Comprehensive Summaries of Uppsala Dissertations
from the Faculty of Medicine 1321

Health and Nutrition in the Tarahumara of Northern Mexico

Studies among Women and Children

BY

JOEL MONÁRREZ-ESPINO

ACTA UNIVERSITATIS UPSALIENSIS
UPPSALA 2004

Dissertation presented at Uppsala University to be publicly examined in Rosensalen, University Hospital, Uppsala, Monday, March 8, 2004 at 09:15 for the degree of Doctor of Philosophy (Faculty of Medicine). The examination will be conducted in English.

Abstract

Monárrez-Espino, J. 2004. Health and Nutrition in the Tarahumara of Northern Mexico. Studies among Women and Children. (Hälsa och nutrition hos Tarahumara indianer i Norra Mexiko. Studier på kvinnor och barn). Acta Universitatis Upsaliensis. *Comprehensive Summaries of Uppsala Dissertations from the Faculty of Medicine* 1321. 95 pp. Uppsala. ISBN 91-554-5866-1

Belonging to an indigenous group in Mexico is usually associated with poor health, mainly as the result of social isolation from the mainstream society. The Tarahumara are no exception. They constitute the largest indigenous group in northern Mexico and one of the most marginalized ethnic minorities in North America. Health conditions are precarious, yet very little data are available to facilitate the design and implementation of programs to prevent and manage the main public health problems affecting this people. This thesis aims at overcoming part of this information gap. It presents and discusses the results from studies focusing on the nutrition of women and children carried out between 1997 and 2002.

A survey in a representative district sample of Tarahumara women of reproductive age found the highest prevalence of anemia among pregnant women in their third trimester (38.5%) and those lactating during the first 6 months after delivery (42.9%), along with a high prevalence of iron deficiency. In this study a technique was developed to collect capillary serum samples spotted onto filter paper to measure serum ferritin in remote settings. In the same study, 52.5% of adult women were overweight, suggesting a process of 'de-Indianization' of their traditional diet and activity patterns. This issue was followed-up in a later study based on perceptions of food and body shape using cognitive anthropological methods. Speaking Spanish emerged as a clear indication of acculturation that could be associated with an increase in the prevalence of obesity and its consequences. A nutrition survey among Tarahumara children at boarding schools found evidence of zinc, vitamin B_{12}, iron, and iodine deficiencies but found similar anthropometric status to other rural Mexicans. Finally, a qualitative assessment was carried out to identify culturally accepted foods to redesign a food aid basket aimed at alleviating malnutrition among young Tarahumara children.

The results from this thesis provide relevant data for an improved design of interventions to combat and prevent some of the nutritional problems that affect the Tarahumara. These data could also constitute a baseline to which future changes can be compared if similar sampling strategies are used. Overall, the findings highlight the importance and challenge of achieving modernization in a way that not only improves health but at the same time supports, maintains and encourages traditional cultural values. These are not only the foundations of the Tarahumara society, but in some cases also contribute to a better diet and health.

Keywords: acculturation, anemia, anthropometry, body shape, cognitive anthropology, qualitative methods, ferritin, food, indian, infant feeding, malnutrition, Mexico, micronutrients, obesity, overweight, Raramuri, school children, Tarahumara, westernization, women

Joel Monárrez-Espino, Department of Women's and Children's Health, Uppsala University, SE-75185 Uppsala, Sweden

ISSN 0282-7476
ISBN 91-554-5866-1
urn:nbn:se:uu:diva-3987 (http://urn.kb.se/resolve?urn=urn:nbn:se:uu:diva-3987)

Att tänka fritt är stort, men att tänka rätt är större

a Irma

Mírame, madre, y por tu amor no llores
Si esclavo de mi edad y mis doctrinas
Tu mártir corazón llené de espinas
Piensa que nacen, entre espinas, flores

José Martí

ORIGINAL PAPERS

This thesis is based on the following papers, which will be referred to in the text by their Roman numerals:

I. Monárrez-Espino J, Martínez H, Greiner T. Iron deficiency anemia in Tarahumara women of reproductive-age in Northern Mexico. Salud Publica Mex 2001;43:392-401. [Monárrez-Espino J, Greiner T. Measuring serum ferritin under field conditions. Am J Clin Nutr 2002;76:1138]

II. Monárrez-Espino J, Greiner T. Anthropometry in Tarahumara Indian women of reproductive age in northern Mexico: Is overweight becoming a problem? Ecol Food Nutr 2000;39:436-457.

III. Monárrez-Espino J, Caballero-Hoyos R, Greiner T. Perception of food and body shape as dimensions of Western acculturation potentially linked to overweight in Tarahumara women of Mexico. Ecol Food Nutr 2004 (in press).

IV. Monárrez-Espino J, Martínez H, Martínez V, Greiner T. Nutritional status of indigenous children at boarding schools in northern Mexico. Eur J Clin Nutr 2004 (in press).

V. Monárrez-Espino J, Greiner T, Martínez H. A rapid qualitative assessment to design a food basket for young Tarahumara children in Mexico. Scand J Nutr 2004 (in press).

Reprints were made with permission from the publishers

CONTENTS

PREFACE

"La Nación mexicana tiene una composición pluricultural sustentada originalmente en sus pueblos indígenas"
Artículo 4. Constitución Política de México

"The Mexican Nation has a multicultural composition sustained originally in its indigenous peoples"
Article 4. Political Constitution of Mexico

Since I started working with the Tarahumara nearly ten years ago, statements from medical professionals working at local clinics have been increasingly calling attention to the increase in infant deaths linked to malnutrition among the Tarahumara people.

These statements, with the help of the mass media, have turned the Tarahumara health situation into a political agenda. This eventually results in the allocation of human and financial resources to the various organizations working in the region, as if this would automatically solve the problems.

However, scientific evidence backing up such statements is never provided, as if these anecdotal reports were adequate and sufficient to summarize the entire Tarahumara health situation. Moreover, very little, if anything, is done to identify and document other less visible public health problems that might also be affecting the members of this indigenous group.

Generating awareness of a potential public health problem is usually the first step when attempting to alleviate it. Followed by obtaining detailed information on the magnitude, characteristics and determinants of these problems, leading to the design and further implementation of better targeted interventions. What is more, these data often constitutes the baseline reference to evaluate the impact of the secular change, as well as any intervention programs undertaken.

Obtaining accurate and comprehensive population-based information is essential to understand and eventually overcome health problems at population level. On the

other hand, prioritizing and targeting the interventions to the most vulnerable groups is imperative in areas where the available means are scarce, not only because it is the most efficient way to utilize the limited resources, but also because it increases the likelihood of improving the health indicators of concern, which in turn will have a positive effect on the programs' sustainability.

The Tarahumara Indian of northern Mexico is one of the most isolated and deprived ethnic communities in North America. Although this isolation has had a "positive" effect by preserving the Tarahumara traditional culture, it also has resulted in marked health and educational deficits compared to Mexican standards, even when compared with most other indigenous groups in the country.

Low immunization coverage, gastrointestinal infections, parasite infestations, pneumonia, tuberculosis, and malnutrition are prevalent among Tarahumara children. Various governmental and non-governmental organizations have attempted to deal with some of these issues. However, most of their activities have been carried out at individual level within the frame of curative medicine. Unfortunately, prevention and rehabilitation still play very minor roles in these endeavors.

Even though some health and nutritional problems affecting the Tarahumara have been recognized, especially protein-energy malnutrition among infants, many other problems have not yet been acknowledged, hence no programs are devised to prevent or tackle them. The coexistence of micronutrient deficiencies is an example of an issue where the local health authorities have paid little attention.

Women's health and nutrition also constitutes one of the most neglected areas of concern. The notion still persists that lack of food is "the problem" among the Tarahumara, ignoring many others. For instance, emphasizing the health risks linked to the overweight seen among adult Tarahumara women can sound naïve or of secondary importance to many policy and decision makers in the area. Health

care for these women has been limited to trying to provide some prenatal care and family planning.

Therefore, this thesis aims at identifying and characterizing some of the various nutritional problems affecting the Tarahumara children and women of fertile age. With this work, I hope to be able to create awareness of some public health problems affecting the Tarahumara that have not yet been recognized, and to provide detailed data to assist in designing pertinent interventions intended to improve the health of this people that can be translated into a better life.

INTRODUCTION

The Tarahumara

Inhabiting the southwestern quarter of Chihuahua State, the Tarahumara or *Rarámuri* (foot runners), as they are known in their language, are the most numerous indigenous group in northern Mexico (INEGI, 2001), and were once described as one of the least affected by modern society (Kennedy, 1978).

The Tarahumara belong to the cultural area called the Greater Southwest, which includes the States of Arizona, New Mexico, and Western Texas in the United States, and the Mexican States of Sonora and Chihuahua. Linguistically, their language belongs to the Taracahitan family of the Uto-Aztecan stock, which extends from central Mexico up to Utah (Grimes, 2000).

They number approximately 80,000 people and represent nearly 3% of the State population and 1% of the total indigenous population in the country (INEGI, 2001). They share with the mestizo (of mixed European -mainly Spanish- and indigenous ancestry) the barren wilderness of the Sierra Madre Occidental, in an area called *Sierra Tarahumara*.

Their ability to preserve their cultural integrity is derived chiefly from the fact that their environment is among the least hospitable in North America. They differ from other indigenous groups in Mexico in that the central stronghold of their distinctive culture is still relatively intact and in that in their communities are almost independent of outside control (Champion,1962: "There have been no significant or basic changes in the culture of the Tarahumara since at least 1700"; Kennedy, 1963: "There is an amazing correspondence between what Lumholtz found in 1896 and what I found in 1960").

Historical review

The Spaniards originally encountered the Tarahumara in the eastern edge of the *Sierra Tarahumara* upon arrival in the late sixteenth century, but as they encroached on their civilization, the Tarahumara retreated to unreachable regions in the mountains and gorges. The main factors leading the Spaniards to settle in this area were the search for mineral or other wealth, and, in the case of missionaries, to Christianize the Indians.

Understanding the Jesuit era (1607-1767) is essential in understanding the Tarahumara culture. The Jesuits settled 28 missions and 50 pueblos, and converted to Christianity nearly half of the Tarahumaras (Dunne, 1948). The basic structure of the Tarahumara economy was established during the Jesuit era through the introduction of domestic animals, European fruits, and new tools, including the ax and the wooden plow.

From 1767 to 1825 the Tarahumaras were left rather alone because the country was involved in the struggle that led to Mexican independence in 1821. During this time, the Tarahumara enjoyed a period of relative peace and isolation, as they were very little affected by the Franciscan missionaries who replaced the Jesuits after their removal in 1767 (Pennington, 1963).

The Mexican independence brought new laws aimed at abolishing the status "Indian" and recognizing only "Mexicans" with equal rights. Uncultivated public lands were open for homesteading colonization to anyone who would settle them, but most Tarahumaras did not understand these laws and many were not interested in returning to mission towns. The mestizo took advantage of this and penetrated into the area, driving the Indians away from much of the good land that they still held (Lumholtz, 1902).

The Jesuits came back to the region in 1900, along with government intention to assist the Indians towards betterment of their lives. However, the revolution of

1910 hindered the efforts of both Church and State to deal with the problems of the Indians. Governmental attention was aroused again in 1934 when the Department of Indian Affairs was created to avoid the mestizo encroachment onto Indian lands. A few schools were started in an effort to teach reading and writing in the indigenous language, yet the content and the values of what was taught expressed the ideals of Mexican nationalistic culture, resulting in the generation of partially acculturated people who remained in servile positions around mestizo towns and were unable or unwilling to return to their own communities (Kennedy, 1978).

In 1952, the National Indigenous Institute was created to provide land, education and health to the indigenous people. The Tarahumara Coordinating Center was established in Guachochi and in 1961 the first indigenous boarding school was opened (Romano, 1992).

Between 1950 and 1980 many new roads were constructed in the region resulting in the exploitation of the Tarahumara forest. Many small merchants opened stores and money increased greatly in use and significance among the Tarahumara. Some Indians were hired for commercial interests because they accepted lower wages. Nevertheless, those who participated in the economy were the few acculturated Indians, rather than a majority of the ethnic group (Kennedy, 1990).

At the present time, the Tarahumara communities are relatively autonomous. They have their own officials, who govern their internal affairs by a set of rules and procedures differing from the Mexican laws and practices common to the mestizo. This system handles cases and disputes between members of the community except cases of murder or serious injury from attempted murder where the guilty party is taken to the authorities under Mexican law.

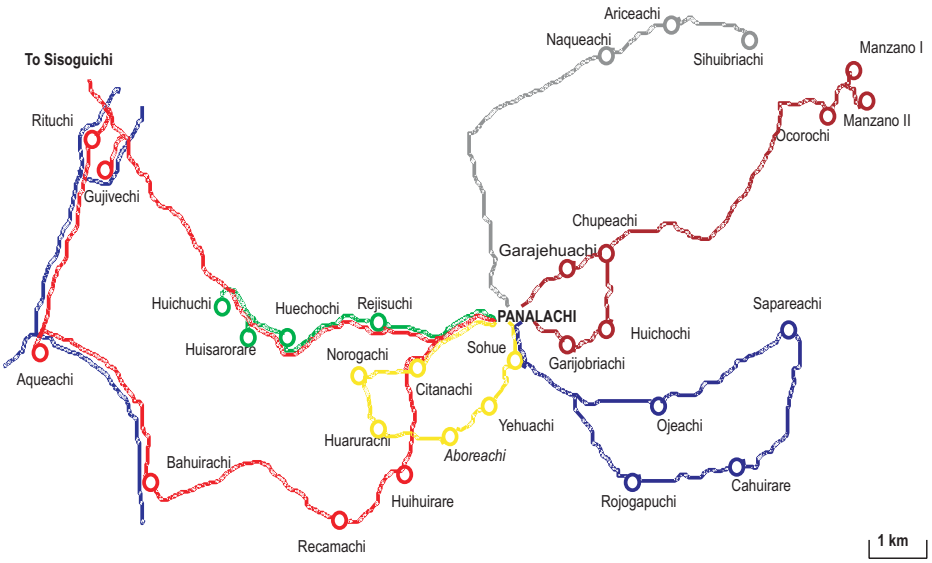
The relationship between the mestizo and the Tarahumara has always been adversarial. The mestizos call themselves “los de razón” (those of reason) reflecting their self-image of superiority. Animal qualities, laziness, simple-

mindedness, and filthiness are believed to be innate to the Tarahumara. Sierra mestizo value light skin and associate it with intelligence and civilization. The Tarahumara call the mestizo "*chavóchi*", a term with derogatory implications, which connotes "disliked outsider".

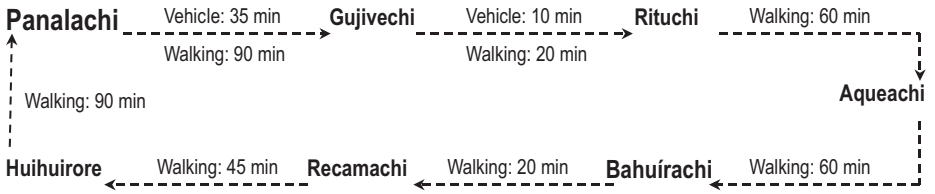
Most mestizos in the area still attempt to draw the Tarahumaras into the net of their cultural assimilation, leaving many Tarahumaras teetering between their traditional lifestyle and the assimilation into the Mexican culture.

Living conditions

Tarahumaras live in small, loose, scattered ranch clusters (*ranchería* or *comunidad*) with houses and cultivation plots dispersed along valleys and hillsides. Households may be separated from each other by several kilometers and can be accessed through narrow trodden routes. These settlements are not particularly stable. During the harsh winter months, many Tarahumaras move to the deep gorges to escape the rigorous cold. The following map exemplifies a route system to access small Tarahumara localities (<10 houses) in the municipality of Bocoyna, Chihuahua.



The time required to travel a route varies, but it can take from a few hours to more than a day. The following scheme presents the estimated time needed to travel the red route.



In most areas, Tarahumara housing is more precarious than that of the rural poor in Mexico. In fact, Tarahumaras live in notably poorer socioeconomic conditions compared to the national average for indigenous groups (Table below). Dwellings primarily consist of a one-room log or stone house with a dirt floor and a storage hut. Furniture is quite scarce, often consisting of only a table and a few chairs. Water, electricity, and sewage disposal are practically nonexistent (Monárrez-Espino, 1998; CONAPO and INI, 2002).

Selected socioeconomic indicators (%) for Mexican localities with ≥40% of indigenous population

	Electricity	**Water**	**Sewage**	**Literacy**	**Income from salary**
All indigenous groups	79.3	57.3	27.0	68.9	69.3
Tarahumaras	8.7	21.1	3.4	46.1	43.5

Source: CONAPO and INI, 2002

Although the precarious health conditions of the Tarahumara have been widely recognized, they have been poorly documented. Only a few studies have called attention to the low immunization coverage, high rates of respiratory and diarrheal diseases (Monárrez-Espino, 1998), and high mortality rates (95 per 1000 live births) among infants (Fernandez, 1992).

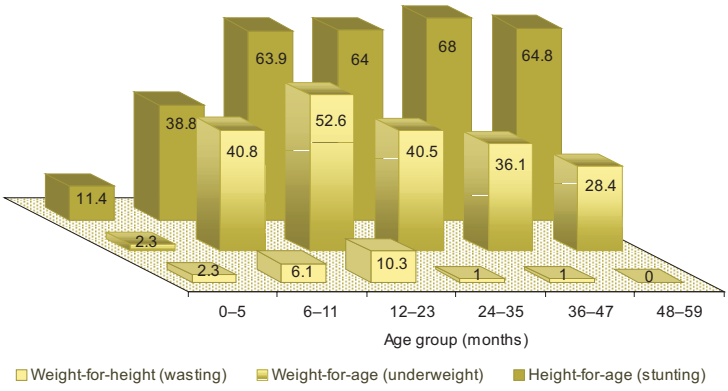
The Tarahumara infant mortality rate is nearly double that of the national

indigenous infant mortality rate and triple that of the overall national infant mortality rate (Gómez de León and Partida, 1992). Education conditions are also poor. High illiteracy rates still prevail, above all among women, and only a fraction of the population finishes primary school (Monárrez-Espino, 1998). Even though agricultural conditions are unfavorable due to the thin soils with poor capacity to absorb humidity and fertilizers (Arriaga *et al.*, 2000), homestead agriculture is the basis for subsistence. Crops are grown in small pockets of suitable soil. The land produces an average of 300-450 kg of maize per hectare (Monárrez-Espino, 1998), which is just sufficient for survival. However, droughts affect the area cyclically, resulting in famine and malnutrition among young children.

Food is largely based on vegetable products, of which the staples are maize tortillas and beans. The Tarahumara also grow potatoes, green peas, broad beans, and squash, and collect edible weedy plants (*quelites*) used as potherbs (Bye, 1981). *Quelites* are alternative food supplies during the critical period before crops mature. Among the most common eaten by the Tarahumara are *"basolí"* (Amaranthus palmeri), and *"mequasare"* (Brassica tarahumara). In fact, it has been estimated that adult Tarahumaras can consume 100-150 g of fresh *quelite* per day from April to September (Bye, 1979).

