ISSN 0025-7680

ORIGINAL ARTICLE

MEDICINA (Buenos Aires) 2000; 60: 109-114

DIET AND NUTRITION OF PREHISTORIC POPULATIONS AT THE ALLUVIAL BANKS OF THE PARANA RIVER

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Abstract This study attempts to characterize the health status and diet of prehistoric populations (1 000-2 000 years BP), dwelling at both banks of Parana River, between 29°S and 32°S. The data obtained suggest that these prehistoric populations had an adequate nutritional status, with complete proteins in the diet, as suggested by the ratio strontium/calcium in their bone mineral (0.71 ± 0.04 µg Srx1 000/mg Ca). The overall frequency of dental caries (4.9%) coincides with that reported for hunters-gatherers. The average mineral densities of the tibiae of adult subjects exhumed at two sites (males: 1.51 ± 0.07 gr/cm^2; females: 1.24 ± 0.06 gr/cm^2) suggested that they had significant bone mass, an asset compatible with adequate nutrition. In metacarpals, the amount of cortical tissue also suggests bone mass comparable to contemporaneous controls. The growth and development of the prehistoric populations studied are deemed normal as shown by the clear sexual dimorphism of their estimated heights at adult age (males: 177-183 cm; females 152-166 cm) and their bone mass.

Resumen ***Dieta y nutrición de poblaciones prehistóricas residentes en ambas márgenes del río Paraná***. Este estudio intenta caracterizar el estado de salud y características de la dieta de poblaciones prehistóricas (1 000-2 000 años antes del presente), residentes en ambas márgenes del Río Paraná, entre 29°S y 32°S. La relación estroncio/calcio del mineral de sus huesos (0.71 ± 0.04 µg Srx1 000/mg Ca) sugiere que estos sujetos tenían una dieta mixta, con proteínas completas de su dieta. La frecuencia de caries dentales (4-9%) coincide con la de otras poblaciones prehistóricas de subsistencia cazadora-recolectora. La densidad mineral de tibias de adultos sugiere que poseían una masa ósea comparable a la de controles contemporáneos (hombres: 1.51 ± 0.07 gr/cm^2; mujeres: 1.24 ± 0.06 gr/cm^2), compatible con una nutrición adecuada. La misma conclusión es sugerida por la proporción de hueso cortical de los metacarpianos. El crecimiento y desarrollo de estas poblaciones prehistóricas se suponen normales en función del claro dimorfismo sexual observado en la estatura de los adultos (hombres: 177-183 cm; mujeres 152-166 cm) y en sus masas óseas.

Key words: prehistoric populations, bone, bone mineral density, strontium, dental caries

Due to its remarkable plastic ability, the skeleton of a living being is an open system in active exchange with the environment. Bone tissue registers environmental phenomena and vital circumstances along its lifespan[1].

This study attempts to characterize the health status and diet of prehistoric residents (1 000-2 000 years BP), at both banks of Parana River, between 29°S and 32°S. Only preliminary reports[2, 5] have been published on these matters.

Materials and Methods

Bone collections. This study was carried out on human bones exhumed from ten sites (Table 1) at both margins of the Parana River (Middle Sector). The human osteological register is formed by individuals of both sexes and all ages. Very often, it is incomplete or fragmentary because of funerary practices and adverse preserving conditions (flooding) of the site. The bones of the deceased received a second burial (a common ritual practice) and were deposited in funerary packages of more than one individual. The reader should be aware that the number of individuals per site (Table 1) do not indicate complete skeletons.

The age of bone remains exhumed from five sites (Table 1) was determined at the *Laboratorio de Tritio y Radiocarbono, (LATYR), Universidad de La Plata).* Determination of the age of organic matter is based on the proportion of ^{14}C in the carbon sample[6, 7].

Anthropometric studies

Estimation of height. This variable was estimated by means of the length of the femurs and the use of a defined anthropometric relationship[8].

