secular changes in stature may account for the statistically significant differences between Tukanoan and Achuar children. The fact that Tukanoan adults (30.0–49.9 years) are approximately the same height as Tukanoans in the oldest age group (50.0+ years), while there is a 4–5 cm difference between Achuar in these age groups (Table 1), might be evidence of secular increases in stature acting in the Achuar but not the Tukanoans. However, the height differences may be a consequence of sample size, $n = 11$ and $n = 3$, respectively, in the Achuar in these age groups. Furthermore, secular change does not explain the pattern of uniformly lower absolute values for the Tukanoans at all ages.

In summary, nutritional status as measured by weight-for-height and UMA is good in both the Tukanoan and Achuar populations, indicating that current food intakes meet needs. Low height-for-age, however, is prevalent in both populations, suggesting long-term nutritional inadequacy coupled with infectious disease problems. The greater prevalence of stunting in Tukanoan children may be related to lower availability of animal protein in Tukanoan households, and a reflection of resource availability in blackwater ecosystems.

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