Infant malnutrition

Children's anthropometry typically reveals extensive signs of chronic malnutrition. A large percentage (57.1%) of children under five years old are stunted (height-for-age <-2 SD) but only a low percentage (3.5%) is wasted (weight-for-height <-2 SD) (Monárrez and Martínez, 2000). However, wasting is more prevalent and severe in children aged 6-23 months (10.3%) (Figure below), and is probably often associated with death . In most years, high numbers of child deaths are reported in the local hospitals due to infectious diseases along with



Health authorities have focused on the high fatality rate associated with malnutrition among Tarahumara children. In an attempt to alleviate the problem, various governmental and non-governmental agencies have established food aid projects, some entailing the delivering of free food baskets to Tarahumara families.

However, the foods included in the food baskets offered to the Tarahumara are rarely tailored to their cultural beliefs regarding to young child feeding practices, so they may not reach the young child and thereby may have little if any impact in increasing food intake in this group.

Photographs Joel Monárrez-Espino

Although the benefits associated with supplementary feeding programs for children, including prevention of starvation and growth failure, treatment of current malnutrition, control of morbidity and mortality, promotion of normal physiological and psychological development, and micronutrient

supplementation, have long been the focus of debate (Beaton, 1993), recent epidemiological evidence indicates that nutritional supplementation programs, along with other measures, such as nutrition education, during early childhood can prevent malnutrition (Shrimpton *et al.*, 2001).

Direct food aid supplementation, such as that provided by the government for Tarahumara children, can only succeed if a combination of actions is employed, including nutrition education and a community participation component, and if the items included in the food basket are culturally acceptable to the recipients.

However, it is crucial to keep in mind that the climate conditions, the limitations in labor surface, and the accessibility to fertilizers and pesticides have, together with other factors, a considerable effect on the Tarahumara agricultural productivity. The balance between these factors is frequently difficult to maintain and small changes in its components can influence the volume of crops leading to insufficient amounts of food in the household. This eventually leaves small children at increased risk of malnutrition, as families need to struggle to ensure that the working members remain fit to keep on working. But even when there is enough food to meet energy needs, food might not be divided within the household according to need, nor might all micronutrient requirements be met.

On the other hand, the Tarahumara have never been object of any wide-ranging intervention aimed at creating jobs to increase the income level of the families. The food industry has never been developed and the scarce transfer of subsidized food has been insufficient and ineffective. Therefore, any punctual intervention to combat infant malnutrition that is not accompanied with broader development measures will not be able to prevent its recurrence.

Malnutrition

Social and economic development requires an adequately nourished, intelligent and productive population. Reducing malnutrition can have a profound effect on child survival, women's health, educational attainment and worker productivity.

Malnutrition is usually the result of a combination of inadequate dietary intake and infection. It contributes to more than 10% of all deaths worldwide (Murray and Lopez, 1996), with much of this toll arising from low consumption of protein, energy, and key micronutrients (World Bank, 1993).

Protein-energy malnutrition (PEM) affects every fourth child worldwide: 150 million (26.7%) are underweight while 182 million (32.5%) are stunted. Geographically, more than 70% of PEM children live in Asia, 26% in Africa and 4% in Latin America and the Caribbean (WHO, 2003). Poverty is the root cause of most malnutrition. In fact, one out of every five people in the developing world does not have access to enough food for a healthy living (FAO, 1996). Many poor families lack the economic, environmental, or social resources to purchase or produce enough food.

In rural settings such as in the Tarahumara, land scarcity and degradation, soil erosion, and droughts undermine the family's ability to grow enough food. Other environmental factors also limit the adequacy and variety of the diet. The geography and soil characteristics influence the amount of nutrients commonly found in food. For instance, mountainous areas are often deficient in iodine (WHO, UNICEF, ICCIDD, 1993).

In children, malnutrition is synonymous with growth failure. Malnourished children are shorter and lighter than they should be for their age. Growth failure in children results not only from a deficiency of protein and energy but also from an inadequate intake of vital minerals and vitamins.

Although the terms “malnutrition”, “undernutrition”, and “PEM” have been generally utilized to describe abnormal anthropometric findings, they should not be associated solely with hunger or inadequate dietary intake since abnormal findings related to excess intake leading to overweight and obesity, more and more common in developing countries, also indicate a form of malnutrition.

Nutrition surveys are commonly used to assess the magnitude and geographic and demographic distribution of nutritional deficiencies, as well as related factors (e.g.

socioeconomic, food intake, clinical symptoms). Survey results are used for policy formulation and program planning, and as a baseline for future evaluations, providing program planners with critical information about the effectiveness of interventions.

Anthropometric status in schoolchildren

Anthropometry has been widely used for several purposes, including the identification of individuals or populations at risk of malnutrition, the selection of individuals or populations for an intervention, and the evaluation of the effects of changing nutritional, health, or socioeconomic influences (WHO, 1990). The basic measurements to construct anthropometric indices are weight and height, which can be expressed in terms of Z-scores, percentiles, or percent of median to compare an individual or group to a reference population. For population-based applications, Z-scores are usually preferred as they allow the mean and standard deviation to be calculated (WHO, 1995).

An anthropometric indicator relates to the use or application of indices (e.g. the proportion of children below a certain level of weight-for-height in comparison to an accepted international growth standard). Indicators can be classified according to the objective of their use (e.g. reflect past or present risk). A good indicator is one that best reflects the issue of concern or predicts a particular outcome; thus, the selection of a cut-off point for an indicator is a trade-off between sensitivity and specificity. At the present time, conventional cut-offs are recommended based on the NCHS/WHO reference data (NCHS, 1977).

Three anthropometric indices are used as the main criteria for assessing the adequacy of diet and growth in infants and young children: height-for-age (stunting), weight-for-age (underweight), and weight-for-height (wasting/overweight). However, anthropometric findings alone do not define the process leading to malnutrition.

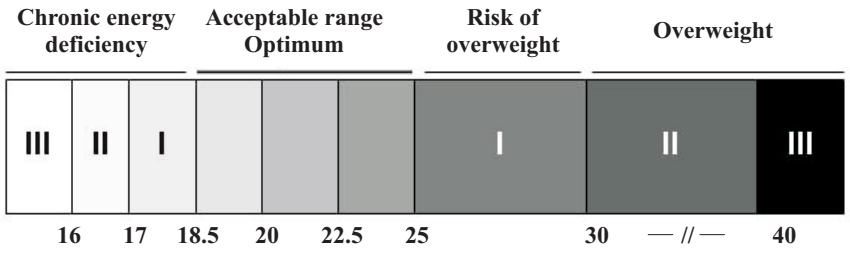
Currently, the WHO Expert Committee (WHO, 1995) recommends the use of

weight-for-height Z-score (WHZ) to assess wasting (<-2 SD) and overweight (>2 SD) in children aged 6-9 years, and height-for-age Z-score (HAZ) to evaluate stunting (<-2 SD) among those aged 6-12 years using the NCHS/WHO population reference (NCHS, 1977). Assessing stunting in older children is not recommended, as its interpretation is difficult in the absence of sexual maturity indicators. In children aged 10-14 years it is also possible to use the new CDC international reference (NCHS, 2002) using the Body Mass Index (BMI)-for-age percentile to define underweight (<5th), risk of overweight (85-95th) and overweight (>95th).

Overweight in adolescent and adult women

Obesity constitutes a major public health concern in many developed and developing countries, as it is associated with several chronic diseases such as non-insulin dependent diabetes mellitus, essential hypertension and various cancers. It occurs when energy intake exceeds energy expenditure. This excess is stored in adipose tissue in the form of triglycerides, and is associated with increased morbidity and mortality (WHO, 1990).

However, because fat mass in the human body is very difficult to measure under field conditions, overweight, defined as an excess of weight relative to height, is preferred as a practical indicator of obesity. Overweight calculations are based on the BMI or Quetelet's Index, which relates weight to height (kg/m^2). In adults, the recommended cut-off values (Figure shown below) are appropriate for identifying the extent of overweight in individuals and populations, as they are associated with adverse health consequences, particularly mortality (WHO, 1995; Troiano *et al*., 1996).



Adolescent anthropometric dimensions vary widely mainly due to differences in the timing, intensity and duration of the growth spurt (Roche and Davila, 1974; Eveleth and Tanner, 1990), which is determined by genetic inheritance and environmental influences (Tanner, 1962; Malina and Bouchard, 1991).

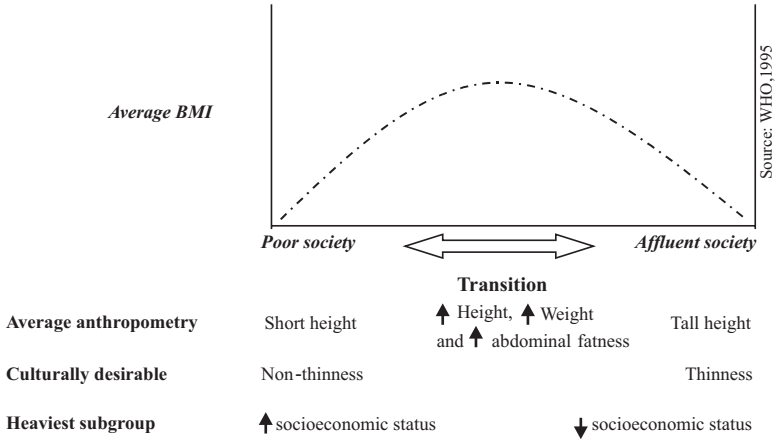
In adolescents, there are still no well-defined BMI cut-off points that relate to specific health risks, and therefore statistical cut-offs are conventionally used as follows:

Indicator	Anthropometric Index	Cut-off values
Stunting	Height-for-age	< 3rd percentile or <-2 Z-scores
Thinness	BMI-for-age	< 5th percentile
At risk of overweight	BMI-for-age	>85th percentile
Obesity	BMI-for-age	>85th percentile

Several factors are responsible for the occurrence of overweight. Age, sex and physiological status are important biological determinants; socioeconomic status, educational level and marital status constitute the most common social determinants; and physical activity, alcohol consumption and smoking habits are among the important behavioral determinants (WHO, 1995).

Socioeconomic levels, degree of industrialization and urbanization, present and previous undernutrition, infection and chronic disease may limit growth to an important extent. Where health-related factors limit the full genetic expression, the observed growth and maturation will reflect the environment more than the inherited potential (Proos, 1993).

Social, cultural, and behavioral factors are important factors in the occurrence of overweight in traditional societies (Figure below). High-fat diets combined with low levels of physical activity are responsible for the increase of overweight that accompanies the transition from poverty to affluence (WHO, 1990).



In the last few decades, obesity has become a major public health concern among several Native American groups in United States (Story *et al*., 1999), secondary to the relative abundance of high-fat foods and to a decreased physical activity pattern (Byers 1992). The Tarahumara, ethnically related to some of these Native American groups, might be following the same pattern, as constant and intensive *mestizo* (Western) pressure could be altering their traditional food consumption and physical activity patterns, and this may be reflected in terms of anthropometry.

Indeed, most humans beings live today in a nutritional environment that differs form that for which our genetic constitution was selected. Major modifications in the diet have taken place over the last few centuries. The proportion of calories from fat (especially saturated) has increased dramatically since the industrial revolution, and the type and amount of essential fatty acids and antioxidants in the foods has also changed, with a range of effects on health (Simopoulos, 1999). "Westernisation" of traditional societies has changed the diets of indigenous groups to a western diet with attendant health risks (Broussard *et al.*, 1991; O'Dea, 1991; Smith *et al.*, 1996; Ballew *et al.*, 1997).

The striking prevalence of NIDDM in American Indian groups created the suspicion that there might be a special predisposition among some ethnic groups. The "thrifty genotype" hypothesis postulated that populations exposed to

inadequate food supplies were genetically selected for a high level of efficiency in caloric utilization permitting survival through famine cycles, and that obesity could result when environmental changes made food more consistently available (Neel, 1962).

However, the reservation-style living among these Native American groups, where inactivity and overeating prevailed, made this hypothesis of limited ethnic applicability. A few years ago, in redefining the "thrifty genotype", the author admitted that the original hypothesis presented "an overly simplistic view of the physiological adjustments involved in the transition from the lifestyle of our ancestors to life in the high-tech fast lane". He introduces the term "civilization syndromes" to conceptualize diseases that share many epidemiological characteristics (NIDDM, obesity, and hypertension) resulting from previously adaptive multi-factorial genotypes, and points to the importance of genetic susceptibilities to these diseases, and to the interactions between the potential genetic components and the environment (Neel, 1999).

Recent studies have illustrated this genetic-environmental interaction where the genetic susceptibility can be seen as a prerequisite for the development of NIDDM, and the exposure to adverse environmental factors (diet and activity level) as essential conditions for its appearance (Bennett, 1999; Hegele, 1999; Valencia *et al*., 1999; Pérusse and Bouchard, 1999)

Micronutrient deficiencies

All of the minerals and most of the vitamins required by the body have to come either from the food we eat or from supplements. However, more than half the world's population does not consume enough of these nutrients in their diet and a third is affected by iron, iodine or vitamin A deficiencies. Clinical manifestations are present in half a billion people, and another 2 billion are marginally deficient in micronutrients and unable to achieve their mental and physical potential (Howson *et al.*, 1998).

While micronutrients are needed at all ages, the effects of inadequate intake are particularly serious during periods of rapid growth such as pregnancy and childhood. For this reason, the 1990 World Summit for Children singled out deficiencies of iron, iodine, and vitamin A as being particularly common and of special concern for women of childbearing age, pregnant women, lactating mothers, and children under 5 years of age.

Micronutrients are needed for the production of enzymes, hormones and other substances that are required to regulate biological processes leading to growth, activity, development, and the functioning of the immune and reproductive systems. Subclinical consequences of micronutrient deficiencies include compromised immune functions that increase the risk of morbidity and mortality, impaired cognitive development and growth, and reduced reproductive and work capacity and performance. The adverse effects of micronutrient malnutrition are most severe for children, pregnant women, and the fetus (Howson *et al.*, 1998).

Various interventions are proven to be effective to combat micronutrient deficiencies. These include fortification programs and use of concentrated micronutrient supplements. Programs aimed at the elimination and control of iron, vitamin A and iodine deficiencies and their health-related consequences as public health problems need are currently ongoing. Remarkable progress is occurring in the control of vitamin A, and iodine deficiencies, but iron deficiency has been less responsive to prevention and control efforts.

Iron deficiency and anemia: Iron is needed for the production of hemoglobin (Hb), which transports oxygen to the body tissues. Most of the body iron is functional iron, mostly Hb but it is also present in myoglobin and in certain enzymes. The remainder is storage iron existing mainly as ferritin, to be mobilized as needed for Hb production (Bothwell, 1996).

Iron is normally lost via the gastrointestinal tract, the skin, and the urine. In addition to basic losses, non-pregnant women of fertile age lose iron due to

menstrual blood loss. During the 2nd-3rd trimesters of pregnancy, women's iron requirements for fetal and maternal tissue development rise by 3-4 times. (Hallberg and Hulten, 1996).

Iron status depends upon the balance between iron consumption, absorption, losses, and the level of iron stores. When the body has been in long-term negative iron balance and the storage iron has been consumed, iron deficiency appears. If this situation continues, functional iron becomes depleted, Hb concentration falls below normal levels, and the erythrocytes become microcytic and hypochromic (Bothwell, 1979). This condition is defined as iron deficiency anemia (IDA).

In humans, iron deficiency has numerous negative consequences, including impaired physical growth, compromised cognitive development, short attention span and impaired learning capacity, reduced muscle function and energy utilization, decreased physical activity and lower work productivity, lowered immunity, increased infectious disease risk, and poorer pregnancy outcomes (Viteri, 1998; Haas and Brownlie, 2001)

Iron deficiency is the most common nutritional disorder worldwide. In developing countries, 3.6 billion people suffer from iron deficiency, constituting a public health condition of epidemic proportions (WHO, 1997). Iron deficiency is also the main cause of anemia affecting 30% of the world's population, and 50% of pregnant women in developing countries contributing to 20% of all maternal deaths (WHO-UNICEF, 1998).

The main causes of IDA in the developing world are insufficient dietary iron intake; poor bioavailability of the iron consumed; increased requirements during pregnancy and rapid growth; blood loss due to menstruation, childbirth, ulcers, and parasites; and impaired iron utilization due to infections (Gillespie, 1998). Poverty underlies many risk factors for IDA.

Well-documented consequences of anemia include diminished learning ability, reduced work capacity, increased morbidity from infections, and greater risk of death associated with pregnancy and childbirth (Royston and Armstrong, 1989; Institute of Medicine, 1990; Walter, 1996; Scholz *et al.*, 1997; Brabin *et al*., 2001a-b; Grantham-McGregor and Ani, 2001; Oppenheimer, 2001; Rasmussen, 2001).

Infants born to anemic mothers are more subject to low birth weight and prematurity (Klebanoff *et al.*, 1991; Hirve and Ganatra, 1994). Furthermore, some studies have also supported the hypothesis of an association between iron deficiency without anemia and poorer performance on tests of cognitive development in children (Deinart *et al.*, 1981; Oski *et al.*, 1983; Deinard *et al.*, 1986).

Of the three micronutrient deficiencies (vitamin A, iodine, and iron) iron deficiency has been relatively neglected because it has been perceived as less harmful, difficult to measure in the field, and difficult to treat and prevent. Lately, however, a better understanding of the consequences of IDA and simpler assessment methods are leading to more action in many places. For instance, a new laboratory method to measure serum ferritin, regarded as an indicator of total body iron stores and frequently used to evaluate iron deficiency (Worwood, 1990; Cook *et al.*, 1992), that does not require a venous puncture or the freezing of the sample, as it can use serum from capillary blood spotted on filter paper, has been developed (Ahluwalia *et al.*, 1998), with large potential of use in remote settings

In the World Summit for Children of 1990, governments of the participant countries, made a commitment to achieving a reduction of IDA in reproductive-age women by one-third of the 1990 levels by the year 2000. Mexico joined this initiative and in 1991 a plan of action was set up to reach this goal through programs conducted by several health institutions (SSA, 1990). Unfortunately, these programs have not yet reached some marginalized areas occupied by indigenous populations such as the Tarahumara.

The high fertility rates, the extremely closely spaced pregnancies, the precarious education and health conditions of the Tarahumara women of reproductive age, along with other ecological and demographic indicators, could make of this group very vulnerable to IDA and its sequelae.

In Mexico, where most deliveries are carried out in hospitals, approximately 25% of the maternal deaths are due to hemorrhage during the delivery period (Reyes, 1994). Although the maternal mortality rate in this ethnic group has never been determined, the poor prenatal care coverage and the fact that 3 out of 4 children are born at home with no health care whatsoever (Monárrez-Espino, 1998), pose significant risks for the mother and baby. Improving the mothers' Hb status prior to delivery could thus diminish their risk of dying during delivery (Brabin *et al*., 2001b).

Vitamin B_{12}

It contains cobalt, and so is also known as cobalamin. It is a water-soluble member of the vitamin B complex naturally found in animal foods such as meat, fish, poultry, eggs and diary products. It can be stored for long periods in small amounts by the body, mostly in the liver (USDA, 1999). Vitamin B_{12} is bound to the protein in food, and hydrochloric acid in the stomach releases it during digestion. It then combines with a glycoprotein known as intrinsic factor before it can be absorbed in the ileum.

This vitamin is necessary for DNA synthesis during cell division, especially in bone marrow tissues responsible for red cell formation. It also plays a vital role in the metabolism of fatty acids essential in the maintenance of myelin, a complex protein that forms an insulating fatty sheath that surrounds the nerves (Herbert, 1996). If deficiency occurs, DNA production is disrupted and abnormal cells are formed leading to anemia. Prolonged deficiency can also lead to nerve degeneration and irreversible neurological damage (Healton *et al.*, 1991).