Assignment of sex. This variable was assigned by analysis of several morphoscopic attributes of crania and pelvis[9]. Male crania (compared with females) are characterized by more prominent supraorbital ridges, a more prominent glabellar region, and heavier temporal and nucal lines. Male frontals and parietal bones tend to be less bossed than females ones. Males tend

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TABLE 1.– *Origin of skeletal collections, name and approximate geographical location, radiocarbon dating and number of individuals exhumed*

Museum	Site number and name	Approximate geographical location	^{14}C Dating years BP**	N*
Arqueología y Paleontología				
(Reconquista, Sta. Fe)	1. Arroyo Aguilar	29°16'S 59°38'W	2 200 ± 50, 1850 ± 50[a]	23
	2. Nicanor Molinas	29°10'S 59°44'W	2 050 ± 60[a]	4
Regional de Alejandra				
(Alejandra, Sta Fe)	3. La Lechuza	29°54'S 59°55'W	1 750 ± 60[b]	30
Provincial de Ciencias				
Naturales y Antropológicas				
(Paraná, E. Ríos)	4. Las Mulas	29°16'S 59°38'W	1 020 ± 50[c]	10
	5. Puerto Cuartel	30°44'S 59°37'W		1
	6. Arroyo Arenal			1
Etnográfico Provincial				
(Santa Fe, Sta. Fe)	7. Isla Barranquita	31°16'S 60°27'W	1 150 ± 50[d]	17
	8. Puesto Rolancito	31°32'S 60° 7'W		4
	9. Las Garzas	31°32'S 60° 7' W		2
Universitario F. y C. Ameghino				
UNRosario (Rosario, Sta. Fe)	10. Los Marinos	32°55'S 60°31'W		28

** Number of subjects exhumed. ** Years before present (1950) ± estimated SD*

[a] *Echegoy C. Los fechados de ^{14}C de Arroyo Aguilar. Museo Municipal de Reconquista. 1994. Not published*

[b] *Reference 5*

[c] *Ceruti C. Arqueología del arroyo Las Mulas. Revista de Antropología 1990; 5: 60-67*

to have large, broader palates, squarer orbits, larger mastoid processes, larger sinuses, and greater occipital condyles than do females.

Methods used to assign sex based on pelvis morphology are based on the following tendencies: the sacrum and os coxae of females are smaller and less robust than those of males. Female pelvic inlets are wider than male ones. The greater sciatic notch on female os coxae is relatively wider than notch on male bones. Females have relatively longer pubic portions of the os coxae, including the superior pubic ramus, than males. The subpubic angle is larger in females than in males. The acetabulum is relatively larger in males than in females.

Assignment of age. This variable was assigned studying eruption and dental wear, cranial suture closure, epiphyseal closure, pubic symphysis surface, and ilium auricular surface. Age of skeletons were grouped as juvenile (approximate age: less then 12 years), subadults (approximate age: 12 to 20) and adults (more then 20 years).

Dental caries. The identification of caries[10] was done with the assistance of a magnifying glass and a dental explorer. The data presented in this report are based on permanent teeth. Enamel hypoplasia (amelogenesis imperfecta), an index of nutritional stress, was not observed during the inspection procedure. Amelogenesis imperfecta is a disturbance of enamel formation, manifested as parallel lines or bands, in the frontal surface of teeth.

Radiological studies

Bone Mineral Density (BMD). This variable was determined in leg bones (tibiae) using absorptiometry of a double beam of photons (DXA) with a Lunar instrument. Precision was 2%. Only well preserved bones were measured. The data were expressed as grams of mineral per cm^2 of the projected area.

Cortical bone volume of metacarpal bones. The external (D) and internal (d, medullary canal) diameters of metacarpal bones were measured on X-ray films, with a precision caliper at the middle of the diaphysis. The area of cortical bone is reported as the fraction of the total section area (CA/TA: cortical area/ total area) and it is calculated as $[(D^2-d^2)/D^2]$[11].

