Traditional Versus Agricultural Lifestyle Among Shuar Women of the Ecuadorian Amazon: Effects on Leptin Levels

Folke Lindgärde, Iréne Widén, Miriam Gebb, and Bo Ahrén

Leptin is a key biological marker related to energy balance and development of diabetes and cardiovascular diseases. Its levels are increased in populations with a high degree of the metabolic syndrome. Life history of evolution has, however, largely taken place under the ecological context of hunting and gathering. In this study, we explored whether the first steps of transition to sedentary agriculture involve a change of body composition, plasma leptin concentration, and markers of the metabolic syndrome. A total of 59 healthy Shuar Amerindian women living in 5 isolated communities in the Ecuadorian Amazonian rain forest were examined. Women (n = 33) from the largest and oldest community, Yuwientsa, who are more dependent on agriculture had higher fat mass (11.7 ± 3.3 *v* 14.5 ± 4.0 kg; *P* = .023) but the same body mass index (24.1 ± 2.7 *v* 23.1 ± 2.8 kg/m^2; not significant [NS]) and lean body mass (41.0 ± 5.0 *v* 40.2 ± 6.2 kg; NS) than women (n = 26) from the 4 traditional hunter/gather settlements. Furthermore, women from Yuwientsia had higher leptin (5.5 ± 3.1 *v* 4.1 ± 2.7 ng/mL; *P* = .021) and plasma insulin levels (49.8 ± 37.4 *v* 35.5 ± 12.7 pmol/L; *P* = .013). Homeostasis model assessment (HOMA) values (8.8 ± 4.8 *v* 6.1 ± 2.2; *P* = .004) and plasma triglyceride levels (2.3 ± 1.0 *v* 1.7 ± 0.6 mmol/L; *P* = .025) as markers of the metabolic syndrome were also increased in the Yuwientsa population. Mean plasma glucagon concentrations were not different between the groups. We conclude that body fat and levels of insulin and leptin are higher in the population more dependent on agriculture for living. In fact, the leptin concentrations from the 4 hunter/gather communities are the lowest mean value ever reported from a population of healthy females. As there are no genetic or biologic differences between the Shuar Indians from the 5 communities, we hypothesize that behavioral responses to a changing environment may be the key to the development of the metabolic syndrome and elevated plasma leptin concentrations.

PRESENT DAY Andean natives are descendants of the Amazonian groups that migrated eastwards some 3,500 years ago.[1] Their lifestyle has undergone transition from a more traditional through an agricultural to the urbanized style.[2,3] This lifestyle transition is associated with altered occurrence of disease states related to the metabolic syndrome. Thus, the lifestyle in isolated Amerindian populations in the Amazonian region seem to protect against the development of hypertension, obesity, and diabetes,[4,5] while high rates of cardiovascular risk factors are found when an Indian tribe in the Amazonian region has undergone rapid and cultural changes.[6] Particularly the rapid lifestyle transition during recent years may be of importance, as is evident from studies showing very low rates of cardiovascular diseases among North American Indians in the 1960s[7] in relation to the Strong Heart Study indicating that coronary heart disease rates in these groups now exceed rates in other US populations.[8]

A metabolic marker for the change in prevalence of cardiovascular diseases is leptin, which is an adipocyte-derived hormone of importance as a signal for the regulation of energy stores.[9,10] Thus, hyperleptinemia is associated with development of diabetes and cardiovascular diseases.[11] Consistent with the notion that risks for cardiovascular diseases increase in Peruvian Indians undergoing urbanization[2] and that this risk is associated with high leptin levels, we recently found that leptin concentrations in Quechua-speaking women living in small rural villages in the high-altitude-situated Cuzco region in Peru are lower than in women who migrated from the Andean highland to Lima.[3] This finding thus supports that the transition to urbanization is associated with elevated leptin levels, which may relate to increased occurrence of the metabolic syndrome. However, whether the transition of lifestyle from the traditional hunter/gather style to the agricultural style is similarly associated with altered leptin levels is not known. A study demonstrating very low plasma leptin levels in healthy female Ache Amerindians living in eastern Paraguay might support this.[12]

The purpose of this study was to investigate the impact of the first step of transition from hunter/gather communities to sedentary agriculture on plasma leptin concentrations in relation to body composition among Amerindian women. To that end, we examined women in 4 small settlements in the Amazonian rain forest in Ecuador characterized by traditional living conditions in comparison to women living in a larger and older community that to some degree is more dependent on agriculture.