Vitamin B_{12} is excreted in the bile and is reabsorbed via the enterohepatic

circulation; thus, it can take a long time for deficiency disease to develop (Herbert, 1996). Deficiency occurs frequently linked to a failure to effectively absorb B_{12} from the intestine, such as in people unable to produce intrinsic factor who develop pernicious anemia, but it can also occur due to a poor dietary intake or linked to intestinal parasite infestation (Herbert, 1996; Carmel, 1997).

Signs of deficiency include fatigue, weakness, nausea, constipation, flatulence, anorexia, and weight loss (Herbert, 1996). Deficiency also can lead to neurological changes such as numbness and tingling in hands and feet, and others including difficulty in maintaining balance, depression, confusion, poor memory, and soreness of the mouth or tongue (Healton *et al.*, 1991).

Vitamin B_{12} and folic acid are involved in similar chemical processes. Since vitamin B_{12} reactivates folic acid, a deficiency of B_{12} results in a folic acid deficiency if folic acid levels are marginal. On the other hand, a high intake of folic acid may mask a vitamin B_{12} deficiency because it prevents the changes in the red blood cells, though it does not counteract the deficiency in the brain (Herbert, 1996).

Because primary sources of vitamin B_{12} are foods of animal origin, people like the Tarahumara who eat little of these products are likely to ingest less than the amounts recommended and become deficient. Measuring the serum cobalamin level is commonly used in the initial assessment of vitamin B_{12} deficiency (Zittoun and Zittoun, 1999). However, measuring the plasma homocysteine and urinary methylmalonic acid levels are considered more specific for the diagnosis of vitamin B_{12} deficiency (Stabler *et al.*, 1996; Klee, 2000). The Schilling test is commonly used to determine whether there is sufficient output of intrinsic factor (Herbert and Das, 1994).

Folate: Folate and folic acid are forms of a water-soluble B vitamin. Folate occurs naturally in a wide variety of foods such as dark green leafy vegetables, wheat bran and other whole grains, dry beans and peas, citrus fruits, and liver (USDA, 1999)

while folic acid is the synthetic form found in supplements and fortified foods.

Unlike folic acid, which is almost completely stable for months, natural folates rapidly lose activity in foods over periods of days. The chemical lability of naturally occurring folates results in a significant loss of biochemical activity during harvesting, storage, processing, and preparation. In fact, 50-75% of initial folate activity may be lost during these processes (FAO and WHO, 2002). Natural folates are conjugated to a polyglutamyl chain and removed in the brush border of the mucosal cells by the enzyme folate conjugase and folate monoglutamate to be subsequently absorbed (Scott and Weir, 1994).

Folates are needed for the production and maintenance of new cells. This is especially important during periods of rapid cell division and growth such as infancy and pregnancy. They are necessary for to make DNA and RNA, and prevent changes to DNA that may lead to cancer (Herbert, 1999). Folates are thus required to make normal red blood cells and prevent anemia. In fact, folate deficiency it is the second most frequent cause of nutritional anemia. Both vitamin B_{12} and folate are key components in the synthesis of DNA due to their role in conversion of uridine to thymidine. When vitamin B_{12} or folate is deficient, thymidine synthase function is impaired and DNA synthesis is interrupted leading to megaloblastic changes in rapidly dividing cells, including inadequate erythropoiesis (Herbert, 1999).

Signs are often subtle including diarrhea, anorexia, weight loss, sore tongue, headaches, behavioral disorders, and those related to anemia (Herbert, 1999). Deficient pregnant women are more likely to give birth to low birth weight and premature infants, and infants with neural tube defects such as spina bifida and anencephaly (Scott *et al*., 1994; Daly *et al*., 1995).

Folate deficiency is frequent in individuals with inadequate dietary intake and can be exacerbated by malabsorption conditions (Chanarin, 1979). It also occurs when

needs are increased such as during pregnancy and lactation (McPartlin *et al*., 1993).

Even though folates are present in various foods of animal and vegetable origin, dietary intake may be low due to poor storage conditions or excessive cooking (FAO and WHO, 1988), common practices observed at indigenous boarding schools and other settings in the Tarahumara region.

Zinc: It is an essential component of enzymes participating in the synthesis and degradation of carbohydrates, lipids, proteins, and nucleic acids as well as in the metabolism of other micronutrients. It stabilizes the molecular structure of cellular components and membranes and therefore contributes to the maintenance of cell and organ integrity (Hambidge, 1987). Zinc has an essential role in the immune system (Shankar and Prasad, 1998), and in the process of genetic expression (Hambidge, 1987).

Lean red meat, whole-grain cereals, pulses, and legumes provide the highest concentrations of zinc. Its utilization depends on the overall composition of the diet, with several dietary factors acting as promoters (e.g. amino and hydroxy acids) or antagonists (e.g. organic compounds) of absorption. Two factors together with the total dietary zinc are major determinants of absorption and utilization: the content of inositol hexaphosphate (phytate) and the level and source of dietary protein. Competitive interactions between zinc and other ions with similar properties (e.g. iron or copper) affecting the intestinal absorption of zinc have also been documented (Sandström and Lönnerdal, 1989).

The clinical features of severe zinc deficiency include growth retardation, delayed sexual and bone maturation, skin lesions, diarrhea, alopecia, impaired appetite, increased susceptibility to infections, and the appearance of behavioral changes (Hambidge, 1987).

Zinc deficiency is a widespread public health problem with almost half of the world's population at risk of insufficient zinc intake, especially pregnant and

lactating women and young children (Brown and Wuehler, 2000). In children, reduced growth rate, impaired resistance to infections (Black, 1998) and abnormal neurobehavioral development are often the only manifestations of zinc deficiency and thus commonly overlooked (Hambidge, 1987).

Zinc is present in all body tissues and fluids. Although total body zinc has been estimated to be 2 g, plasma zinc represents only about 0.l% of this content due to the rapid turnover rate; this level appears to be under close homeostatic control (Hambidge, 1987).

There are no generally accepted, reliable biomarkers of zinc status. Of the alternative techniques that have been proposed for direct evaluation on a population's zinc status, serum zinc concentrations is one of the most promising for field application (Brown *et al*., 1998). However, serum zinc not always reliably indicate total-body zinc stores because the concentration in tissues is many times larger than in serum and minor changes in uptake or release of zinc from the peripheral sites can have a major effect on the serum concentration (WHO, 1996).

Iodine: The only physiologic function known for iodine in humans is the synthesis of thyroid hormones by the thyroid gland; thus, all biologic actions of iodide are attributed to the thyroid hormones including growth, development and control of metabolic processes in the body (FAO and WHO, 2002).

Iodine deficiency is the world's leading single cause of preventable brain damage and mental retardation. In 1991, an estimated 1.5 billion people were at risk of iodine deficiency disorders (IDD); 655 million people were affected by goiter, an indicator of IDD; and 26 million people suffered from brain damage associated with iodine deficiency (WHO, 1993). In children, iodine deficiency may have serious irreversible consequences including retarded mental and physical development, impaired intellectual function and diminished school performance (Hetzel, 2000).

The iodine content of food depends on the iodine content of the soil in which it is

grown; thus, the food grown in iodine-deficient regions, such as in mountainous regions and flood plains, can never provide enough iodine for the people and livestock living there (Koutras *et al*., 1985). Consequently, it cannot be eliminated by changing dietary habits or by eating specific kinds of foods but must be corrected by supplying iodine from external sources. It has, therefore, been a common practice to use common salt as a vehicle for iodine fortification since the entire population of a region consumes salt at approximately the same level throughout the year.

However, iodine loss from salt can occur as a result of improper packaging or due to exposure to humidity and sunlight. In addition, losses during the cooking process vary from 20 to 40% depending on the cooking method used (ICCID, UNICEF, WHO, 2001). To compensate for these losses, higher levels of iodine can be used during the production of iodized salt.

To ensure the consumption of recommended levels of iodine, the iodine content of salt at the production level should be monitored with proper quality assurance programs. In addition, periodic assessment of the population by means of thyroid examination and urinary iodine excretion, a good marker of very recent dietary iodine intake, is necessary to prevent iodine deficiency and its consequences. Iodine concentrations in casual urine samples provide an adequate assessment of population's iodine nutrition (ICCID, UNICEF, WHO, 2001).

AIM

The overall aim of the studies presented in this thesis was to fill part of the knowledge gap regarding the nutritional problems that affect the Tarahumara women and children of northern Mexico.

The specific objectives of the studies were:

- Establishing the nature, magnitude, severity and geographical distribution of IDA in Tarahumara women of fertile age in northern Mexico and developing a field technique for spotting capillary serum on filter paper to measure SF in remote settings (Paper I).

- Assessing the anthropometric status of adolescent and adult Tarahumara women to evaluate whether overweight constitutes a public health problem (Paper II).

- Exploring food and body shape perceptions as dimensions of Western acculturation linked to overweight among Tarahumara women (Paper III).

- Assessing the nutritional status of Tarahumara children at indigenous boarding schools including growth retardation and micronutrient deficiencies (Paper IV).

- Identifying culturally accepted foods using a qualitative assessment to redesign a food aid basket for young Tarahumara children (Paper V).

SUBJECTS AND METHODS

Study area

This thesis consists of various studies performed between 1998 and 2002 among Tarahumara women and children. The studies were conducted in four predominantly indigenous municipalities (>40% of indigenous population based on linguistic definition), located in the southwestern quarter of the State of Chihuahua, in northern Mexico (INEGI, 2001).

This territory is a mountainous chain with a maze of arroyos, valleys, and canyons. The climate is widely variable depending on the altitude. In the mountains, at 2000-2500 meters above sea level (municipalities of Guachochi and Balleza) it is temperate to cold, and in the gorges, at 500-1000 m (municipalities of Batopilas and Urique) it is subtropical. The mean annual temperatures in these municipalities range from 13 to 24ºC, and when there are no droughts, the rainfall averages 500-700 mm, most of it coming during the summer months (INAFED, 1988).

Study population

A linguistic criterion was used to define being Tarahumara, namely, those individuals capable of speaking the indigenous language *Rarámuri*. A demographic description of the municipalities covered by the studies included in the thesis is shown in the next table.

Predominantly indigenous municipalities from Chihuahua State where the studies were done

Municipality	Area in km^2	Speaks Rarámuri (%)	Proportion of the total Tarahumaras	Paper included in the thesis				
				I	II	III	IV	V
Balleza	7 073	6 020 (42.2)	8.5			X	X	
Batopilas	2 065	4 589 (45.7)	6.5			X	X	
Guachochi	7 340	20 926 (60.1)	29.5	X	X	X	X	X
Urique	3 969	6 578 (44.5)	9.3			X		

Source: INEGI, 2001.

The study population included women aged 12-49 years (papers I-II), women and men aged 16-60 years (paper III), schoolchildren aged 6-14 years (paper IV), and women with children aged 6-36 months (paper V).

Women play a central role in the Tarahumara household. They are involved in almost all domestic tasks, the care of the children, and also take an important role in productive activities. Their work sphere varies from herding and making handicrafts for sale to agricultural labor. They usually join the men in weeding, harvesting and planting activities, and occasionally perform tasks such as hoeing maize or plowing with oxen. These activities frequently demand a huge physical effort that can be better achieved by those with better nutrition and health status.

Tarahumara women are responsible for cooking for the whole family, including the preparation of food for young children. Thus, women determine to a great extent the children's diet based on their knowledge and cultural beliefs regarding infant feeding.

A large proportion of Tarahumara children of school age attend one of the many boarding schools run by the National Indigenous Institute, which provides food to 3000 indigenous children in its 38 boarding schools (INI, 2000). These schools are located mostly in the municipalities of Guachochi (20), Batopilas (8) and Balleza

(4), with the aim of promoting the education and also nutritional development of those living in highly marginalized areas with extreme poverty. However, no efforts have previously been made to identify possible nutritional problems among these children.

Study design

The design, sample size and sample strategy of the studies with Tarahumara women and children included in this thesis are presented in the summary table.

Due to the lack of a sampling frame for the Tarahumara population, special efforts were made to obtain a representative sample of women from the municipality of Guachochi (papers I-II). It was not possible to construct an updated and accurate sample frame given the relatively large indigenous population in Guachochi municipality (~20 000 inhabitants). The cost and time involved in setting up such a detailed frame and in attempting to contact randomly selected individuals from a highly dispersed population living in a difficult topography was out of consideration. Therefore, multistage proportional sampling was utilized. The population was divided into 3 strata based on the number of eligible Tarahumara women in each locality as shown in the table ahead.

The relatively small number of localities with 50-99 and 100 persons (108 and 39 respectively) allowed drawing of systematic sample. These localities were listed with the numbers of households in alphabetical order, the cumulative frequency of households and range of households between the previous and the current locality. Then a random number was located. Once in the field, 8 houses were randomly selected from the inhabited Tarahumara households in each selected locality, and all reproductive-age women in them were included in the sample.

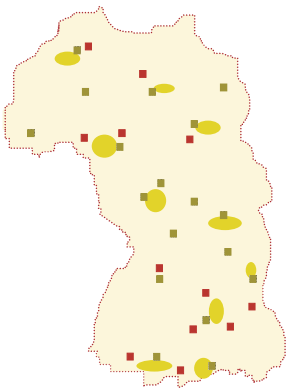
Summary table. Summarized description of the studies conducted among Tarahumara women and children included in the thesis

	Paper in the thesis				
	I	**II**	**III**	**IV**	**V**
Aim	To determine the prevalence of IDA and to develop a field technique for spotting capillary serum on filter paper	To assess whether overweight is a public health problem among women	To explore food/body shape perceptions as dimensions of Western acculturation linked to overweight in women	Assessing the nutritional status of children at indigenous boarding schools	Identifying culturally accepted foods to redesign a food aid basket for young children
Study design	Population-based cross-sectional nutrition survey; development of a field technique to measure SF on filter paper in remote areas	Population-based cross-sectional nutrition survey	Community-based study using cognitive anthropological methods with systematic data collection	School-based cross-sectional comprehensive nutrition survey	Community-based study using a combination of qualitative techniques
Participants	Women aged 12-49 years	Non-pregnant women aged 12-49 years	Women and men aged 15-60 years	Indigenous school children aged 6-14 years	Mothers with children aged 6-36 months.
Sample size	481 women for assessing capillary Hb, and a sub-sample of 171 women to assess capillary SF	459 non-pregnant women for assessing the anthropometric status	81 respondents: 53 women and 27 men for food and body shape perception interviews	5 boarding schools; 331 children for Hb, anthropometry, goiter; 99 for micronutrient assessment	9 for free listing; 60 for semi-structured interviews and pair comparisons; 30 for addition/deletion; 6 focus groups
Sampling strategy	Multistage proportional sampling based on the number of persons in the locality: Systematic and quota sampling. Convenience sampling for the field technique	Multistage proportional sampling based on the number of persons in the locality: Systematic and quota sampling	Haphazard selection of respondents from the predetermined sampling strata based on age and community size	All eligible children from a purposive sample of schools. Random sample for micronutrient assessment	Convenience stratified quota sampling

In communities with <50 persons, quota sampling was used. As most of these small villages surround the bigger ones, a random sample from the surrounding localities with 50 persons was drawn, and all reproductive-age women found were sampled until the quota was reached.

Proportional sampling strategy of the Tarahumara women in the municipality of Guachochi, Mexico

Municipality characteristics	No. Inhabitants the in locality [1] <50	50-99	≥100
Localities in the municipality	1 012	108	39
Inhabitants in the municipality	14 891	7 104	16 775
Proportion who are Tarahumara	85.3%	78.2%	32.6%
Tarahumara women aged 49-12 y	3 381	1 478	1 460
Proportional distribution of women	53%	23.9%	3.12%
Tarahumara women sampled	255	115	111
Number of sampled localities	93	18	12
Number of sampled households	207	95	85
Sampling strategy	Quota	Systematic	



[1] *Estimated from the National Census (INEGI, 1997)*
[2] *Based on the 25% prevalence of anemia found among indigenous women at national level in 1988 (Martínez et al., 1995), a 95% confidence level, and a relative precision of the estimate of 15% (Lemeshow et al., 1990)*

For the study on food and body shape perceptions in women (paper III), the number of respondents was a haphazard sample of persons of different ages living in localities of different sizes. Three age groups in years were defined: young (16-30), middle (31-45) and mature (46-60). The locality size was categorized based on the number of households: Very small (<10), small (10-30) and medium or large (>30). Thus, 6 women and 3 men were selected from each of the 9 predetermined sampling strata for the food and body shape perception structured interviews.

The sampling framework for the study of school children (paper IV) aimed for variation in the characteristics of the schools sampled (i.e. location, altitude, infrastructure, size of enrolment, and accessibility). Schools I and II represented the 'better-off' and 'poor', respectively (based on amount and quality of buildings, furniture and other equipment); school III represented the 'overcrowded' (hosting

twice the average number of children); school IV was the 'traditional' (located in an area with strong presence of Tarahumara customs); and school V was typical of the 'gorge' (fruits and vegetables grow here thanks to the subtropical environment). All children present during the school visits and choosing to participate were surveyed and a random sample of them was included in the micronutrient assessment.

For the study to identify culturally accepted foods for young children (Paper V), we used a stratified quota sampling to interview mothers from 3 different strata based on the level of marginalization of the respondents (i.e. living at the periphery of the Mexican society) to look for possible gross differences across the strata. Characteristics considered for the sampling scheme were closely related to the isolation of the population, not only in terms of the number of households in the community but also in terms of its accessibility and the ratio of Tarahumaras to mestizos, factors likely to relate to food preferences

Data collection

A brief gynecological clinical history to evaluate reproductive health risks was obtained and a short questionnaire focusing on basic demographic, educational, socioeconomic, and health information was administered (Papers I-II). A physician assessed the gestational age of the pregnant women clinically.

Anthropometric measurements

The women were weighed with an electronic scale with 150 kg capacity and 100 g precision (Paper II). As asking Tarahumara women to undress is not culturally sensitive, various types of typical clothing were weighed and the corresponding adjustments were made to weights according to what each woman was wearing. A vertical board with 200 cm capacity was used to measure height. Heights were measured with no shoes and recorded to the nearest mm. The chronological age was registered as reported by the woman herself, but it was corroborated in adolescents (12-18 years) and older women (>45 years) using an official document whenever possible. Two persons took all measurements.

Schoolchildren wearing no shoes and light clothes were weighed using a scale with

100 g precision (Paper IV). A 200 cm measuring board was used to measure heights. Children stood barefoot and their height was recorded to the nearest mm. The children's age was obtained from their birth date as written in the school records. A single experienced person took all anthropometric measurements using standard techniques (Cogill, 2001).

Capillary blood samples

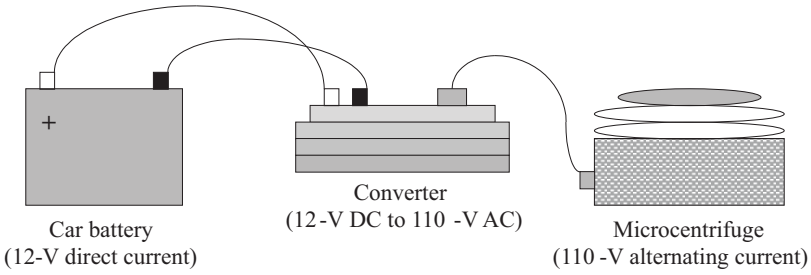
From the second drop of capillary blood obtained by finger prick, Hb was measured using a portable photometer (HemoCue AB) (Paper I). This azide methemoglobin method provides accurate measurements of Hb concentration (Schenck *et al.*, 1986), as well as adequate prevalence estimates of anemia at population level (Morris *et al,* 1999).