Chemical analyses

Chemical analyses were carried out on samples of cortical bone. There were brushed with a steel brush under a stream of distilled water, to remove clay deposits and debris. They were then dried oven at 110°C for ten hours.

Bone strontium (Sr) and the ratio (Sr/Ca). These elements were measured by atomic absorption spectrophotometry, as indicated by Schoeninger[12]. The data are reported as 1 000 x [Sr µg/Ca mg].

Bone strontium content (adjusted to calcium content) has been assumed to suggest the composition of the diet[28]. This hypothesis is based on two facts: a) the Sr content of vegetables is in equilibrium with that of the soil[29] and b) intestinal epithelium (as well a cell membranes) discriminates Sr against Ca in a 5:1 ratio[30]. The chemical behavior of Ca is similar to that of Sr. The metabolic fate of Sr is either to be excreted or deposited in bone mineral. It can be concluded that soft tissues of men or animals have a lower Sr content than the vegetables they feed on. The Sr content of bones from vegetarian species will be higher than that of carnivorous ones.

Bone fluorine (F) and the ratio F/Ca. Bone samples of 25-75 mg of dry bone were submitted to the Taves isothermal distillation of fluorine[13] as described elsewhere[14]. At the end of the distillation period, the acid residue was diluted further with 6M HCI containing 2% of lanthanum chloride to measure calcium[12]. The data are reported as 1 000 x [F µg/Ca µg].

Statistical analysis. Standard statistical techniques (t tests for independent groups) were employed for evaluation of the data[15].

Results

Anthropometrical studies. A total of 49 femurs were measured (25 adult females, 24 adult males) obtained from 7 sites. The data show the sexual dimorphism of healthy communities (Fig. 1). The range of heights were: males = 177-183 cm; females = 152-166 cm.

Frequency of dental caries. The teeth of 41 subadults and adults individuals, exhumed from eight sites were investigated (Table 2).

Bone strontium. The determination of the ratio Sr/Ca is assumed by some to provide information on the prevailing component (meat/vegetables) of the diet[16]. Table 3 displays the data obtained, which do not differ significantly ($P < 0.05$) from contemporary controls.

Bone fluorine. This element was measured to investigate whether the spontaneous intake of this element could have been a determinant of bone mass. The ratio F/Ca is very low (Table 3), in agreement with the low F content of soil (Site 1: 52 µmoles F/gram, Site 10:73 µmoles F/gram) or that of the river water (55 µmoles/liter, approximately 1 mg/liter or 1 ppm). The F/Ca ratio has a theoretical maximum of 95 for fluorapatite [$Ca_{10}(PO_4)_6F_2$].

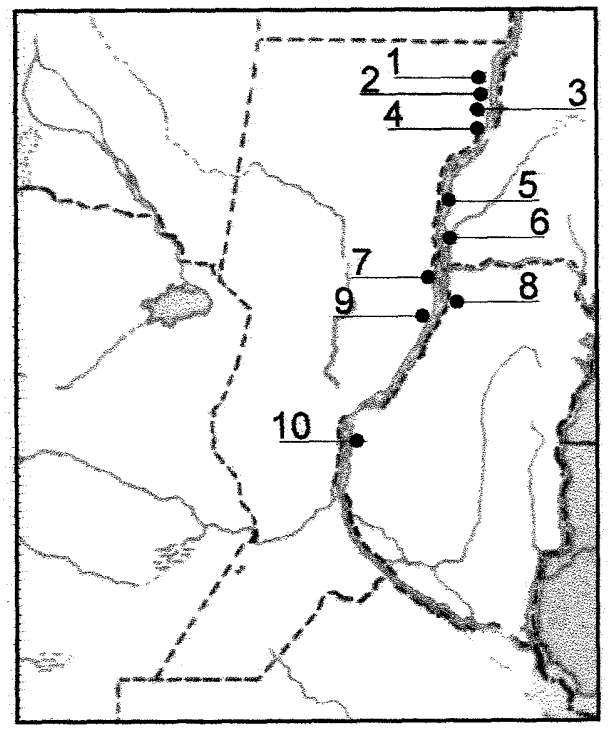

Fig. 1.– Approximate geographical location of acheological sites at the Middle Sector of the Parana River. The figures identifies the sites described in Table 1.