SUBJECTS AND METHODS

The Shuar Communities

Women living in 5 Shuar communities were examined. The villages are located in the Amazonian rain forest at an altitude of 700 m about 100 miles southeast from Shell Mera in the Pastanza region in Ecuador. People living in 4 of the communities, Yampuna, Tinche, Tresmaria, and Iniaya have maintained the traditional hunter/gather lifestyle, whereas people living in the Yuwientsa community have introduced an agricultural lifestyle. Yuwientsa is the largest and oldest one of the communities, 36 years in existence. The settlement has grown from just a few families to about 120 inhabitants. In contrast to the other communities, it has a small governmental school and through a contribution from a German organization got a cottage where some basic

From the Department of Vascular Medicine and Medicine, Lund University, Malmö, Sweden; Hospital Vozandes del Oriente Shell, Shell, Ecuador; and the Department of Medicine, Lund University, Lund, Sweden.

Submitted January 22, 2004; accepted April 9, 2004.

Supported by Grant No. 6834 from the Swedish Research Council, Albert Påhlsson Foundation, Swedish Diabetes Association, and Stiftelsen för forskning inom diabetes och kärlsjukdom.

Address reprint requests to Bo Ahrén, MD, PhD, Department of Medicine, Lund University, B11 BMC, SE-221 84 Lund, Sweden.

0026-0495/04/5310-0043$30.00/0

doi:10.1016/j.metabol.2004.04.012

Table 1. Characteristics of Women From the Traditional Shuar Villages in Relation to Women From the Yuwientsa Community

Variable	Traditional Shuar Villages (n = 26)	Yuwientsa Community (n = 33)	*P*
Age (yr)	32.0 ± 2.2	36.9 ± 2.1	NS
Height (cm)	151.5 ± 4.1	151.1 ± 4.3	NS
Weight (kg)	52.7 ± 6.8	56.5 ± 7.4	NS
BMI (kg/m^2)	23.1 ± 2.8	24.1 ± 2.7	NS
Waist circumference (cm)	79.7 ± 8.2	84.2 ± 8.3	NS
LBM (kg)	40.2 ± 6.2	41.0 ± 5.0	NS
Fat mass (kg)	11.7 ± 3.3	14.5 ± 4.0	.023
Fat mass/LBM (ratio)	0.30 ± 0.08	0.35 ± 0.09	.004
Fat mass (% of body weight)	22.1 ± 4.9	25.4 ± 4.9	.032
Plasma glucose (mmol/L)	3.9 ± 0.58	4.1 ± 0.6	NS
Plasma insulin (pmol/L)	35.5 ± 12.7	49.8 ± 37.4	.013
HOMA index	6.1 ± 2.2	8.8 ± 4.8	.004
Plasma leptin (ng/mL)	4.1 ± 2.7	5.5 ± 3.1	.021
Leptin per kg body fat (ng/mL/kg)	0.33 ± 0.03	0.36 ± 0.03	.032
Plasma cholesterol (mmol/L)	4.5 ± 0.7	4.5 ± 0.4	NS
Plasma triglycerides (mmol/L)	1.7 ± 0.6	2.3 ± 1.0	.025
Plasma glucagon (ng/L)	63.3 ± 29.1	61.0 ± 13.0	NS

NOTE. *P* indicates probability level of random difference between the groups.
Abbreviations: LBM, lean body mass; HOMA, homeostasis model assessment; NS, not significant.

medications are stocked. Traditional Shuar settlements as the 4 other ones are located approximately 50 miles from Yuwientsa and range in size from 15 to 60 persons. Yampuna, the largest one, with approximately 50 inhabitants, was founded 18 years ago. Both Yuwientsa and Yampuna are connected to Shell Mera and the hospital by Mission Aviation flights and get irregular visits from 1 of us (M.G.). In none of the villages piped water or electricity are available.

Study Design

All women aged 20 to 61 years and living in the 5 communities were invited to take part in the study. In 2 of the communities, all women responded positively to the invitation and participated. In the other communities, all women responded positively, but a few were away from the community at the time of the study. Therefore, participation rate exceeded 95%. Two of the investigators (F.L. and M.G.) performed the examinations. Body height (m), weight (kg), and waist circumferences (cm) were measured after an overnight fast. Body adiposity was measured by a bioelectrical impedance method (The Biodynamic Model 310, version 8.0; Biodynamic Research, Seattle, WA). Measurements were performed with subjects lying on a couch and the electrodes placed on the dorsal surfaces of the right hand and foot. A venous blood sample (6 mL) was obtained in Vacuette test tubes immediately after aprotinin (250 KIU/mL blood; Bayer AG, Leverkusen, Germany) was added. The blood was centrifuged, plasma was stored in an ice cooler with blue pack ice at 4°C for 24 to 30 hours, and kept frozen for 3 days at −20°C, and then brought to Sweden for analyses. Insulin, glucagon, and leptin were analyzed with double-antibody radioimmunoassay techniques using guinea pig antihuman insulin antibodies, human insulin standard, mono-^{125}I-Tyr-human insulin, guinea pig antihuman glucagon antibodies specific for pancreatic glucagon, ^{125}I-labeled glucagon and glucagon standard, and rabbit antihuman leptin antibodies, ^{125}I-labeled human leptin and human leptin as standard, respectively (Linco Research, St Charles, MO). Plasma glucose was determined using the glucose oxidase procedure. Blood triglycerides and total cholesterol were analyzed by use of a paper strip. Approval for the study had been given by Hospital Vozandes in Quito, Ecuador.