The prevalence of anemia was assessed based on the recommended Hb cutoff at sea level for males (6-11 y: <115 g/l, 12-13 y: <120 g/l, 14 y: <130 g/l) and females (6-11 y: <115 g/l, 12-14: non-pregnant of pregnant in 1st trimester <120 g/l; pregnant in 2nd3rd trimester: <110 g/l) (CDC, 1989). The cut-offs were corrected for altitude using an exponential model (Cohen and Hass, 1999) that has shown a better fit to the data than previous models (Dallman *et al.*, 1980; Dirren *et al.*, 1994), rendering the following increases in the cutoffs: 1800-1899 m: 6 g/l, 1900-2099 m: 7 g/l; 2100-2199 m: 8 g/l; 2200-2299 m: 9 g/l; 2300-2399 m: 10 g/l; 2400-2499 m: 11 g/l; 2500-2599 m: 12 g/l). A Global Position System instrument was employed to measure the altitude in each of the sampled localities.

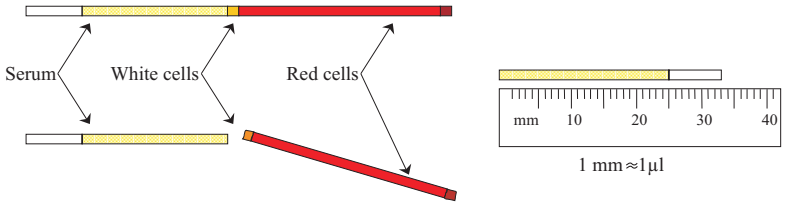
Dried serum spot

A capillary specimen was taken from a finger using a disposable lancet (Paper I). After wiping away the first drop and taking the next for the Hemocue®, a capillary tube was filled with free-flowing blood.

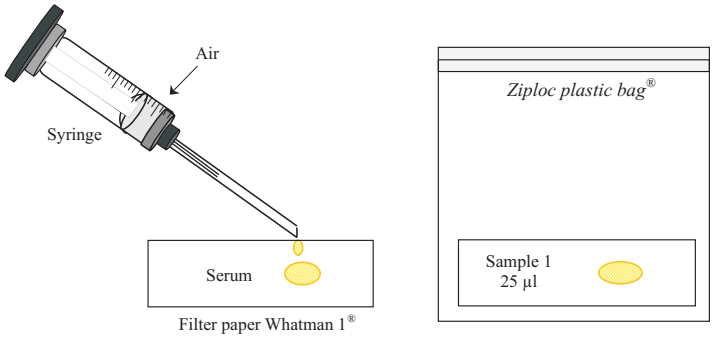
This was a 75 x 1 mm standard microhematocrit tube (contents ~ 75µl, which was sealed at one end, and centrifuged on site. The electricity source for the microcentrifuge run was a car battery that had a converter to transform 12-V direct current to 110-V alternating current.



Al least 20µl of serum were obtained (the laboratory method requires a minimum of 20µl to be spotted on filter paper) after spinning at 4 500 rpm for five minutes. The tube was broken just above the cell layer without spillage. The volume of serum left in the tube was then measured in mm, each being equivalent to one µl.



A syringe with a cut-off needle that fitted exactly into the microtube was held to make it airtight, and the serum was then expelled from the end of the capillary tube onto the filter paper. The samples were air-dried, placed in polyethylene bags at room temperature and sent to the University of California at Davis for analysis.



Unlike other type of filter papers used for micronutrient assessment (e.g. serum retinol), the paper required for measuring SF (Whatman 1®) does not distribute the serum volume evenly per square mm, and therefore it was not possible to punch out a plug of filter paper of standard size. This filter paper is completely digested by cellulase, releasing the total volume of serum spotted on the paper. For this reason it was essential to know the exact volume of serum spotted. The field technique developed measured the volume in the microcapillary tube using a ruler. The SF level was determined using radioimmunoassay (Ahluwalia *et al.*, 1998). As the samples contained different volumes, normalization of the values was required to be able to obtain the SF level per µl.

Because SF values may be spuriously high in response to inflammation (Birgegård *et al*., 1978; Worwook, 1990), we included the measurement of temperature and a series of questions to identify the presence of infection within 2 weeks prior to the interview.

Micronutrient assessment

Non-fasting 10 ml cubital vein blood samples were taken from 100 schoolchildren for the micronutrient assessment (Paper IV). No child had history of clinical infection during the week before the venipuncture. Blood was allowed to coagulate at room temperature before serum was separated by centrifugation, kept in liquid nitrogen at -72°C, and sent to Mexico City for laboratory analysis.

Iron status was assessed using serum iron (SI) and total iron-binding capacity (TIBC) of transferrin in serum to calculate the transferrin saturation percent (TfS= SI / TIBC x 100), and serum ferritin (SF). SI and TIBC were determined using atomic absorption spectrophotometry (NCCLS, 1998). SF was quantified using a solid-phase immunoradiometric assay (Ferritin CTK-IRMA; Italy).

SF $\leq$ 12 ng/ml and TfS $\leq$14% were used as cut offs for iron deficiency (Dallman *et al.,* 1996). As no single indicator reflects the entire spectrum of iron status (Cook *et*

al., 1976), a common multiple biochemical test strategy was used (Yip *et al.,* 1984; Expert Scientific Working Group, 1985; English and Bennett, 1990; Preziosi *et al.,* 1994). The model included SF, TfS and Hb and used the following iron nutrition definitions: No iron deficiency (no anemia + SF >12 + TfS >14), anemia without iron deficiency (anemia + SF >12 + TfS >14), iron depletion (no anemia + SF≤12 + TfS >14), iron deficient erythropoiesis (no anemia + SF ≤12 + TfS ≤14) and iron deficiency anemia (anemia + SF ≤12 + TfS ≤14).

Some children could not be placed in any of these iron status categories, as others have noted (Dallman *et al,* 1981; Hallberg *et al.,* 1993). In such cases, we used SF as the most reliable indicator, as TfS is influenced by the wide diurnal variation of serum iron (Cook *et al.,* 1992).

Vitamin B_{12} and folic acid levels were determined by radioassay (SimulTRAC-SNB; New York). Serum vitamin B_{12} concentrations <200 pg/ml were considered low and 200-300 pg/ml marginal (Lindenbaum *et al.,* 1990). The cut-offs used for folate were <3 ng/ml for low and 3-6 ng/ml for marginal status (Sauberlich, 1977).

Serum zinc was measured by atomic absorption spectrophotometry (Smith *et al,* 1979). Following the recommendation by the International Zinc Nutrition Consultative Group, the cut-off point for low serum zinc was reduced from <70 to <60 µg/dl because fasting blood was not taken.

To complete the assessment, the size of the thyroid was measured to calculate the total goiter rate (TGR) in the surveyed children; and the iodine content in salt used for food preparation was tested using a colorimetric method (ICCID, UNICEF, WHO, 2001) at the selected schools. A 2-week meal content inventory was used to document the foods served at each sampled school, focusing on foods rich in iron, vitamin B_{12}, and folate (1994).

Structured interviews

Systematic data collection relying on structured interviews (Bernard, 1994; Weller and Romney, 1988) was used to explore food and body shape perceptions (paper V). Six photograph series were designed to explore perceptions regarding foods. Each contained 3 photographs portraying typical Tarahumara, mestizo and western foods. The series depict prepared dishes, food preparation methods and drinks.

Prepared dishes

Beans and meat

Pork *asado*

Hamburger

Yorique [1]

Burrito [2]

Hotdog

[1] Recipe made of maize, nopal, chili and *arí* (a reddish material produced by ants)
[2] A flour tortilla rolled around a filling made of chili and chopped meat

The topics studied within this food dimension included: *preference*, denoting the desire of the respondents to eat certain foods; *taste*, the perceived palatability of the depicted foods; *health*, dealing with the respondents' beliefs as to foods that promote or maintain health; and *regularity*, indicating the respondents' judgments regarding their frequency of consumption of the foods.

Preparation mode

Boiled potatoes

Smashed potatoes

French fries

Boiled beans

Smashed beans

Fried beans

Boiled meat

Dry meat

Fried meat

To measure food perceptions, the partial rank order method (Weller and Romney, 1988) was used. Respondents were shown the photo series and were asked: "which of these would you like to eat now?" (*preference*), "which of these do you think tastes better?" (*taste*), "which of these do you think is better for your health?" (*health*), and "which of these do you eat more frequently?" (*regularity*). After each question, the respondents were asked for their second choice and the responses were ranked

Drinks

Pinole[1]

Limeade

Coca Cola

[1] A thin gruel made with toasted maize and ground to a powder mixed with water

Body shape perceptions were explored using a series of photographs portraying ten Tarahumara women dressed in traditional garments. The photographs were arranged from the thinnest to the fattest based on their BMI (range 18.5-41.5). Respondents were asked to judge them on the following traits: *beauty*, indicating the ideal body shape in esthetic terms; *health*, relating to the possibility of living a healthy and lengthy life; *motherhood*, comprising the women's capability to deliver, breastfeed, raise and protect their children; and *industriousness*, dealing with the women's ability to run their households and take care of their families.

The constrained pile sort method (Weller and Romney, 1988) was used. Respondents were shown the photo series and were asked: ”which of these women do you think has the prettiest body?” (*beauty*), ”which of these women do you think looks healthiest?” (*health*), ”which of these women do you think would be the best mother?” (*Motherhood*), and ”which one these women do you think works hardest?” (*industriousness*). They were also asked for their second choice and thus grouped the photos into two piles, the two selected and the remaining eight unselected.

Age, locality size, interview language and gender were the variables used to explore acculturation. A trained simultaneous translator was employed for those persons for whom interviews needed to be conducted in the indigenous language.

Qualitative methods

We used a combination of rapid qualitative techniques (Pelto, 1983; Scrimshaw and Gleason 1992; Weller and Romney, 1988; Bernard, 1994; Morgan, 1996) to

identify the most important food items eaten by young Tarahumara children. Data were collected over an 8-week period. The study was carried out only with Tarahumara mothers who had children aged 6-36 months. Most interviews were conducted at the interviewees' household in the community. A trained simultaneous translator was used with mothers who did not speak Spanish.

1. *Free listing from key informants:* These were 9 female indigenous health care workers and health promoters aged 23-54 years. Each was asked to list the 10 foods that they considered the most appropriate to feed young children (which foods or drinks do your children aged 6-36 months eat or drink?).
2. *Pair comparisons:* From the foods selected in the free listing, 2 balanced groups of 6 foods were shown to 60 mothers with young children. Actual foods were placed in identical dishes and in similar amounts and were shown to 20 women from each stratum. They were asked to choose between all possible combinations in each food group, according to what they considered appropriate to feed their children (which one do you prefer to feed your children, this or this?).
3. *Listing of foods to be added or deleted:* Ten mothers from each sampling stratum were shown the foods actually in the governmental food basket in identical dishes and similar amounts, which included chocolate powder, cookies, lard, maize flour, wheat noodles, salt, canned sardines and sugar. Mothers were asked to delete or add 5 foods from this basket, according to what they considered appropriate for their children (if you could add foods to the basket: which foods would you add? and, if you had to delete foods: which ones would you prefer to delete?).
4. *Semi-structured interviews:* Twenty mothers from each stratum were interviewed using a semi-structured format covering the following topics: Concepts and practices on complementary feeding and breastfeeding, knowledge about appropriated complementary foods to feed young children, consistency of foods to feed young children, utensils used to feed young children, beliefs about complementary feeding and breastfeeding simultaneously, beliefs about feeding children during illness, opinions on the food basket, and attitudes towards participation in the delivery of the food

basket.

5. *Focus groups:* Two focus-group sessions, each involving 5 to 8 mothers of different ages from the same sampling stratum, were conducted to validate findings of the previous procedures. All sessions were conducted in health care centers and school classrooms with the help of a trained simultaneous translator. Sessions lasted 50-60 minutes. The sessions were videotaped and thereafter translated for analysis. The group discussions gravitated towards the results form the previous phases.

Data analyses

Paper I: Data were captured and analyzed in the SPSS® computer software (Chicago, Illinois). Box plot graphs, and means (SD) for Hb were presented to describe the Hb distribution. Analyses were stratified according to the women's reproductive status, age, number of inhabitants in the locality, use of contraception method, and ability to speak Spanish. Because SF was not normally distributed, a logarithmic transformation (Log SF) was done and the correlation between Hb and Log SF was plotted. To determine the prevalence of depleted iron stores, a cut-off point of SF<12 µg/L was used. SF values of women with temperatures >37.5 °C or history of urinary, respiratory or gastrointestinal infection were considered to be possibly falsely high. The proportion of women who received iron supplementation, including the prescribed duration and schedule, was tabulated stratifying by size of the locality. Pearson Chi-squared tests were used to detect differences between categorical variables. ANOVA and Bonferroni post hoc tests were used to identify mean differences. As for all other papers, the level at which differences were considered statistically significant was 0.05.

Paper II: The mean (SD) of the different anthropometric indexes used were calculated and stratified by age and size of the community. Prevalence of stunting in adolescents, as well as thinness and risk of overweight in adolescents, young adults and adults were calculated using the cut-off points recommended by a WHO expert committee (WHO, 1995). The anthropometric index height-for-age z-score

(HAZ) was calculated using the ANTHRO computer software. Pearson chi-square and Fisher exact tests were used to calculate differences between categorical variables. ANOVA and Bonferroni post hoc test were used to detect significant mean differences.

Paper III: The respondents' answers were coded and entered into databases following the requirements of the analytical software ANTHROPAC (Borgatti, 1996). Analyses were stratified by age, locality size and interview language only for women. Data were cross-tabulated in item-by-item matrices and their values transformed to similarity proportions between items. The resulting similarity matrices were analyzed separately by means of cultural consensus (Romney *et al.*, 1986) for the individual values for food perception, and by tabu search clustering (Glover and Laguna, 1997) and multidimensional scaling (Kruskal and Wish, 1978) for the aggregated values for body shape perception.

The consensus analysis statistically measured the reliability of individual informants in relation to each other and in reference to the group as a whole. It created models of cultural consensus using a procedure adjusted for ordinal responses (Romney *et al.*, 1987) and generated a predictive model of responses based on the correlation between the individual responses and the average group response. In also included a factorial analysis of main components to group individuals according to their responses. The goodness-of-fit test used to obtain consensus required the 1^{st} factor to be 3 times greater than the 2^{nd} factor, implying high concordance of the responses of the informants (Weller and Mann, 1997).

The tabu search clustering produces a proximity matrix using an algorithm for grouping together members that are most similar into blocks by searching for sets of members that produced the smallest sum of within-block variances. Correlating the block model against a “perfect” model assesses the goodness-of-fit. A fit coefficient >0.43 was used, as no well-established criterion exists (Hanneman, 2003). Tabu search produced 2 clusters, one indicating the selected responses for

body shape perception. This cluster was classified as falling within 1 of 3 defined groups: Thin-normal (women photo numbers 1-4), plump (5-7) and obese (8-10).

A 2-dimensional spatial representation of the similarities between items (i.e. responses) was produced through the non-metric method (Kruskal and Wish, 1978) to obtain a separate source of validation for the body shape perception responses. The idea was to plot the items on a map such that those items that were perceived to be very similar to each other were placed near each other, forming clusters. The degree of correspondence among the distances between items was measured by a stress function (the smaller the stress, the better the representation). A cut-off stress value of 0.13 for a 10-item representation was used (Sturrock and Rocha, 2000).

Paper IV: Anthropometric indices were expressed in terms of mean Z-scores (SD) using the Nutritional Anthropometry Program from EpiInfo. Results were stratified by sex, age in years, and school. Analyses included descriptive statistics for the micronutrient data. Logarithmic transformation was used to normalize skewed vitamin B_{12} and folic acid distributions before statistical testing. Means (SD) were calculated for capillary Hb and serum vitamin B_{12}, folic acid and zinc. Data were stratified by sex and age group (6-8, 9-11 and 12-14 years) and by school (only for Hb). SF, TfS and Hb data were combined and presented as proportions falling within each specific iron nutrition category. ANOVA was used for multiple comparisons of means and Newman-Keuls tests were used to investigate differences between means. Chi-squared tests were conducted to identify differences in proportions.

Paper V: In the free listing, the foods mentioned by at least one-third of the mothers were selected for the pair comparisons. Foods were ranked according to the proportion of preference or selection by mothers in the pair comparison procedure and the listing of foods to be added or deleted from the governmental basket. The results from the semi-structured interviews were categorized and summarized by strata for each of the topics covered. The focus group discussions gravitated

towards the results form the previous phases; every food was discussed in terms of its adequacy for young children, its nutritional value, cultural acceptability, cost, local availability, accessibility and consumption by other family members.

Ethical considerations

The aims of each study were explained to all potential participants along with the fact that they were free to choose not to participate. The name of the participants was not used, as a number identified them.

The Uppsala University Ethics Committee approved all studies presented in this thesis, except for the qualitative study to redesign a food aid basket for young children (Paper V), which was approved by the Ethics Committee at the Mexican Institute of Public Health. Permission was also obtained by the local health authority (Secertaría de Salud, Chihuhahua; Jurisdicción VII, Guachochi), and when possible, traditional authorities were also asked for cooperation.

In the survey with Tarahumara women, participation required them to accept having a finger pricked for capillary blood to be used to determine Hb and SF levels (Paper I). As Hb determination took only 1-2 minutes, all women found to be anemic received oral supplementation. We avoid undressing the women to be culturally sensitive and made adjustments in their weights based on the average weight of the type of clothing used (Paper II). The faces of the women who provided consent to be photographed for the study on food and body shape perceptions (paper III) were distorted using computer techniques to be unrecognizable. Parents gave informed consent for all participating children, and children themselves gave witnessed verbal consent (Paper IV). Experienced medical personnel performed the venipuncture following the standard protocol. As with women, all anemic children were supplemented with tablets of iron.

RESULTS

Iron deficiency anemia in women of fertile age

The overall prevalence of anemia (mean Hb±SD) in pregnant and non-pregnant women was 25.7% (129.3±12.6 g/l) and 16.1% (140.2±16.1 g/l), respectively. The lowest mean Hb, and highest prevalence of anemia was found in women pregnant in the 3rd trimester (124.8 g/l; 38.5%) and in those breastfeeding their babies during the first 6 months after delivery (125.5 g/l; 42.9%). The best status was seen in pre-menarcheal and post-menopausal women (Table 1).

Among non-pregnant women, those aged 12-29 years had a lower mean Hb and a higher prevalence of anemia than women aged 30-49 years. Non-pregnant women living in localities with ≥100 inhabitants had a significantly lower mean Hb than to those in localities with <100 inhabitants.