TABLE 2.– *Frequency of caries*

	Individuals	Teeth	Caries	Frequency %
Site 1	9	245	8	3.2
Site 2	1	9	1	11.0
Site 3	10	185	12	6.4
Site 6	2	39	0	0.0
Site 7	7	46	6	13.0
Site 8	1	4	0	0.0
Site 9	1	31	0	0.0
Site 10	8	64	4	6.2
Total	39	623	31	4.9

TABLE 3.– *Sr/Ca and F/Ca ratios in cortical bone*

	[µg Sr/mg Ca]x1000	[µg F/µg Ca]
Contemporary controls	0.77± 0.10[9]	0.27±0.02[9]
Site 1	0.70 ± 0.13[18]	0.27 ± 0.02[16]
Site 3	0.69 ± 0.27[7]	
Site 4	0.73 ± 0.08[10]	0.28 ± 0.02[10]
Site 5	0.55, 0.77	0.15, 0.42
Site 6	0.67, 0.79	0.22, 0.23
Site 7	0.68	0.30
Site 8	0.78 ± 0.03[4]	0.26 ± 0.02[3]
Site 9	0.76 ± 0.04[4]	0.26 ± 0.01[3]
Site 10	0.75 ± 0.25[5]	

The figures indicate the mean±standard error (n)
Sr/Ca and F/Ca ratios of prehistoric bone do not differ from contemporary controls

Estimations of bone mass. Two operational definitions of bone mass were used in this study. The BMD is a measure of the mineral content of a given bone normalized by the area of the bone projection on a plane at right angle with the photons beam. Table 4 displays the values for tibiae of subjects exhumed from sites 1 and 3. Pooling the data of these sites, the difference between sexes is significant ($P = 0.015$).

The reader should note that no contemporary reference values for tibiae are available. The closest reference available is that of leg BMD values (averaging femur, knee, tibia, perone and foot): men (20-40 years): 1.31±0.09 g/cm^2 (n=40)[11]; women (20-40 years), 1.13±0.09 g/cm^2 (n=40) (Personal communication of authors of ref. 11). The tibiae of the Anatomy Museum were discarded because no data were available on the clinical history of those subjects.

TABLE 4.– *Bone mineral density of tibiae, adult subjects*

	BMD, g/cm^2
Site 1	
Men	1.56 ± 0.10[4]
Women	1.22 ± 0.12[2]
Site 3	
Men	1.48 ± 0.10[6]
Women	1.27 ± 0.05[3]

The figures indicate the mean±standard error of the mean (n)
The reader should note that no contemporary reference values for tibiae are available.
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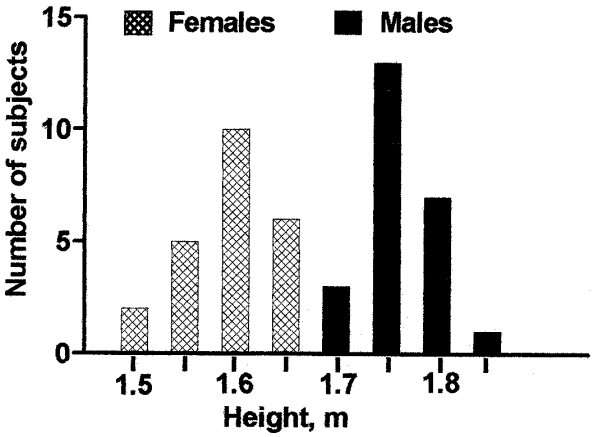

Fig. 2.– Distribution of stature estimates. The figures of the abcissa indicate the begining of each class. Class width is 5 cm.