Statistical Analyses

All results are presented as mean values ± SD. Insulin resistance was calculated as the homeostasis model assessment (HOMA) index according to the HOMA using the formula fasting insulin × fasting glucose/22.5.[13] Statistical analyses were performed with the SPSS for Windows system (SPSS, Chicago, IL). Differences between the groups were analyzed using Mann-Whitney *U* test, and Pearson's product moment correlation coefficients were obtained to estimate linear correlation between variables. A *P* value of .05 was considered significant.

RESULTS

The characteristics of the 59 Amazonian Shuar women from Ecuador are shown in Table 1, divided into 2 subsets, "Traditional Shuar villages" (n = 26) and "Yuwientsa community" (n = 33). All subjects had normal fasting glucose values, and there were no differences between the 2 groups with respect to age, waist circumference, height, body weight, body mass index (BMI), lean body mass (LBM), plasma glucose, plasma glucagons, and total blood cholesterol concentrations. In contrast, women from Yuwientsa had a higher amount of body fat, an increased percentage of body fat, and a higher body fat mass/LBM ratio than women from the other communities. Furthermore, concentrations of fasting triglycerides, leptin, and insulin were higher in women from Yuwientsa. As an indicator of peripheral insulin resistance, the HOMA values were higher in the Yuwientsa group. Across the entire study population, leptin correlated to insulin ($r = 0.28$; $P = .035$), HOMA ($r = 0.27$; $P = .040$), and percent body fat ($r = 0.55$, $P < .001$).

DISCUSSION

The main finding of this study is that the rather modest change of social structure taking place within a relatively short time period of these Amerindian women results in increased plasma leptin and insulin levels and body fatness. The findings, in fact, suggest that the changes in lifestyle are associated with

development of insulin resistance, as for example, both fasting insulin and HOMA values are increased, and development of early signs of the metabolic syndrome, as for example, trglycerides levels are elevated. The change in lifestyle is of short duration, because until the late 1970s, people in Yuwientsa subsisted on full-time forest foraging. Thereafter, this community has transformed into a more agricultural community, whereas the 4 other villages that are smaller have retained the traditional household-focused economy that embraces a mixed strategy of hunting, fishing, horticulture, and gathering.[14] Game in the vicinity of established human settlements in Amazon Basin is extremely scarce.[15] Hunters in Yuwientsa had to go 8 to 10 hours to hunt larger animals, such as deer and wild pork (peccary).

The mean plasma leptin level in the Shuar population, 4.9 ng/mL, was found to be very low in comparison to rural Amerindians women who have an agricultural lifestyle as those in Andean highlands, 9.7 ng/mL, even though BMI is not different.[3] Similarly, the leptin levels in the Shuar population are lower than those in Mexican Pima Indians, 10.9 ng/mL,[16] but similar to what was observed among Ache Amerindians living in eastern Paraguay, 5.6 ng/mL, who until the late 1970s subsisted on full-time forest foraging, but now live primarily through farming.[12] Parkatêjê Indians living in the southeast of the state of Pará, part of the Amazon Region of Brazil, a tribe that has undergone a rapid and intensive change in lifestyle since the 1960s, present at medical examinations a high rate of cardiovascular risk factors with a mean plasma leptin value of 10.0 ng/mL.[5] A Swedish age-matched sample of women with normal fasting plasma glucose and the same BMI as the Shuar and Cuzco groups had a mean plasma leptin concentration of 16.1 ng/mL[2] emphasizing the hypothesis that chronic environmental factors may play an important role in leptin variation.

We thus show in this study that a first step of transition in lifestyle, from the hunter/gather lifestyle to the agricultural lifestyle is associated with increased fat body mass with concomitant increase in circulating insulin and leptin. Hypothetically, these alterations may be due to adoption of a more sedentary lifestyle and altered dietary habits. We did not include actual measurements of lifestyle changes, such as changes in physical activity, in this study. Therefore, a possible relation of changes in leptin and insulin to changes in lifestyle is circumstantial. Nevertheless, even though women in Yuwientsa are very active in collecting wild food products and performing manual agriculture, reduction in physical activity is probably not a main cause to the observed results, because lean body mass was not lower in these women. Regarding diet, all 5 villages are surrounded by gardens in which varieties of manioc and plantain predominate. The main protein sources in the diet when large game is scare are rodents, which are attracted by these plants, wild birds, small vertebrates, and insects.[14] We have no reliable data indicating a deficiency of protein in the diet in the Yuwientsa study group even if relatively little animal flesh is eaten. Studies of the total protein consumption in the 1970s among the Shuar indicate that the animal-derived protein intake is higher than recommendations given by Western research councils.[14]

In contrast to leptin values, mean plasma glucagon concentration was in this study within the range observed in Caucasians and Pima Indians[17] and, as in Pima Indians, there was no relation for glucagon levels to body adiposity.[18] Therefore, the change in lifestyle does not seem to be associated with altered glucagon levels.