Table 1: Distribution of non-altitude-adjusted hemoglobin (Hb) and prevalence of anemia (using altitude-adjusted cut-offs[1]) in Tarahumara women of northern Mexico

Stratified category	n	Mean Hb (SD) in g/L		Severity of anemia[2]		
			Total	Mild	Moderate	Severe
Pregnant women	35	129.3 (12.6)	25.7	17.1	8.6	-
1st-2nd trimesters	22	132.0 (11.4)	18.2	13.6	4.6	-
3rd trimester	13	124.8 (13.8)	38.5	21.1	15.4	-
Non-pregnant women	446	140.2 (16.1)	16.1	12.1	2.9	1.1
Pre-menarcheal	20	140.2 (13.4)	15.0	15.0	-	-
Menstruating	234	142.0 (14.7)	13.2	9.4	3.4	0.4
Lactating <6 months	35	125.5 (27.4)*	42.9	25.8	5.7	11.4
Lactating ≥6 months	104	138.0 (11.8)	18.3	15.4	2.9	-
Post-menopausal	53	146.6 (13.6)	7.5	7.5	-	-
Age group						
12 – 29 years	248	138.2 (16.1)*	19.7	14.9	3.6	1.2
30 – 49 years	198	142.9 (15.7)	11.6	8.6	2.0	1.0
Size of the locality						
<100 persons	342	141.0 (14.6)	14.6	12.6	1.2	0.6
≥100 persons	104	137.7 (20.0)*	22.2	10.6	8.7	2.9

[1] The Hb cut offs were calculated every 100 m using the formulas proposed by Cohen and Hass (1999).

[2] The cut offs for mild anemia at sea level for non-pregnant and pregnant in the 1st Trimester were 100 -119 g/L and for pregnant in the 2nd -3rd trimesters 100-119 g/L; the cut-offs for moderate and severe anemia at sea level in all women were 80-99 g/L and <80 g/L, respectively (CDC, 1989).

** Statistically different Hb mean (p<0.05); ANOVA and Bonferroni were used.*

Figure 1 shows a significantly positive correlation (0.31; p= 0.000) between Hb and logarithmic transformation of SF (Log SF) in the subsample of 171 women.

Figure 1. Correlation between Hb and log SF in the subsample of women (n=171)

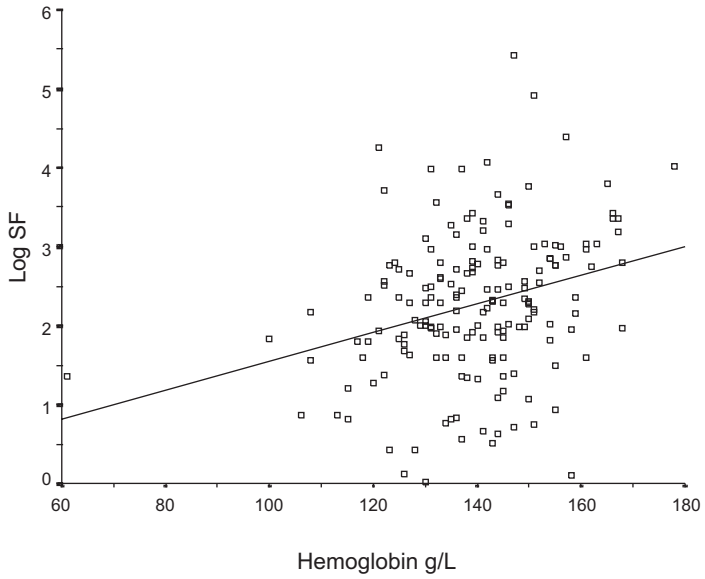


Table 2 presents the relationship between anemia and depleted iron stores using the whole subsample of women. Over half of the women had depleted iron stores, whether anemic or not. Iron depletion was more common in anemic women, although this difference was not statistically significant.

Table 2: Relationship between prevalence of anemia and iron depletion, measured as serum ferritin (SF) <12µ/L by pregnancy status in Tarahumara women of northern Mexico

	Anemic n (%)	p-value *	Non-anemic n (%)	Total n (%)
Non-pregnant	23		132	155
SF <12µ/L	16 (69.6)	0.28	76 (57.6)	92 (59.4)
SF ≥12µ/L	7 (30.4)		56 (42.4)	63 (40.6)
Pregnant	3		13	16
SF <12µ/L	3 (100.0)	0.19	8 (61.5)	11 (68.8)
SF ≥12µ/L	0 (-)		5 (38.5)	5 (31.2)

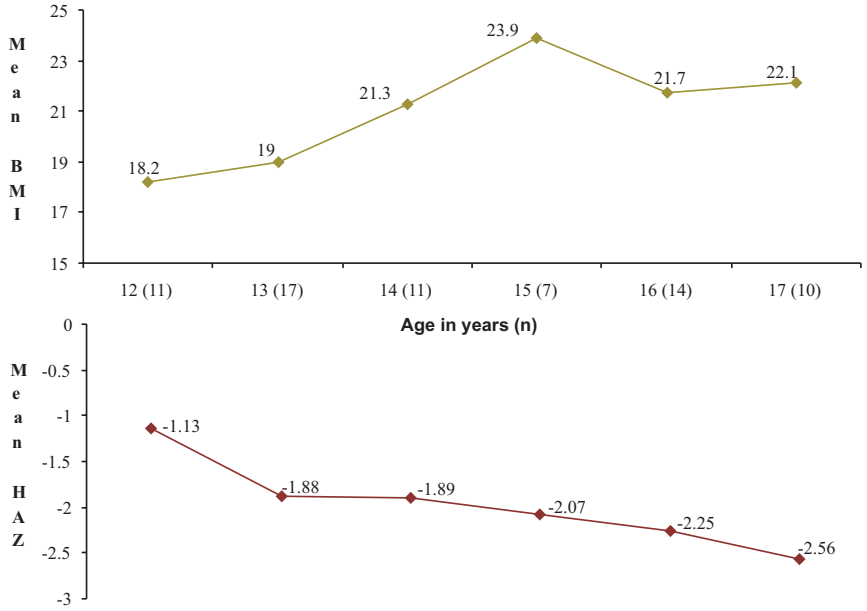
** Pearson X^2 was used*

Among the non-pregnant women, 6.3% had received iron supplementation within 6 months prior to the interview (localities with: ≥100 persons 8.6%, <100 persons 5.5%), compared to 25.7% of the pregnant women (localities with: ≥100 persons 57.1%, <100 persons 17.8%). Among the pregnant women, 10%, 33.3% and 30.8% received iron supplementation in the 1st, 2nd, and 3rd trimester, respectively. Three iron tablets (75 µg elemental iron) per day were prescribed to 45.9% of the supplemented women, and one per day to 48.6%. The prescribed duration of supplementation was ≤1 month in 40.6% and 1-2 months in 29.7% of the women.

Anthropometric status of women of fertile age

The prevalence of underweight was 1.4% in adolescents (12-17 years), 3.2% in young adult women (18-24 y) and 0.8% in adult women (25-49 y). In adolescents, the mean BMI tended to increase and the mean HAZ to decrease with age (Figure 2), but the BMI and mean HAZ were not statistically different between those who lived in communities with <100 and ≥100 persons. The overall prevalence of stunting was 47.2%.

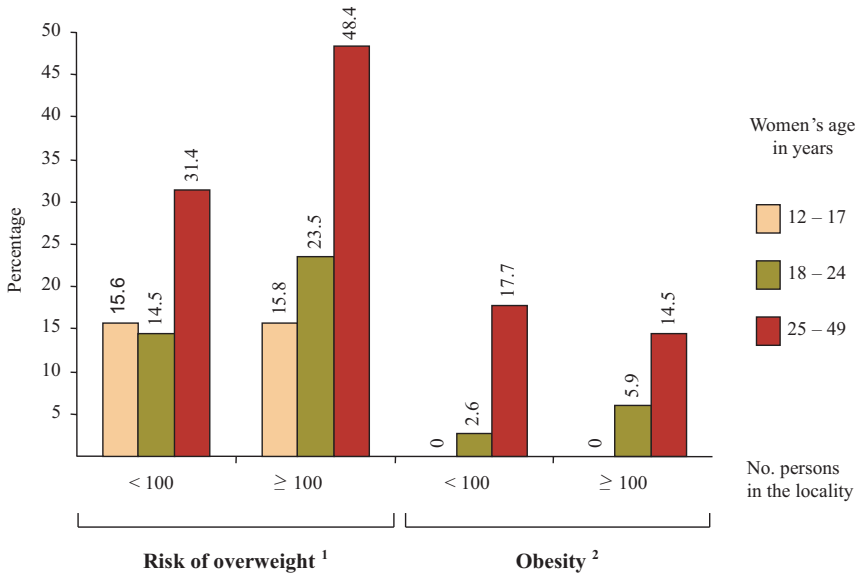
Figure 2. Mean body mass index (BMI) and mean height-for-age Z-score (HAZ) among Tarahumara adolescents by age



The prevalence of "risk of overweight" was higher than the prevalence of obesity in all non-pregnant, non-lactating women. There was a trend toward increased prevalence of risk of overweight and obesity by age. Adults (35-49 years) had the highest prevalence followed by young adults and adolescents irrespective of size of the locality (Figure 3).

The prevalence of risk of overweight and obesity tended to increase with age in both types of localities, but this trend was more marked for risk of overweight in localities with ≥100 persons. When looking at adult women (25-49 y), a higher prevalence of risk of overweight (BMI 25-30) was seen in women from localities with ≥100 persons than in those with <100 persons (48.4% vs. 31.4%), but similar proportions of obesity were seen in both types of localities (17.7% vs. 14.5%).

Figure 3. Prevalence of risk of overweight and obesity among Tarahumara women aged 12-49 years of northern Mexico stratified by age and size of the locality



[1] For women aged 12-24 y BMI-for-age 85-95th percentile and for women aged 25-49 y BMI 25-29.9
[2] For women aged 12-24 y BMI-for-age >95th percentile and for women aged 25-49 y BMI ≥30

All of the women with type II diabetes had either risk of overweight (n=2) or obesity (n=3), and of those with hypertension (n=9), four had risk of overweight

and other four had obesity. Overweight (BMI ≥25) was statistically and positively associated with educational level, measured through either literacy (yes 60.6%, no 47.6%; p=0.04) or capability to speak Spanish (yes 59.3%, no 37.1%; p=0.003).

Food and body shape perceptions in women

The predictive model of responses for food perception with consensus ratio is presented in Table 3. For the topic "taste", either mestizo or Western items were selected before traditional items. Conversely, for the topics "preference", "health" and "regularity", the response model was traditional-mestizo-western irrespective of age and locality size. Spanish speakers tended to prefer mestizo or Western to the traditional items. Cultural consensus (factorial ratio ≥3) was common for "regularity", but less so for "health" and absent for the other topics.

Table 3. Predictive model of responses for food perception in women and consensus ratio for the topics covered stratified by age, locality size and interview language

Topics covered	Age in years			Locality size			Interview language	
	16-30	31-45	46-60	<10	10-30	>30	Spanish	Raramuri
Preference	□	□	□	□	□	□	⬡	□
Taste	⬡	△	✚	✚	△	⬡	⬡	⬡
Health	□	□	□	□	□ **	□	□ **	□
Regularity	□	□ **	□ **	□ **	□ **	□	□ **	□ **

□ Traditional–mestizo–western ⬡ Mestizo–western–traditional

✚ Western–mestizo–traditional △ Mixed responses ** Factorial ratio of consensus ≥3

The cluster identification via tabu search for body shape perception with fit coefficient is presented in Table 4. For the trait "industriousness", the cluster for the perceived body shape thin-normal was seen in all stratified categories. For the traits "beauty", "health" and "motherhood", the predominant cluster was plump with some obese. No clear trends were seen by age or locality size in any trait except for interview language. Obese women were selected by Spanish speakers and plump women by non-Spanish speakers for the traits "beauty", "health" and "motherhood" (Table 4).

Table 4. Clusters identified via tabu search for body shape perception in women and fit coefficient* for the four traits covered stratified by age, locality size and interview language

Trait covered	Age in years			Locality size			Interview language	
	16-30	31-45	46-60	<10	10-30	>30	Spanish	Raramuri
Beauty								
Health								
Motherhood								
Industriousness								

* All fit coefficients ≥ 0.43

Similar clusters to those from the tabu search were visually observed in the MDS for most of the results, namely, predominantly thin-normal women for "industriousness" and obese versus plump in the Spanish and Raramuri speakers, respectively. All representations showed a stress value <0.13

Nutritional status of children at boarding schools

Table 5 presents the proportion of schoolchildren with anemia, wasting, overweight and stunting. The prevalence of anemia using altitude-adjusted cut-offs was 11.4% for boys and 14.5% for girls. It ranged from 6.4% in the school in the gorge to 20.9% in the traditional school.

The overall prevalence of wasting was 1.1%. The prevalence of overweight was 4.6%, with no overweight found in the traditional school and 11.5% in the school in the gorge. The prevalence of stunting ranged from 16.2% to 30.9% across the schools, and it increased from 19.1% among children aged 6-9 years to 29.6% in those aged 10-12 years. The prevalence of underweight and overweight in children aged 10-14 years was 3.2 and 5.7%, respectively, using the CDC 2000 reference data.

Table 5. Anemia and anthropometric status of Tarahumara children at indigenous boarding schools, stratified by sex, age and school

Stratified group	Percent of children			
	Anemia[1]	Wasting[2]	Overweight[3]	Stunting[4]
Sex				
Boys	11.4	0	4.8	21.7
Girls	14.5	2.2	4.4	22.8
Age (y)				
6–9	14.2	1.1	4.6	19.1
10–14	11.6	(3.2) [5]	(5.7)[5]	26.6[6]
School				
Better-off	13.0	0	2.7	17.2
Poor	16.9	0	3.3	30.9
Overcrowded	10.6	1.8	5.4	25.3
Traditional	20.9	4.0	0	16.2
Gorge	6.4	0	11.5	17.4
Total	13.0	1.1	4.6	22.3

[1] Hemoglobin (g/L) cut offs at sea level, 6-11y: <115, 12-13y:-<120, 14y: boys <130; girls <120 (CDC, 1989); corrections for each school's altitude were made (Cohen & Hass, 1999)(n=331).
[2] Weight-for-height z-score <-2Z (n=174, excludes children aged 10-14y)
[3] Weigth-for-height z-socre >+2Z (n=174, excludes children aged 10-14y)
[4] Height-for-age z-score <-2Z (n=301, excludes children aged 13-14y)
[5] For chilren aged 10 -14y BMI-for-age <5th percentile was estimated for wasting and BMI-for-age >85th percentile for overweight using the CDC 2000 reference data (n=155)
[6] Includes only children aged 10-12y (34/128)

Table 6 presents the micronutrient assessment for vitamin B_{12}, folic acid, zinc, iron (by means of SF) and iodine (by means of TGR). The overall prevalence of low vitamin B_{12} level (<200 ng/dl) was 20.2% (marginal level 200-300 ng/dl: 27.3%), with a statistically higher prevalence in children aged 10-14 y (45.8%) compared to the other age groups. No children had serum folic acid concentration <3 ng/ml, and only 3% had marginal values between 3-6 ng/ml. Most children had potentially deficient serum zinc values <60 µg/dl. The total prevalence of iron deficiency in the subsample, as measured by SF <12 ng/ml was 24.4%.

The TGR for the whole sample of children (n=331) was 5.4% (grade 1: 5.1%; grade 2: 0.3%) with similar rates by sex and age group. All school kitchen salt packages tested for iodine content contained >50 ppm.

Table 6. Micronutient deficiencies in the subsample (n=99) of Tarahumara children at indigenous boarding schools stratified by sex, age and school

Stratified group	Percent of children				
	Vitamin B_{12} <200 ng/dl	Folic acid 3-6 ng/ml[1]	Zinc <60 µg/dl	Iron (SF^2) <12 ng/ml	Iodine TGR[3]
Sex					
Boys	22.2	2.2	85.7	20.5	3.8
Girls	18.5	3.7	75.9	27.5	5.8
Age (y)					
6–8	14.7	0	87.9	23.5	4.8
9–11	9.8	4.9	82.1	27.3	5.2
12–14	45.8*	4.2	66.7	21.7	5.8
Total	20.2	3.0	80.2	24.4	5.4

[1] *No children had a serum folic acid level <3 mg/ml*

[2] *Serum ferritin as an indicator of iron depletion*

[3] *Total goiter rate was evaluated in the whole sample of children (n=331)*

** Statistically different proportion ($p<0.05$); X^2 test was used*

The 2-week recall of foods served at the schools showed that milk, meat, eggs, cheese and fruit were regularly provided in all the schools. Fish was occasionally served but poultry was not. Fresh foods, including fruits, were very seldom served.

Foods selected for the food basket for young children

In the free listing, the key informants mentioned a total of 31 foods thought to be the most appropriate for children aged 6-36 months. Those mentioned by at least one-third of the informants included *quelite* (an edible green wild plant), beans, *pinole*, (a traditional toasted maize powder prepared as gruel), wheat noodles, potatoes, green peas, chicken broth, eggs, maize *tortilla* (a round thin cake of unleavened cornmeal), coffee, broad beans and sardines.

As shown in Table 7, no major differences in the selection of food by level of marginalization of the respondents were identified in the pair comparison procedure; potatoes, broad beans and noodles were the most preferred foods in Food Group A, and eggs, *tortilla* and green peas for Food Group B across the 3 strata. The traditional foods *quelite* and *pinole* received low rankings among respondents' preferences.

Table 7. Proportion of respondents showing preference for each food when matched with each other food within each group in pair comparisons by level of marginalization*

Food group	% Preferred by level of marginalization of the respondents			
	High	Middle	Low	Total
A				
Potatoes	76	75	72	74
Broad beans	58	76	88	74
Noodles	60	60	54	58
Chicken broth	56	51	54	53
Quelite[1]	26	16	24	22
Coffee	26	20	4	17
B				
Eggs	75	82	87	80
Tortilla[2]	62	67	62	64
Green peas	58	45	58	53
Beans	42	36	44	40
Pinole[3]	42	22	40	34
Sardines	24	47	9	27

[1] *Edible green wild plant, spinach-like (Amaranthus palmeri)*
[2] *A round thin cake of unleavened cornmeal*
[3] *Toasted maize powder, prepared as gruel*
* *Based on the number of houses in the community, its accessibility, and the ratio of Tarahumaras to mestizos*

Regarding listing of foods to be added or deleted from the government food basket the 3 foods most often added were beans, green peas and potatoes, almost irrespectively of level of marginalization of the respondents (Table 8). Although not selected by all mothers in the 3 strata, wheat flour, milk, eggs, broad beans and oats were also mentioned. Canned sardines, cookies, lard, and chocolate powder were the foods most often deleted, while wheat noodles, maize, sugar, and salt were the least deleted.

The *semi-structured interviews* revealed no uniform criteria about the age when complementary feeding should be initiated. Mothers for the middle and highly marginalized strata mentioned very few appropriate foods for complementary feeding and knew very few preparation methods. Harmful beliefs regarding withholding food to young children during illness were seen among highly marginalized respondents. Harmful beliefs were also associated with simultaneous complementary feeding and breastfeeding by several mothers from

the middle and highly marginalized strata. Otherwise, no differences in the responses across the marginalization strata were identified for other topics. Breastfeeding up to 2 years was common, mothers used the same utensils to feed their children, and a liquid or semi-liquid consistency of the food was considered appropriate to feed young children in all strata.