The morphometric study on metacarpals measures the amount of cortical bone. Because of the number of available metacarpals, this variable was measured in skeletons exhumed at site 1. The bone mass of these prehistoric aborigins (0.81 ± 0.04, n = 9), do not differ significantly (P > 0.05) from contemporary standards for men and women 25-50 years (Cortical area/Total area: 0.77±0.22, n=48)[11].

Discussion

The archeological registers of the sites investigated in this study share similar cultural patterns (mortuary practices, ceramic design, instruments technology). They belonged to the entity called *ribereños plásticos*[18] or Goya-Malabrigo[19]. These individuals lived in the alluvial banks of the Paraná and (a sector of) Uruguay Rivers. They produced pottery with geometric and zoomorphic designs (jaguars, monkeys, ducks, snails and parrot heads). These designs may be interpreted to indicate that their subsistence was based on fishing and hunting.

Climatic conditions have been assumed to remain constant along the time span alluded in this study.

Growth and development are the result of an extremely complex interaction of genetical, environmental and nutritional factors. The main objective of this study is to define (by inference) the quality of nutrition as revealed by the archeological register. Under nutritional stress conditions, growth rate decreases (or stops) until the availability of nutrients improves. Growth is a very useful indicator of the degree of environmental stress[9, 20].

Under severe and prolonged nutritional stress[21] sexual dimorphism vanishes. Because it last longer, pubertal growth of males is more sensitive (than in females) to prolonged nutritional stress. It can be assumed that sexual dimorphism depends on environmental conditions (availability of food and energetic equilibrium). The strategy of reproduction in our species appears to guarantee a greater genetical-environmental stability for women than for men[22]. The difference in height and bone mineral density associated to sex (Fig. 1, Table 4) clearly suggests that the individuals under study did not suffer nutritional stress.

It is reasonable to assume that adequate nutrition during growth and development is an essential condition to attain peak bone mass. However, experimental support for this idea began to accumualte only recently. In some modern studies[23, 24] significant positive associations between protein intake and bone mass have been observed. In one of these studies[24], the associations were not altered by adjustment for age, weight and physical activity. In another[25], vertebral and metacarpal morphometric measurements were carried out in two groups of women. One group was born during a period of widespread malnutrition (Spain, 1934-1944). The other was formed by women born between 1960-1970, a period considered as having normal nutrition. Protein, carbohydrate and fat intakes and morphometric indices were significantly better (P < 0.001) in the second group. It is clear then, that significant bone mass (and growth) can be attained only with adequate nutrition.

When flooding of the burial site is recurrent, the close contact of bone with soil for long periods, allows to exchange elements (diagenesis process) that may affect BMD measurements. The bones of men and women studied here must have undergone similar diagenetic processes. The persistence of sexual dimorphism of BMD supports the hypothesis of equilibrated nutrition in these populations. According to current standards, the bone mass of these prehistoric aborigines can be qualified as normal or normal-high.

The frequency of dental caries is a function of diet. Carbohydrate-rich diets tend to increase caries frequency. Turner[26] observed a frequency of caries 0.0-5.3% for hunters-gatherers, 0.44-10.3% for mixed diets and 2.2-26.9% for farmers. Similar frequencies have been reported by Larsen[27]. The observed frequency of dental caries (Table 2) coincides with that of hunters-gatherers.

The data displayed in Table 3 suggest that the communities investigated had a mixed diet, in agreement with that reported for human skeletal remains found in the natufian level at Hayonim Cave[31] (0.77 ± 0.10, mean ± SD; Israel, 9 970 ± 90 BC). Bones of animals with vegetarian and carnivorous habits had Sr/Ca ratios 0.62 ± 0.13 and 0.98 ± 0.08, respectively[31]. The Sr/Ca ratio of modern controls does not differ significantly from the prehistoric samples. The bone remains of a fox found at site 10, produced a Sr/Ca ratio of 0.43 congruent with mammals known to have a diet with high meat content.