As human evolution has occurred largely during conditions similar to those existing in the traditional Shuar villages, eg, hunting and gathering, the observed low plasma leptin conentration may represent “the normal” range of this hormone. Perhaps due to greater adiposity and lower energetic stress, women with similar genetic background have adopted to sedentary agriculture as Andean[3] and Mexican Pima Indians[16] through a transition phase as Ache females[12] and women in Yuwientsa. Also this transition phase thus seems to represent an increased risk for cardiovascular diseases.

ACKNOWLEDGMENT

The technical assistance of Lilian Bengtsson is gratefully acknowledged.

REFERENCES

1. Rothhammar F, Llop E, Carvallo P, et al: Origin and evolutionary relationships of native Andean populations. High Alt Med Biol 2:227-233, 2001

2. Lindgärde F, Söderberg S, Olsson T, et al: Overweight is associated with lower serum leptin in Peruvian Indian than in Caucasian women: A dissociation contributing to low blood pressure? Metabolism 50:325-329, 2001

3. Lindgärde F, Ercilla MB, Correa LR, et al: Body adiposity, insulin and leptin in subgroups of Peruvian Amerindians. High Alt Med Biol 5:27-32, 2004

4. Davis EW, Yost JA: The ethnomedicine of the Waorani of Amazonian Ecuador. J Ethnopharmacol 9:273-297, 1983

5. Pavan L, Casiglia E, Braga LM, et al: Effects of a traditional lifestyle on the cardiovascular risk profile: the Amondava population of the Brazilian Amazon. Comparison with matched African, Italian and Polish populations. J Hypertens 17:749-756, 1999

6. Tavares EE, Vieira-Filho JPB, Andriolo A, et al: Metabolic profile and cardiovascular risk patterns in an indigenous population of Amazonia. Hum Biol 75:31-46, 2003

7. Nelson RG, Sievers ML, Knowler WC, et al: Low incidence of fatal coronary heart disease in Pima Indians despite high prevalence of non–insulin-dependent diabetes. Circulation 81:987-995, 1990

8. Howard BW, Lee ET, Cowan LD, et al: Rising tide of cardiovascular disease in American Indians. The Strong heart study. Circulation 99:2389-2395, 1999

9. van Dijk G: The role of leptin in the regulation of energy balance and adiposity. J Neuroendocrinol 13:913-921, 2001

10. Havel PJ: Control of energy homeostasis and insulin action by adipocyte hormones: Leptin, acylation stimulating protein, and adiponectin. Curr Opin Lipidol 13:51-59, 2002

11. Söderberg S, Ahrén B, Stegmayr B, et al: Leptin is associated with increased risk of myocardial infarction. J Intern Med 246:409-418, 1999

12. Bribiescas RG: Serum leptin levels and anthropometric correlates in Ache Amerindians of eastern Paraguay. Am J Phys Anthropol 115:297-303, 2001

13. Mathews DR, Hosker JP, Rudenski AS, et al: Homeostasis model assessment insulin resistance and beta-cell function from fasting

plasma glucose and insulin concentrations in man. Diabetologia 28: 412-417, 1985

14. Ross EB: Food taboos, diet, and hunting strategy: The adaptation to animals in Amazon cultural ecology. Curr Anthropol 19:1-37, 1978

15. Smole W: The Yanoama Indians: A Cultural Geography. Austin, TX, University of Texas Press, 1976

16. Fox CS, Esparza J, Nicolson M, et al: Is a low leptin concentration, a low resting metabolic rate, or both the expression of the "thrifty genotype"? Results from Mexican Pima Indians. Am J Clin Nutr 68:1053-1057, 1998

17. Aronoff SL, Bennett PH, Rushforth NB, et al: Normal glucagon response to arginine infusion in "prediabetic" Pima Indians. J Clin Endocrinol Metab 43:279-286, 1976

18. Vasquez B, Nagulesparan M, Unger RH: Fasting and postprandial plasma glucagon and glucagon-like immunoreactivity are normal in obese Pima Indians. Horm Metab Res 15:218-220, 1983