Table 8. Proportion of food items selected to be added[1] and deleted[2] from the government food basket[3] to feed children between 6 months and 3 years by level of marginalization[4]

Foods	% Selected by level of marginalization of the respondents			
	High	Middle	Low	Total
Added				
Beans	50	73	80	67
Green peas	40	90	45	58
Potatoes	60	60	36	52
Wheat flour	30	0	55	28
Milk	50	30	0	27
Eggs	0	40	36	25
Broad beans	30	0	36	22
Oats	30	0	36	22
Deleted				
Canned sardines	100	100	100	100
Cookies	80	80	100	87
Lard	70	70	90	77
Chocolate powder	60	60	60	60
Salt	50	70	50	57
Sugar	50	60	50	53
Maize flour	40	40	70	50
Wheat noodles	20	10	20	17

[1] *"If you could add foods to the basket, which foods would you add?"*
[2] *"If you had to delete foods from the basket, which ones would you prefer to delete?"*
[3] *Chocolate powder, cookies, lard, maize, noodles, salt, sardines and sugar*
[4] *Based on the number of houses in the community, its accessibility, and the ratio of Tarahumaras to mestizos*

Based on the focus group discussions (Table 9), nine culturally acceptable were proposed for the food basket for young children: beans, broad beans, green peas, potatoes, skim milk powder, wheat noodles, maize flour, sugar, and iodized salt.

Table 9. Results from the focus groups discussions with Tarahumara women with young children

Foods retained from the government basket in the proposed basket	**Maize flour:** A staple food in the Tarahumara diet. Well accepted by young children in different preparations. Maize is easy to grow. **Noodles:** Preferred for children but eaten by all family members. Mothers like its easy preparation, consistency and low price. **Salt:** Considered a necessary ingredient in food preparation ("children don't eat without it"). **Sugar:** A multi -purpose ingredient very often mentioned in liquid preparations for young children. Considered very expensive.
Culturally accepted foods to be included in the proposed basket	**Beans:** Beans are also base of the Tarahumara diet in different preparations, easy to grow and well accepted by young children. **Broad beans:** Mothers like its consistency and ease of preparation. Very well accepted for children and easy to grow. **Green peas:** Easy to grow and to prepare, and have a soft consistency. Very well accepted by young children. **Milk:** Associated with children's growth, and therefore it is widely used for children of all ages, but especially for young children. **Potatoes:** Very good for children, but they are consumed by all the family. Mothers like their soft consistency and preparation.
Foods not retained from the government basket in the proposed basket	**Cookies:** Regarded as candy, hence associated to tooth damage. **Chocolate powder:** Not well known, so it is little used. It is difficult to obtain and expensive. **Lard:** Related to preparation of adults' foods, seen with reticence for small children for they may "get sick". **Canned sardines:** Well accepted by adults, but not children. "With sardines children may get diarrhea".
Culturally accepted foods not included in the proposed basket	**Eggs:** Considered as a very nutritional food for small children, but most mothers recognized that it is difficult to transport. **Chicken broth:** Although prepared when a chicken or hen is killed, it is well accepted and consumed by all family members. **Pinole**: Mothers feel they show their care for their family by preparing this traditional gruel. After two days it gets rancid. **Squash:** Although not a favorite food, it is accepted by children, but available only in season.
Other foods not included in the proposed basket	**Quelite**: Mothers do not want to receive this edible green spinach-like wild plant, because it is readily found nearby, and because young children can choke on it or get diarrhea. **Coffee:** Although very well accepted by adults, mothers revealed that it is not acceptable for young children. **Oats:** Require special preparation for children, and even so, young children can choke on it.

DISCUSSION AND CONCLUSIONS

Nutritional status of Tarahumara women

The National Nutrition Surveys (NNS) from 1988 did not sample indigenous women from the northern region of the country (Sepúlveda-Amor, 1990). Thus the present study presents the first population-based data on nutritional status for Tarahumara women of reproductive age.

The fact that it was not possible to attain a random sample for the whole population due to the lack of a reliable sampling frame may raise some legitimate concerns regarding the external validity of the results. Although we used a two-stage probability proportional to size stratified systematic sampling strategy -a form of probabilistic sampling- to reduce sampling bias in localities with more than 50 inhabitants, quota sampling had to be used in localities with less than 50 inhabitants because it did not require a list of potential respondents; thus, it was not based on random selection. Instead, respondents who fit into the predetermined sampling criteria were surveyed until the quota was filled.

An additional limitation pertains to the fact that the study area only covers one-third of the total Tarahumara population. The reasons for not having attempted to sample the whole population relates mainly to geographic and demographic difficulties (~20 000 women living in several thousand localities distributed in an area the size of Denmark), which translate to important budgetary and timing constraints.

Iron deficiency anemia

The results of our survey regarding anemia can be compared to those from the NNS of 1988 among indigenous women (Martínez *et al.*, 1995). At national level, the prevalence of anemia was 24.8% for non-pregnant and 22.9% for pregnant indigenous women, compared to 16.1% and 25.7% in our sample, respectively.

A comparison can also be made with Mexican women from the recently published

results from the NNS of 1999 (Shamah-Levy *et al.*, 2003), one year after the Tarahumara study was carried out. Nationwide the prevalence of anemia for indigenous women was 24.8%. Although no estimates for indigenous pregnant women were presented, the prevalence among pregnant rural women in general was 28.0%.

These comparisons suggested that the prevalence of anemia in Tarahumara women of reproductive age was either similar or lower than the national estimates. This finding was not anticipated, given the enormous socioeconomic segregation of the Tarahumara. However, this could reflect a possible sampling bias toward a better off segment of the community. Also, the IDA study included relatively few pregnant women (n=35). Thus prevalence estimates are rather unstable for Hb, and especially for SF (n=16).

On the other hand, women at the peak of their reproductive life had the highest prevalence of anemia; 38.5% among pregnant women in their 3rd trimester and 42.9% in those lactating during the first 6 months after delivery.

Also contrary to expectations, mean Hb among non-pregnant women was significantly higher and the prevalence of moderate and severe anemia significantly lower in women living in localities with <100 persons than in those living in localities with ≥100 persons. The significant effect of locality size was corroborated later in a regression analysis (Monárrez-Espino, 2003) after adjusting for various independent variables.

Parasitic diseases such as hookworm, not evaluated in the survey, are known causes of anemia (Stephenson, 1993; Stoltzfus, 1997; Stephenson, 2000) and could partially explain the differences found. Whereas one might expect higher infection rates in smaller communities, as parasites are found in the more deprived and marginalized settings, they can be more common in crowded environments.

Dietary intake of iron in these women was not measured. Meat, as source of haem iron, is costly and traditionally eaten mainly on ceremonial occasions. Still, on the whole, meat is more commonly eaten in the better off and larger localities. But perhaps factors that influence non-haem iron absorption could also help explaining this differential. For instance, women in smaller communities might eat more wild plants and fruits like berries with high contents of ascorbic acid, a powerful enhancer of non-haem iron absorption (Hallberg *et al.*, 1986). In addition, women in larger villages might drink more coffee containing phenolic compounds that inhibit iron absorption (Brune *et al.*, 1989).

Cultural explanations should also not be ruled out. For instance, women living in small localities possibly drink more "tesgüino" than those in the larger localities. This traditional Tarahumara beer is a thick and nutritious brew made from fermented corn prepared in iron containers. There is evidence that extrinsic iron from the surface of cooking vessels used to brew traditional alcoholic beverages, as in some southern African tribes, can add up to 100 mg to the daily iron intake (Charlton *et al.*, 1973). More research to illuminate these factors would thus be valuable.

Based on these cross-sectional data, pregnancy appears to have an important impact on the Hb and anemia levels of these women, lasting into the first months of lactation. The high prevalence of severe anemia among lactating women during the first 6 months after delivery (11.4%) was also possibly due to high blood losses at delivery, particularly considering that 73% of the Tarahumara children are born at home with no any health care attention whatsoever (Monárrez-Espino, 1998).

The majority of the anemia was related to iron depletion (SF<12 μ/L) in both non-pregnant (69.6%) and pregnant (100%) women. This is consistent with the common finding that for every case of IDA found in a population, there are at least 2 cases of non-anemic iron deficiency (INACG and WHO, 1989). However, most of the women were iron-depleted whether anemic or not, making it difficult to know the role of iron in this anemia.

SF values were obtained from a non-random but probably non-selected subset of women due to the need to develop the field technique for the DSS during the early stages of the study. Although no statistically significant differences were seen between the mean Hb from women with and without SF values, selection bias affecting the prevalence of iron depletion cannot be ruled out.

Very few women had received iron supplementation within 6 months prior to the interview, especially in the small localities. In spite of the Mexican technical norm for prenatal consultation stating that all women should receive iron supplementation during the last trimester of pregnancy (SSA, 1993), only 30.8% received it in the present survey. The fact that almost half the supplemented women received 3 high-dose tablets per day (each tablet containing 25% more iron than that recommended) suggested a delay in the implementation of the more recently recommended single dose per day schedules (Stoltzfus and Dreyfuss, 1998). This could cause more side effects, leading to problems with compliance, as well as representing a waste of economic resources.

These findings point to the need to improve not only the coverage, but also the quality of health care, in particular for pregnant women living in small communities. Prophylactic treatment should be given throughout pregnancy and for the first 3 to 6 months after delivery.

In Mexico as a whole, where most deliveries are carried out in hospitals, it has been calculated that 25% of the maternal deaths among hospital deliveries are due to hemorrhage during the delivery period (Reyes, 1994). Although the maternal mortality rate in the Tarahumara has never been determined, it is high in many predominantly indigenous municipalities in the country (SSA, 1999).

The relatively high prevalence of anemia among pregnant women reported here, along with closely spaced pregnancies, poor prenatal care coverage and the high levels of home delivery mentioned above pose significant risks for the mother and

baby during the perinatal period. Improving the mothers' Hb status prior to the delivery maybe one crucial way to diminish their risk of dying during delivery.

Field technique for capillary DSS

The laboratory method used to measure SF spotted on filter paper reported a very high correlation (r=0.99; p=0.0001) with the conventional analytical technique (Ahluwalia *et al.*, 1998). However, this method was evaluated using venous blood instead of capillary blood and was carried out under laboratory conditions and not under those in remote field settings where the method could be particularly useful.

For these reasons, we developed the adaptations needed to spot serum from capillary blood under field conditions in a very remote setting such as in the Sierra Tarahumara and presented them at a International Nutritional Anemia Consultative Group Symposium (Monárrez-Espino *et al.*, 1999). This led us to make the following observations:

1. Even though using filter paper avoids the need for a cold chain, the samples still need to be centrifuged. Transporting and employing a centrifuge and source of electricity can be difficult in isolated locations.
2. Breaking the capillary tube accurately between the serum and the cell layer can cause spillage, especially if done by a poorly trained person.
3. Extracting accurately 20 µl of serum can only be done using a specialized micropipette fitted with a precision micrometer adjustment device; otherwise, some measurement error should be expected.
4. The capillary tubes must be centrifuged immediately to keep the blood from clotting within the small diameter of the tube, obstructing the separation of the serum. Using tubes with anticoagulant solves this problem, but measuring ferritin in plasma rather than serum results in higher within- and between-sample variations (Pootrakul *et al.*, 1983).
5. The technique requires several drops of free flowing capillary blood (the first is wiped off, the second is used for measuring Hb, and the last 3-4 are

needed to fill the 75 µl capillary tube), requiring a deep prick with a long-tip lancet. A shallow finger prick is often considered less invasive and more acceptable than drawing venous blood, but this is questionable when a deep prick to obtain 6 or more drops is taken. Many of the surveyed women stated that finger pricking was more painful than having venous blood drawn.

6. The proportion of serum diminishes as the Hb concentration increases; thus, in persons with adequate Hb levels, a larger volume (i.e. more drops of blood) is needed to obtain the minimum 20 µL of serum required for the analysis.
7. SF values may be spuriously high due to recent infections, as serum apoferritin is an acute-phase reactant protein that increases in response to inflammation (Birgegård *et al*., 1978; Worwood, 1990), limiting its interpretation in areas with high infection rates (INACG and WHO, 1989). Measuring C-reactive protein is often used to control for this. However, there is currently no filter paper method to test it.

Recently, a validation study for ferritin in capillary DSS reported a high correlation (r=0.86; p=0.0001) with the traditional SF method (Ahluwalia *et al.*, 2002) and based on this encouraged researchers to utilize the DSS in field surveys. However, we warned (Monárrez-Espino and Greiner, 2002) that the concerns described above need to be taken into account in deciding whether to use this method.

Anthropometric status

The prevalence of thinness in adolescent, young adult, and adult women was very low and should not be considered a problem of public health importance (Shetty *et al.*, 1994).

The high prevalence of stunting among adolescents (47.2%) may reflect not only prior chronic undernutrition but also retardation in growth velocity during the adolescent growth spurt. The absence of maturational indicators makes it difficult

to determine whether this was the result of genetic expression or due to environmental influences. Nevertheless, any intervention will provide benefit only if sufficient time remains before maturation for response to occur. Interventions should therefore focus on pre-menarcheal girls in whom the adolescent growth spurt is yet to occur (Martorell, 1992; Largo, 1993; Proos, 1993). On the other hand, short stature that carries on into adulthood is associated with an increased risk of adverse reproductive outcomes. Risks of low birth weight, cephalopelvic disproportion, dystocia, and cesarean section are increased in shorter mothers (Camilleri, 1981; Harrison, 1990).

The prevalence of risk of overweight and obesity in rural women aged 12-49 years at national level was 27.6% and 16.8%, respectively (Rivera-Dommarco *et al.*, 2001), compared to 26.8% and 11.8%, in the Tarahumara women of the same age. This 5% difference in the prevalence of obesity among the Tarahumara, when compared to the rural Mexican population is smaller than what might be expected considering the important differences between these populations' life styles.

The results can also be compared to that reported in other American Indian groups ethnically related to the Tarahumara. For instance, the prevalence of BMI $\geq 27 (\approx 85^{th}$ percentile) in adult Navajo (62%) (Knowler *et al.*, 1991) and Pima (87%) (White *et al.*, 1997) women was nearly twice that of our sample (35.9%). For other North American Indians, a number of studies have documented a dramatic change in dietary and physical activity patterns (Fontvieille *et al.*, 1993; Smith *et al.*, 1996; Ballew *et al.*, 1997). Although the Tarahumara appear not yet to be a victim of "Westernization" at the level of other American Indians in the U.S., the data presented here might reflect the beginning of a change. A "Mestizoization" of their dietary and activity patterns could constitute an initial step in this process. However, there are no previous surveys on which to base estimates of historic trends in the anthropometric indices of the Tarahumara.

One Study in the early seventies assessed the composition of the diet of 372 semi-

acculturated Tarahumaras, concluding that it was low in fat and cholesterol (Cerqueira *et al.*, 1979). In another study, 13 Tarahumara Indians were fed for 5 weeks with a hypercaloric diet typical of a more affluent society showing a dramatic increase in plasma lipid and lipoprotein levels and in body weight (McMurry *et al.*, 1991).

The Tarahumara traditional diet, based on ethnographic observations, consists chiefly of roasted and ground, or boiled food, with very little meat or animal fat. However, there has been an increasing influence from the outside world in recent decades. The construction of a rail line, unpaved roads, and a modern highway connecting this area with important cities has brought, among other things, the establishment of many governmental and private stores that sell food products to both mestizo and Tarahumaras.

Anthropometric data were stratified by community size (measured by the number of people or households), as this relates to the geographical isolation of the localities, in turn affecting their access to public or private services. For instance, the transportation infrastructure only reaches the larger villages, so that people from the small communities often have to travel several kilometers to reach a health or educational facility. Community size also relates to the proportion of mestizos living in the localities; the larger the locality, the larger the proportion of mestizo inhabitants, and thus the influence of mestizo culture.

The Tarahumara in small communities might not have picked up mestizo customs such as frying with lard, or including meat as a common feature of their meals, as it is eaten mainly on ceremonial occasions and is usually prepared by boiling (Kennedy, 1978).

In adolescents, the prevalence of risk of overweight and obesity was not associated with community size. However, relevant differences were identified among young adult and adult women. The prevalence in the risk of overweight was 14.5% in

young adult and 31.4% in adult women in communities with <100 inhabitants. In localities with ≥100 persons, the risk of overweight was 23.5% and 48.4% in young adult and adult women respectively, but no conspicuous differences were seen in the prevalence of obesity.

The increased prevalence of overweight with age in adolescent and young adult women could in part be due to changes from a child's to an adult diet, to cumulative weight gained in previous pregnancies, and to a decrease in physical activity (Bouchard, 1991).

It was worth noting that almost all reported diabetic or hypertensive women in the study were either overweight or obese. Glucose tolerance tests and repeated blood pressure measurements in a representative sample are needed to identify the prevalence of these diseases among Tarahumara women.

Education, as reflected by literacy and bilingualism was positively associated with the risk of overweight and obesity. This also supports the hypothesis that acculturation increases the risk for obesity, since speaking Spanish is linked to the appropriation of many elements of the mestizo culture (Arrieta, 1984).

Perception of food and body shape

In this study, data were obtained from structured interviews of the type commonly used in cognitive anthropology to facilitate an ethnographic description with regards to food and body shape perception, as dimensions contributing to the role that Western acculturation could be playing in increasing overweight in the Tarahumara women.

Cognitive anthropology emphasizes systematic data collection in an effort to attain reliable and valid results (D' Andrade, 1995). However, the exploratory nature of the study and our incomplete appraisal of the difficult topic of diet acculturation can only illuminate a portion of the cultural elements that could be related to the overweight found in the Tarahumara adult women.

Conducting in-depth interviews or administering structured questionnaires to the Tarahumara can be indeed problematic. The illiteracy of the respondents, their relative uncommunicativeness, reticence towards outsiders ("chavochi"), and the frequent need to translate the responses can threaten the validity of such data. For these reasons, we used semi-structured interviews in a very simple format through which respondents could transmit their views.

We analyze the data using different statistical procedures adjusted for small samples to summarize and organize the perception patterns across the stratified categories to efficiently handle and interpret the large amount of data that were generated.

The link between Spanish language capacity and the desire to eat mestizo and western food suggested a process of western acculturation implying a progression towards a diet higher in fat and empty calories. Indeed, speaking a "foreign" language has been considered one of the most important elements of acculturation (Padilla, 1980).

Respondents, including men, judged mestizo and western foods as tastier than traditional foods but no basis for preferring these foods was expressed. One would expect preference to relate to the organoleptic properties of foods. Possibly taste plays a less important role than the desire to eat food linked with other traits such as traditional values, low cost, health, or availability.

The lack of cultural consensus for the topics "preference", "taste" and "health" suggested an ongoing but incomplete process of acculturation in perceptions related to diet, but the fact that cultural consensus was present for "regularity" suggested that acculturation has not yet impacted on the diet itself.

As to body shape perceptions, Spanish speakers consistently preferred obese women for the topics "beauty", "health" and "motherhood" compared to *Rarámuri*

speakers who selected plump (lower BMI but still overweight) women. This coincides to the higher prevalence of overweight and obesity seen in Spanish speaking women compared to *Rarámuri* speakers (59.3 *vs*. 37.1%; p= 0.003) (Monárrez-Espino and Greiner, 2000).

A corpulent body shape could still symbolize wealth and status in the mestizo society, where the Western ideal of female slimness has perhaps not yet penetrated. For the Tarahumara, thinness relates to poor nutrition and poverty, and those who speak Spanish might be approaching the mestizo ideal but not yet the Western.

The Tarahumara perception that plump women are prettier coincides with anthropological observations made about the Tarahumara over two decades ago: "…physical attractiveness is important, with youth, plumpness, and regular features as the most desired qualities in women" (Kennedy, 1978).