The interpretation of the Sr/Ca ratio is not straightforward. It is complicated by diagenesis (sample contamination with soil components). Unknown metabolic considerations act as confounding factors (diet, pregnancy, lactation, food with different Sr/Ca ratios incoming into the alimentary chain, etc.). In addition, for some investigators[32] the ratio is only an indication of the intake of calcium.

As stated in Results, the bone fluorine content is low, in agreement with that of soil and water.

Final comments. The data obtained suggest that prehistoric subjects, living at both margins of the Parana River (Middle Sector) from 2 000 to 1 000 BP, had an adequate nutritional status, with complete proteins in the diet. They had significant bone mass, an asset compatible with adequate nutrition. Their growth and development are deemed normal as suggested by their height and bone mass (in absolute values) and the sexual dimorphism in these variables.

Acknowledgements: The authors received the assistance of the following persons during this work: Lic. Carlos Ceruti (Museo Provincial de Ciencias Naturales y Antropológicas "Prof. A. Serrano", Paraná (E. Ríos)), Arq. Luis M. Calvo (Museo Provincial Etnográfico y de Estudios Coloniales, Santa Fe (S. Fe)), Prof. Dante Ruggeroni and Prof. Carlos Etchegoy (Museo Municipal de Arqueología y Palentología, Reconquista (S. Fe) facilitated access to the bone collections of the museums under their direction; Dra. Silvia Bidut (Museo Regional de Alejandra, S. Fe) trained and adviced one of the authors (S.C.) in the detection of dental caries; Dr. Juan C. Podadera performed X-rays studies; Drs. Daniel Mailand and Ariel Sanchez did the bone densitometric measurements; Dr. Alfredo Rigalli measured bone fluoride and Lic. Fátima S. Banfi (Museo Universitario "F. y C. Ameghino", Rosario (S. Fe) provided most valuable assistance.

This study was partially supported by a grant from the Agencia Nacional de Promoción Científica y Tecnológica (BID 802/OC-AR, PICT N° 05-00000-01876). RCP is Principal Investigator, CONICET (Consejo Nacional de Investigaciones Científicas y Técnicas).

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A famous Victorian story reports the reaction of an aristocratic lady to the primary heresy of her time: "Let us hope that what Mr. Darwin says is not true; but if it is true, let us hope that it will not become generally known". Teachers continue to relate this tale as both a hilarious putdown of class delusions (as if the upper crust could protect public morality by permanently sequestering a basic fact of nature) and an absurdist homely about the predictable fate of ignorance versus enlightenment. And yet, I think we should rehabilitate this lady as an acute social analyst and at least a prophet. For what Mr. Darwin said is, indeed, true. It has also not become generally known, at least in our nation.

En un famoso cuento victoriano, una señora aristocrática, frente a la principal herejía de su tiempo, reacciona de esta manera: "Espero que lo que dice el Sr. Darwin no sea cierto; pero si fuera cierto, espero que no llegue a difundirse". Los maestros siguen contando este cuento tanto como un ejemplo comiquísimo de las ilusiones de clase (como si la clase alta pudiera proteger la moralidad pública secuestrando un hecho básico de la naturaleza) y como un dicho absurdo sobre el destino predecible de la ignorancia versus la explicación. Y sin embargo, creo que tendríamos que rehabilitar a esta señora como una aguda analista social o al menos una profeta. Porque lo que dijo el Sr. Darwin es, indudablemente, la verdad. También, en general, no ha sido reconocido como tal, por lo menos en nuestra nación.

Stephen Jay Gould

Darwin's more stately mansion. *Science* 1999; 284: 2087