Most respondents selected thinner women for the trait "industriousness". Although they could have been conscious of the link between physical activity and body weight, we did not know whether they perceived thinner women as capable of working harder or if working harder was thought to lead to a thinner body shape.

The multidimensional scaling (MDS) showed very similar cluster representations to those identified via tabu search. These similarities reinforced our confidence in the validity of the observed patterns.

Age and size of locality did not show trends for either perception dimension studied. Age relates in opposite directions to the preference for traditional values and the time exposed to a foreign culture. Smaller localities may have less influence from the foreign culture and yet may have a greater need to migrate temporarily during difficult times. Thus perhaps factors acting in opposite directions have cancelled each other out.

In conclusion, speaking Spanish appears to be a central element of dietary acculturation in the Tarahumara. This could be leading to changes in the perception of diet and body shape eventually contributing to a possible increase of overweight among adult women. A steadily increasing proportion of new generations of Tarahumaras are learning Spanish and becoming more and more influenced by the Mexican culture (Arrieta, 1984). This trend could be leading to an increase in the prevalence of obesity and its consequences. Interventions to prevent obesity among Tarahumara women should take this into account.

Educating the community about diet and activity through culturally appropriate means, identifying non-traditional foods that are associated with lower health risks, encouraging prudent food choices from the traditional diet, and focusing these efforts towards younger adults and school-aged children should be part of a systematic effort to prevent obesity among these women.

Possible modification of physical activity levels among the Tarahumara, resulting from the introduction of mestizo and western cultural elements has not yet been studied. The role of circular migration, the exposure to the media, and the role of men as carriers of diet acculturation also need further clarification.

Nutritional status of schoolchildren

In recent decades, the National Indigenous Institute has promoted the nutritional development of nearly 3000 indigenous children living in highly marginalized areas with extreme poverty in the Sierra Tarahumara through providing free food in shelters located close to boarding school premises.

However, no scientific efforts had been made to identify nutritional problems present among these children nor to compare their status with that of other rural Mexicans. For that reason, a comprehensive diagnostic survey to document potential growth retardation and micronutrient deficiencies in children attending a selected sample of schools was carried out.

Wasting (6-9 years: 1.1% <-2 SD) and underweight (10-14 years: 3.2% <5th percentile) were low, similar to that reported for rural children nationwide in the NNS from 1999 (5-11 years: 0.9% if <-2 SD and ≈2.5% if <5th percentile) (Rivera-Dommarco *et al.*, 2001). Also, the prevalence of overweight in children aged 6-9 years (4.6% >2 SD) was similar to that of rural children at national level (5-11 years: 5.3%) (Rivera-Dommarco *et al.*, 2001). But it was considerably higher than levels previously reported in Tarahumara children aged <5 years (0.7%) from a population-based study (Monárrez-Espino and Martínez, 2000). Moreover, the prevalence of overweight in Tarahumara schoolchildren aged 10-14 years (5.7% >85th percentile) was half of the reported prevalence of overweight among rural Mexicans from a similar age group (10-11 years: ≈12%) (Rivera *et al.*, 2001). Besides, Tarahumara school-aged children have only one-third the prevalence of overweight (14.3%) seen in female Tarahumara adolescents from the study with women of fertile age included in this thesis (Monárrez-Espino and Greiner, 2000).

On the other hand, the prevalence of stunting (6-12 years: 22.3% <-2 SD) also resembled levels reported for rural Mexicans (5-11 years: 28%) (Rivera *et al.*, 2001), but contrasted with that of Tarahumara preschool children (≈60%) (Monárrez-Espino and Martínez, 2000), and female adolescents (47.2%) (Monárrez-Espino and Greiner, 2000).

Thus, on 2 critical indicators, overweight and stunting, the children from this sample of indigenous boarding schools were similar to rural Mexico as a whole, but substantially different from population-based findings for slightly younger and older Tarahumara children.

Nutritional stunting in particular cannot change from a prevalence of >60% in 4-5 year olds to <25% in 6-7 year olds in the same population. The preschool children studied were on average 6 years younger than the boarding school children, but were studied 6 years earlier in time, and thus were essentially the same cohort. Death rates cannot explain much of this difference.

Thus it is likely that the boarding-school children are not representative of Tarahumara school-age children as a whole, but represent instead a select group benefiting from this program that, although not more privileged than average rural Mexicans, is among the better-off groups among the Tarahumara. Thus the boarding schools are almost certainly missing major target groups.

Stunting reflects long-term cumulative effects of socioeconomic, health and nutrition inadequacies that occurred earlier in life (WHO, 1995). As would be expected, we found the highest prevalence of stunting in the school predefined as "poor" (30.9% <-2 SD), and the opposite in the "better-off" (17.2%). While there is evidence that some catch-up is possible, this can be achieve only if the growth-limiting factors are remedied early in the preschool period (Largo, 1993).

The 13% prevalence of anemia in Tarahumara schoolchildren was clearly lower than the reported in the NSS for rural children (5-11 years: 21.9%) (Rivera-Dommarco *et al.*, 2001) and slightly lower than that found in adolescents (12-19 years: 18.5%) from the population-based survey with Tarahumara women (Monárrez-Espino *et al.*, 2001).

In the NNS, the prevalence of iron deficiency (TfS<16%) in children aged 5-11 years living in northern Mexico ranged from 35.3-52.6% (Rivera-Dommarco *et al.*, 2001), yet in this survey it was 22.7% using the same cut-off and age group definitions.

The lower proportions of anemia and iron deficiency found in these Tarahumara schoolchildren may partially relate to the selection bias discussed above. But the fact the schools serve meat regularly, which contains highly bioavailable haem iron, may also be contributing to the lower levels of deficiency observed.

The presence of enhancers and inhibitors of iron absorption in the diet could also have played a role. For example, the school located in the gorge presented the

lowest prevalence of anemia (6%). Typically, people from the gorges grow -and presumably eat- more vegetables and fruits than those form the mountains, including guava, oranges, limes, and berries, all rich in vitamin C.

Although accurate diagnosis of folate and vitamin B_{12} deficiency is difficult because no test can reliably serve as a gold standard (Snow, 1999), the results indicate that deficiency of folic acid is unlikely since all children presented values well above the established lower cut-off, and very few (3%) had marginal levels.

Our finding that 20.2% of the children had low serum vitamin B_{12} values was similar to levels found in Mexican children by others (Figueroa-Sandoval *et al.,* 1975; Allen *et al.,* 1995; Murphy *et al.,* 1995). However, serum vitamin B_{12} measurements have problems with binding proteins and inconsistencies between the vitamin concentration and its metabolic products. Therefore methylmalonic acid and homocysteine assays should be used in any follow-up study, as these have a higher diagnostic utility than the method we used (Klee, 2000).

Although good animal sources of vitamin B_{12} including meat, milk, cheese and eggs appear to be frequently consumed by the schoolchildren, accurate estimations of the daily intake of B_{12} are necessary to rule out inadequate dietary intake. The results presented here suggest that older children especially might not be meeting their dietary needs. Other possible causes of vitamin B_{12} deficiency including malabsorptive conditions and bacterial overgrowth also need to be explored. Research is also needed to evaluate the presence of symptoms associated with vitamin B_{12} deficiency.

There are no generally accepted, reliable biomarkers of zinc status. Serum zinc is not always a trustworthy indicator of body zinc stores, as the concentration in tissues is many times larger than in serum. Also, minor changes in uptake or release of zinc from the peripheral sites can have a major effect on the serum concentration (WHO, 1996). Nevertheless, serum zinc is though to be useful at population level (Brown *et al.*, 1998; Brown and Wuehler, 2000).

In the NNS, the proportion of rural children aged 5-11 years with serum zinc values <65 µg/dl ranged between 28.3-41.1% (Rivera-Dommarco *et al.*, 2001), compared to 85% in the present study, suggesting that zinc deficiency may be a problem in these Tarahumara boarding school children. About one-third of rural children in the NNS did not meet the recommended daily allowances for zinc (Rivera-Dommarco *et al.*, 2001).

A TGR of 5.4% adds to other evidence that goiter is still potentially a public health problem in certain populations in Mexico (Martínez-Salgado *et al.*, 2002). Even if the iodine content in the salt packages tested at the schools was >50 ppm, insufficient iodine intake or interference from goitrogens, especially the popular local brassicas, cannot be completely ruled out. Similar kits were previously used to determine the iodine content in salt from 133 Tarahumara households located in Guachochi municipality revealing that 19.5% contained no iodine (1998, unpublished data). These schoolchildren eat at home on almost half the days of the year. In addition, the effect on iodine in salt of prolonged cooking, a common practice at the schools, could also contribute. A careful evaluation, including urinary iodine levels and the possible presence of goitrogens in the diet, needs to be done.

The foods served in the schools were similar, as all received the same foodstuffs for cooking. Differences were observed mainly in how foods were prepared, with some using more traditional methods than others. However, the food inventory method used did not measure the children's dietary intake at the school nor did it account for the foods eaten outside the school. These factors may also relate to the differences seen in micronutrient serum concentrations.

This is the first nutritional survey conducted among Tarahumara children from boarding schools served by INI. The study identified various nutritional deficiencies, pointed out possible explanations, and established baseline data to which future studies in these schools can be compared.

In conclusion, nutritional underweight and stunting were similar to those reported in rural localities at national level, but overweight was less prevalent in children aged 10-14 years. Deficiencies of zinc and vitamin B_{12} were identified, but the prevalence of anemia and iron deficiency were lower than expected. These results should raise a note of caution for public and private organizations serving marginal populations.

However, these results also suggest that children attending the boarding schools might be the better-off than most other Tarahumara children from these areas, pointing to the need of actively recruiting the worse-off children.

Qualitative methods to redesign a food basket

Although supplying food aid is neither the only nor the most important way to combat malnutrition, direct food aid (food distributed to be consumed in addition to food purchased or produced by the household) has a number of advantages over other types of assistance to improve the nutrition of a vulnerable population (Katona-Apte, 1993).

Although food aid can make a large impact in the case of wasted children, it cannot alone solve the multifactorial problems of malnutrition. Food aid needs to be combined with other efforts such as improved agriculture, health, and education to be most effective in defeating malnutrition. Yet, it is still common for some governments to make a simplistic assumption that distributing food to affected groups can solve nutrition problems, including stunted growth.

It should be noted that most nutrition interventions, including those related to behavior change, require a level of infrastructure and human resources impossible to mobilize in a setting such as the Tarahumara where the affected families live mainly in very isolated and scattered villages, each composed of a few dozen relatively uneducated people. Thus the food basket was considered to be at least one useful effort to assist these families. The study focused on one simple and

feasible way in which it might be improved, namely, increasing the likelihood that the food is eaten by children it targets.

Anthropological techniques have been successfully used in the past to obtain relevant qualitative information for the development of culturally tailored solutions of health and nutritional problems in developing countries (Bentley, 1988; Creed-Kanashiro *et al.*, 1991; Martinez-Salgado *et al.*, 1991; Jinadu *et al.*, 1996). Rapid qualitative techniques were used to identify foods eaten by young Tarahumara children to increase the cultural acceptability of the basket provided by the government. This mixture of relatively simple methods were used because collecting valid and reliable data through other means (e.g. in-depth interviews) in this poorly educated and frequently illiterate population is a very difficult and demanding task. In addition, it was possible to triangulate the results from the different techniques to corroborate the choices of the foods proposed to the basket.

An inexpensive convenience quota sampling method dividing the sample into three strata based on level of marginalization to look for possible gross differences across the strata was used. The results, based on the pair comparisons and the addition-deletion data collection techniques, point to a relatively homogeneous judgment in the children's feeding patterns across the marginalization strata, suggesting that the use of a single food basket for all children may be acceptable to a wide range of groups.

The analyses identified 9 culturally acceptable foods that mothers considered appropriate for young children and that could be included in the proposed food basket: beans, broad beans, green peas, potatoes, skim milk powder, wheat noodles, maize flour, sugar, and iodized salt. Only the final 4 in this list were already in the government food basket. The mothers recommended that the following foods, now in the government food basket, be removed: Sardines, cookies, lard, and chocolate powder. The cost of the suggested food basket was calculated and found not to be significantly different from the original government food basket (data not presented).

The proposed food basket includes staple foods, energy-rich foods, food with high protein content and food that offered vitamins and minerals. Most of these foods are produced in nearby areas of Mexico, and all the vegetables are grown locally.

However, some of the suggested foods are appreciated by other family members as well so some intra-family dilution may occur, particularly at times of food scarcity, known to exacerbate existing disparities in intrahousehold food distribution (Katona-Apte 1983; Pelto 1984). Additional efforts that could be made include minimizing food trading or selling, especially among the poorest groups (Reed and Habicht, 1998), and providing nutrition education, known to strengthen the impact of food aid (Walsh *et al.*, 2002; Ghosh *et al.*, 2002).

The suggested food basket should be pilot-tested for its cultural acceptability in a representative sample of households for taste, palatability, ease of preparation, shelf life and specific acceptability by the target child (Mitzner *et al.*, 1984). Active community participation to achieve a long-term sustainable food basket should be promoted (Jennings *et al.*, 1991), as various community-based programs have proved a substantial effect on declining child malnutrition rates (UN ACC/SCN, 1996).

Changes in attitude, knowledge and practices are essential for achieving desirable, long-term, lasting results. Inappropriate feeding practices should be discouraged and attention must be paid to hygiene, storage, preparation, and safety of foods for young children. Similarly, a strong focus on complementary feeding and continued attention to the protection, support and promotion of breastfeeding remain key components of efforts to tackle nutrition problems.

In conclusion, food aid should take into consideration cultural acceptability of the foods offered. This rapid qualitative approach proved to be useful in redesigning a culturally acceptable food basket targeted at young children.

ACKNOWLEDGMENTS

I would like to express my sincere gratitude to all those persons and institutions that contributed to make of these four years a valuable experience in my life.

Thanks indeed to the Mexican Council for Science and Technology, the Department of Women's and Children's Health, and the Swedish Institute for financially supporting my academic training.

I am grateful to Prof. Torsten Tuvemo, Karin Wennqvist, Vera Holmgren and Inga Andersson at the Department of Women's and Children's health and Karin Törnblom, Kristine Eklund and Anita Ededahl at IMCH for their administrative and organizational support.

Thanks to my doctoral colleague Amal Omer-Salim for her friendship, to Dr. Martha Garrett for introducing my to graduate training in Sweden, and to Prof. Lars-Åke Persson and Dr. Eva-Charlotte Ekström for their constructive criticism of this thesis.

I want to acknowledge the Swedish Agency for Research Cooperation with Developing Countries, the Mexican Institute of Social Security, InDevelops u-landsfond Uppsala, the Swedish Mission Council and ITESM Campus Chihuahua who financially supported the studies presented in this thesis.

Thanks to Prof. Gunilla Lindmark for being part of my research committee and for providing support and guidance.

I am thankful to my teacher, supervisor, and good friend Dr. Homero Martínez who has always encouraged my academic and professional development ever since I started my graduate studies at the National Institute of Public Health in Mexico.

Having Prof. Ted Greiner as major supervisor was certainly an exceptional

experience. Ted not only provided me with excellent academic instruction, valuable criticism and kind guidance, he became my mentor and friend, and taught me through his example about the meaning of modesty and humility. Not many supervisors dedicate such a great deal of time to their students as Ted does. He really deserves the German designation for doctoral supervisor ("Doktorvater", doctoral father), thank you indeed Ted.

Agradezco de corazón a mi amigo Sergio Villarreal por su amistad y por haber ilustrado esta tesis con su arte.

Quiero agradecer a mi hermano Oscar por haber siempre mostrado interés en mi vida académica y profesional, a mi hermana Myrna por su franqueza y cariño, y a mi hermano Daniel por haber compartido su infancia y juventud conmigo.

Me siento agradecido en especial con mi hermano César por la impresión de esta tesis y por el apoyo de imprenta que desinteresadamente ha brindado a mis proyectos de investigación.

Quiero recordar a mi padre Daniel, quien me introdujo al hábito de la lectura, por enseñarme que el conocimiento proviene de todas partes.

Ich muss meiner Frau Laura Renée dafür danken, dass sie zehn Jahre lang meinen Charakter ausgehalten hat. Es war nicht sehr einfach, ich weiss. Aber erinnere dich: "…our true destination is not marked on any chart, we're navigating for the shores of the heart".

Pido una disculpa a mi hijo Joel Wassily, a mi hija Tessa Renée, y a mi pequeño Noam Dimitri por el tiempo que debí pasar con ellos y en cambio utilicé para continuar mi entrenamiento académico. Sepan que ustedes se han convertido en la inspiración de mi vida.

Esta tesis está dedicada a una mujer excepcional a quien debo gran parte de lo positivo que pueda haber en mí.

Finally, I make an apology to all those Tarahumara women and children for having used them to write this thesis. I am indebted to all of you. I endorse it as a commitment to continue trying to improve the health of your families.

REFERENCES

A

Ahluwalia N, Lönnerdal B, Lorenz SG, Allen LH. Spot ferritin assay for serum samples dried on filter paper. Am J Clin Nutr 1998;67:88-92.

Ahluwalia N, De Silva A, Atukorala S, Weaver V, Molls R. Ferritin concentrations in dried serum spots from capillary and venous blood in children in Sri Lanka: a validation study. Am J Clin Nutr 2002;75:289-94.

Allen LH, Rosado JL, Casterline JE, Martínez H, López P, Muñoz E, Black AK. Vitamin B-12 deficiency and malabsorption are highly prevalent in rural Mexican communities. Am J Clin Nutr 1995;62:1013-19.

Arriaga L, Espinosa JM, Aguilar C, Martínez E, Gómez L, Loa E (coordinadores). Regiones terrestres prioritarias de México: Alta Tarahumara-Barrancas. México, D.F.: Comisión Nacional para el Conocimiento y Uso de la Biodiversidad, 2000:191.

Arrieta O. Acculturation and the National Integration of the Tarahumara Indians of Northern Mexico (Ph.D. dissertation at the University of Arizona, 1984). Ann Arbor, MI: University Microfilms No. 84-24914.

B

Ballew C, White LL, Strauss KF, Benson LJ, Mendlein JM, Mokdad AH. Intake of nutrients and food sources of nutrients among the Navajo: findings from the Navajo Health and Nutrition Survey. J Nutr 1997;127:2085S-93.

Beaton G. Which age groups should be targeted for supplementary feeding. In: United Nations Administrative Committee on Coordination/Sub-Committee on Nutrition (UN ACC/SCN), ed. Nutritional issues in food aid ACC/SCN Symposium report. Nutrition Policy Discussion Paper No. 12. Geneva, Switzerland: UN ACC/SCN, 1993:37-54.

Bennett PH. Type 2 diabetes among the Pima Indians of Arizona: An epidemic attributable to environmental change? Nutr Rev 1999;57:S51-4.

Bentley ME. The household management of childhood diarrhea in rural north India. Soc Sci Med 1988;27:75-85.

Bernard HR. Research methods in anthropology: Qualitative and Quantitative Approaches. Thousand Oaks, CA: Sage, 1994:238-9.

Birgegård G, Hallgren R, Killander A, Stromberg A, Benge P, Wilde L. Serum ferritin during infection. Sand J Haematol 1978;21:333-40.

Black MM. Zinc deficiency and child development. Am J Clin Nutr 1998;68:464S-9.

Borgatti SP. ANTHROPAC 4.98. Methods guide. Columbia, SC: Analytic Technologies, 1996.

Bothwell T, Charlton R, Cook J, Finch C. Iron metabolism in man. Oxford: Blackwell Scientific Publications, 1979.

Bothwell T. Iron balance and the capacity of regulatory systems to prevent the development of iron deficiency and overload. In: Hallberg L, Asp N, ed. Iron nutrition in health and disease. London: John Libbey, 1996:3-16.

Bouchard C. Current understanding of the etiology of obesity: genetic and nongenetic factors. Am J Clin Nutr 1991;53:1561S-5.

Brabin BJ, Premji Z, Verhoeff F. An analysis of anemia and child mortality. J Nutr 2001a;131:636-48.

Brabin BJ, Hakimi M, Pelletier D. An analysis of anemia and pregnancy-related maternal mortality. J Nutr 2001b;131:604-15.

Broussard BA, Johnson A, Himes JH, Story M, Fichtner R, Hauch F, Bachman-Carter K, Hayes J, Frohlich K, Gray N. Prevalence of obesity in American Indians and Alaska Natives. Am J Clin Nutr 1991;53:1535S-42.

Brown KH, Peerson JM, Allen LH. Effect of zinc supplementation on children's growth: a meta-analysis of intervention trials. Bibliotheca Nutritio et Dieta 1998;5:76-83.

Brown KH, Wuehler SE. Zinc and human health. Results of recent trials and implications for program interventions and research. Ottawa: Micronutrient Initiative and International Development Research Centre, 2000.

Brune M, Rossander L, Hallberg L. Iron absorption and phenolic compounds: importance of different phenolic structures. Eur J Clin Nutr 1989;43:547-58.

Bye RA. Incipient domestication of mustards in northwest Mexico. The Kiva 1979;44:237-56.

Bye RA. Quelitesethnoecology of edible greenspast, present, and future. J Ethnobiology 1981;1:109-23.

Byers T. The epidemic of obesity in American Indians. Am J Dis Child 1992;146:285-6.

C

Camilleri AP. The obstetric significance of short stature. Eur J Obstet Gynecol Reprod Biol 1981;12:347-56.

Carmel R. Cobalamin, the stomach, and aging. Am J Clin Nutr 1997; 66:750-9.

Centers for Disease Control and Prevention (CDC). Criteria for anemia in children and childbearing age women. Report No. 38. Atlanta: CDC, 1989.

Cerqueira MT, Fry MM, Connor WE. The food and nutrient intakes of the Tarahumara Indians of Mexico. Am J Clin Nutr 1979;32:905-15.

Champion, JR. A study in culture persistence: The Tarahumaras of northwestern Mexico. (Ph.D dissertation at Columbia University, 1962). Ann Arbor, MI: University Microfilms No. 63-6107.

Chanarin I. The Megaloblastic Anemias. 2nd Edition. Blackwell Scientific Publications, Oxford, 1979.

Charlton RW, Bothwell TH, Seftel HC. Dietary iron overload. Clin Haematol 1973;2:383-404.

Cogill B. Anthropometric indicators measurement guide. Food and nutrition technical assistance project. Washington, D.C.: Academy for Educational Development, 2001.

Cohen JH, Hass JD. Hemoglobin correction factors for estimating the prevalence of iron deficiency anemia in pregnant women residing at high altitudes in Bolivia. Pan Am J Public Health 1999;6:392-9.

Consejo Nacional de Población (CONAPO), Instituto Naiconal Indigenista (INI). Indicadores socioeconómicos de los pueblos indígenas de México. México, D.F.: CONAPO-INI, 2002.

Cook JD, Finch CA, Smith NJ. Evaluation of the iron status of a population. Blood 1976;48:449.

Cook JD, Baynes RD, Skikne BS. Iron deficiency and the measurement of iron status. Nutr Res Rev 1992;5:189-202.

Creed-Kanashiro H, Fukumoto M, Bentley, Jacoby E, Verzosa C, Brown K. Use of recipe trials and anthropological techniques for the development of a home-prepared weaning food in the central highlands of Peru. J Nutr Educ 1991;23:30-5.

D

Dallman PR, Siimes MA, Steckel A. Iron deficiency in infancy and childhood. Am J Clin Nutr 1980;33:86-118.

Dallman PR, Reeves JD, Driggers DA, Lo EY. Diagnosis of iron deficiency: the limitation of laboratory tests in predicting the response to iron treatment in 1-year-old infants. J pedatr 1981;98:376-81.

Dallman P, Looker A, Johnson C, Carroll M. Influence of age on laboratory criteria for the diagnosis of iron deficiency anemia and iron deficiency in infants and children. In: Hallberg L, Asp N, ed. Iron nutrition in health and disease. London: John Libbey, 1996:65-74.

Daly L, Kirke P, Molloy A, Weir D, Scott J. Folate levels and neural tube defects. Implications for prevention. JAMA 1995;274:1698-702.

D'Andrade, R. The Development of Cognitive Anthropology. New York: Cambridge University Press, 1995.

Deinard AS, Gilbert A, Dodds M, Egeland B. Iron deficiency anemia and behavioral deficits. Pediatrics 1981;68:828-33.

Deinard AS, List A, Lindgren B, Hunt JV, Chang PN. Cognitive deficits in iron deficient and iron deficient anemic children. J Pediatr 1986;108:681-9.

Dirren H, Logman MH, Barclay DV, Freire WB. Altitude correction for hemoglobin. Eur J Clin Nutr 1994:48:625-32.

Dunne P. Early Jesuit Missions in Tarahumara. Berkeley: University of California Press, 1948.

E

English RM, Bennett SA. Iron status of Australian children. Med J Aust 1990;152:582-6.

Eveleth PB, Tanner JM. Worldwide variation in human growth. Cambridge: Cambridge University Press, 1990.

Expert Scientific Working Group. Summary of a report on assessment of iron nutritional status of the United States population. Am J Clin Nutr 1985;2:1318-30.

F

Food and Agriculture Organization of the United Nations (FAO). The Sixth World Food Survey. Rome: FAO, 1996:5-6.

Food and Agriculture Organization of the United Nations (FAO), World Health Organization (WHO). Requirements of Vitamin A, Iron, Folate and Vitamin B12. Food and Nutrition Series, no. 23. Rome: FAO, 1988.

Food and Agriculture Organization of the United Nations (FAO), World Health Organization (WHO). Folate and folic acid (Chapter 4). In: Human vitamin and mineral requirements. Report of a Joint FAO/WHO Expert Consultation. Rome: FAO, 2002:53-63.

Food and Agriculture Organization of the United Nations (FAO), World Health Organization (WHO). Iodine (Chapter 12). In: Human vitamin and mineral requirements. Report of a Joint FAO/WHO Expert Consultation. Rome: FAO, 2002:181-94.

Fernández P. La Mortalidad infantil indígena en 1990: Una estimación a través de municipios predominantemente indígenas. México, D.F.: Secretaría de Salud, 1992.

Figueroa-Sandoval J, Vaz-Pinto A, Sánchez-Medal L. Anemias megaloblásticas: algunos datos sobre su frecuencia en México. Rev Invest Clin 1975;27:121-6.

Fontvieille AM, Kriska A, Ravussin E. Decreased physical activity in Pima Indians compared with Caucasian children. Int J Obes Relat Metab Disord 1993;17:445-52.

G

Ghosh S, Kilaru A, Ganapathy S. Nutrition education and infant growth in rural Indian infants: narrowing the gender gap? J Indian Med Assoc. 2002;100:483-490.

Gillespie S. Major issues in the control of iron deficiency. Ottawa: Micronutrient Initiative, 1998.

Glover F, Laguna M. Tabu Search. Boston, MA: Kluwer Academic Publishers, 1997.

Gómez de León J, Partida V. Niveles de mortalidad infantil y fecundidad en México por entidad federativa. México, D.F.: Secretaría de Salud, 1992.

Grantham-McGregor S, Ani C. A review of studies on the effect of iron deficiency on cognitive development in children. J Nutr 2001;131:649-68.

Grimes BF, ed. Ethnologue: Languages of the World. 14th edition. Dallas, SIL International and International Academic Bookstore, 2000. http://www.ethnologue.com

H

Hallberg L, Brune M, Rossander L. Effect of ascorbic acid on iron absorption form different types of meals. Hum Nutr Appl Nutr 1986;40:97-113.

Hallberg L, Bengtsson C, Lapidus L, Lindstedt G, Lundberg PA, Hulten L: Screening for iron deficiency: an analysis based on bone-marrow examinations and serum ferritin determinations in a population sample of comen. Br J Haem 1993;85:787-98.

Hallberg L, Hultén L. Iron requirements, iron balance and iron deficiency in menstruating and pregnant women. In: Hallberg L, Asp N, ed. Iron nutrition in health and disease. London: John Libbey, 1996:165-81.

Hambidge KM. Zinc. In: Mertz W, ed. Trace elements in human and animal nutrition. San Diego, FL: Academic Press, 1987:1-137.

Hanneman RA. Introduction to Social Network Methods. On-line textbook chapter 9.

http://faculty.ucr.edu/%7Ehanneman/SOC157/TEXT/TextIndex.html. Riverside, CA: University of California, 2003:106-16

Harrison KA. Predicting trends in operative delivery for cephalopelvic disproportion in Africa. Lancet 1990;335:861-2.

Haas JD, Brownlie T. Iron deficiency and reduced work capacity: A critical review of the research to determine a causal relationship. J Nutr 2001;131:676-90.

Healton EB, Savage DG, Brust JC, Garrett TF, Lindenbaum J. Neurological aspects of cobalamin deficiency. Medicine 1991;70:229-44.

Hegele R. Lessons from genetic studies in native Canadian populations. Nutr Rev 1999;57:S43-50.

Herbert V, Das K. Vitamin B12 in Modern Nutrition in health and disease. 8th edition. Baltimore: Williams and Wilkins, 1994.

Herbert V. Vitamin B12 in Present Knowledge in Nutrition. 17th ed. Washington, D.C.: International Life Sciences Institute Press, 1996.

Herbert V. Folic Acid. In: Shils M, Olson J, Shike M, Ross AC, ed. Nutrition in Health and Disease. Baltimore, MD.: Williams and Wilkins, 1999.

Hetzel SB. Iodine and neuropsychological development. J Nutr 2000;130:493S-5.

Howson CP, Kennedy ET, and Abraham Horwitz A, eds. Prevention of Micronutrient Deficiencies: Tools for Policymakers and Public Health Workers. Committee on Micronutrient Deficiencies. Board on International Health. Food and Nutrition Board. Insitute of Medicine. Washington, D.C.: National Academy Press, 1998.

Hirve S, Ganatra B. Determinants of low birth weight: a community based prospective cohort study. Indian Pediat 1994;31:1221-5.

I

International Council for Control of Iodine Deficiency Disorders (ICCIDD), World Health Organization (WHO), United Nations Children's Fund (UNICEF). Assessment of iodine deficiency disorders and monitoring their elimination. Geneva: ICCIDD-WHO-UNICEF, 2001.

International Nutritional Anemia Consultative Group (INACG), World Health Organization (WHO). Iron deficiency in women. Washington: INACG-WHO, 1989.

Instituto Nacional para el Federalismo y el Desarrollo Municipal (INAFED). Enciclopedia de los Municipios de México (Tomo 4: Chihuahua). Mexico, D.F.: INAFED. Available at 1988. http://www.e-local.gob.mx/encilo/chihuahua/pres.htm

Instituto National de Estadística, Geografía e Informática (INEGI) Resultados definitivos del conteo general de población y vivienda, 1995: Chihuahua. México, D.F.: INEGI, 1997.

Instituto National de Estadística, Geografía e Informática (INEGI). XII Censo General de Población y Vivienda 2000. Aguascalientes, México: INEGI, 2001.

Instituto Nacional Indigenista (INI). Desarrollo económico y social: Albergues escolares indígenas. México, D.F.: INI, 2000.

Institute of Medicine. Iron nutrition during pregnancy. In: Board FaN, ed. Nutrition during pregnancy. Washington D.C.: National Academy Press, 1990:272-98.

J

Jennings J, Gillespie S, Mason J, Lotfi M, Scialfa T, ed. Managing successful nutrition programs: Community participation. Nutrition Policy Discussion Paper No. 8. Geneva, Switzerland: United Nations Administrative Committee on Coordination/Sub-Committee on Nutrition, 1991:33-44.

Jinadu MK, Odebiyi O, Fayewonyom BA. Feeding practices of mothers during childhood diarrhea in a rural area of Nigeria. Trop Med Int Health 1996;1:684-9.

K

Katona-Apte J. The significance of intra-household food distribution patterns in food programmes. Food Nutr Bull 1983;5:35-41.

Katona-Apte J. Issues in food aid and nutrition. In: United Nations Administrative Committee on Coordination/Sub-Committee on Nutrition (UN ACC/SCN), ed. Nutritional issues in food aid ACC/SCN Symposium report. Nutrition Policy Discussion Paper No. 12. Geneva, Switzerland: UN ACC/SCN, 1993:5-20.

Kennedy J. Tesgüino complex: The role of beer in Tarahumara culture. Am Anthrop 1963;65:620-40.

Kennedy J. Tarahumara of the Sierra Madre: Beer, Ecology and Social Organization. Arlington Heights, IL: AHM Publishing Corporation, 1978.

Kennedy J. The Tarahumara. Indians of North America Series. New York: Chelsea House Publications, 1990.

Klebanoff M, Shiono P, Selby J, Trachtenberg A, Graubard B. Anemia and spontaneous preterm birth. Am J Obstet Gynecol 1991;164:59-63.

Klee GG. Cobalamin and folate evaluation: measurement of methylmalonic acid and homocysteine vs vitamin B_{12} and folate. Clin Chemistry 2000;46:1277-83.

Knowler WC, Pettitt DJ, Saad MF, Charles MA, Nelson RG, Howard BV, Bogardus C, Bennett PH. Obesity in the Pima Indians: its magnitude and relationship with diabetes. Am J Clin Nutr 1981;53:1543S-51.

Koutras DA, Matovinovic J, Vought R. The ecology of iodine. In: Endemic goitre and cretinism, iodine nutrition in health and disease. Stanbury JB, Hetzel BS, ed. New York: Wiley Eastern Limited, 1985:185-95.

Kruskal JB, Wish M. Multidimensional scaling. Newbury Park, CA; Sage, 1978.

L

Largo RH. Catch-up growth during adolescence. Horm Res 1993;39:41-8.

Lemeshow S, Hosmer DW, Klar J, Lwanga S. Adequacy of sample size in health studies. West Sussex: John Wiley and Sons for WHO, 1990:43.

Lindenbaum J, Savage DG, Stabler SP, Allen RH. Diagnosis of cobalamin deficiency: II. Am J Hematol 1990;34:99-107.

Lumholtz C. Unknown Mexico. New York: Scribner's Sons, 1902.

M

Malina RM, Bouchard C. Growth, maturation, and physical activity. Champaign, IL: Human Kinetics Books, 1991.

Martínez H, González-Cossío T, Flores M, Rivera J, Lezana M, Sepúlveda J. Anemia en mujeres de edad reproductiva. Salud Publica Mex 1995;37:108-19.

Martinez-Salgado H, Calva-Mercado JJ, Meneses-Diaz LM, Viais-Juarez H. The use of beverages and food at home during acute infantile diarrhea: an ethnographic study in a rural Mexican area. Bol Med Hosp Infant Mex 1991;48:235-42.

Martínez-Salgado H, Castañeda-Limones R, Lechuga-Martín del Campo D, Ramos-Hernández, Orozco-López M, Rivera-Dommarco J, Mendoza I, Magos C. Deficiencia de yodo y otros posibles bociógenos en la persistencia del bocio endémico en México. Gac Med Mex 2002;138:149-56.

Martorell R. Long-term consequences of growth retardation during early childhood. In: Hernandez M, Argente J, ed. Human growth: basic and clinical aspects. International Congress Series 973. Amsterdam: Excerpta Medica, 1992:143-9.

McMurry MP. Cerqueira MT, Connor SL, Connor WE. Changes in lipid and lipoprotein levels and body weight in Tarahumara Indians after consumption of an affluent diet. N Engl J Med 1991;325:1704-8.

McPartlin J, Halligan A, Scott JM, Darling M, Weir DG. Accelerated folate breakdown in pregnancy. Lancet 1993;341:148-9.

Mitzner K, Scrimshaw NS, Morgan R, ed. Improving the nutritional status of children during the weaning period. Boston, MA: Massachusetts Institute of Technology, 1984.

Monárrez-Espino J. Caracterización de la desnutrición infantil Tarahumara y diseño de un programa de ayuda alimentaria con aceptabilidad cultural (Tesis de maestría en ciencias del Instituto Nacional de Salud Pública de México, 1998). Cuernavaca, Mexico: INSP, 1998.

Monárrez-Espino J, Lönnerdal B, Greiner T. Assessment of iron deficiency anemia in Tarahumara women of northern Mexico using filter paper to quantify serum ferritin (abstract). International Nutritional Anemia Consultative Group Symposium, Durban, South Africa. Washington D.C.: INACG Secretariat, 1999:32.

Monárrez-Espino J, Greiner T. Anthropometry in Tarahumara Indian women of reproductive age in Northern Mexico: Is overweight becoming a problem? Ecol Food Nutr 2000;39 437-57.

Monárrez J, Martínez H. Prevalence of malnutrition in Tarahumara children under 5 years in the municipality of Guachochi, Chihuahua. Salud Publica Mex 2000;42:8-16.

Monárrez-Espino J, Martínez H, Greiner T. Iron deficiency anemia in Tarahumara women of reproductive-age in northern Mexico. Salud Publica Mex 2001;43:392-401.

Monárrez-Espino J, Greiner T. Measuring serum ferritin under field conditions. Am J Clin Nutr 2002;76:1138

Monárrez-Espino J. Anemia ferropriva en las mujeres Tarahumaras de México. Buenos Aires, Argentina: Sociedad Iberoamericana de Información Científica, 2003.

Morgan DL. Focus Groups as Qualitative Research. Qualitative Research Methods Vol. 16. Thousand Oaks. CA: Sage Publications, 1996.

Morris SS, Ruel MT, Cohen RJ, Dewery KG, De la Briere B, Hassan MN. Precision, accuracy, and reliability of hemoglobin assesssment with use of capillary blood. Am J Clin Nutr 1999;69:1243-8.

Murphy SP, Calloway DH, Beaton GH: Schoolchildren have similar predicted prevalences of inadequate intakes as toddlers in village populations in Egypt, Kenya and Mexico. Eur J Clin Nutr 1995;49:647-57.

Murray CJL, Lopez AD, ed. The Global Burden of Disease: Volume 1. Geneva: World Health Organization, Harvard School of Public Health, World Bank, 1996:311.

N

National Committee for Clinical Laboratory Standards (NCCLS). Determination of serum iron, total iron-binding capacity and percent transferring saturation; Approved standard H17-A. Wayne, PA: NCCLS, 1998.

National Center for Health Statistics (NCHS). NCHS growth curves for children, birth- 18 years. Publication No. PHS 78-1650. Washington, D.C.: Department of Health, Education and Welfare, 1977.

National Center for Health Statistics (NCHS). 2000 CDC growth charts for the United States: Methods and development. Vital Health Stat 2002;11(246).

Neel JV. Diabetes mellitus: a “thrifty” genotype rendered detrimental by progress. Am J Hum Genet 1962;14:353-62.

Neel JV. The "Thrifty Genotype" in 1998. Nutr Rev 1999;57:S2-9.

O

O'Dea K. Westernization and non-insulin-dependent diabetes in Australian Aborigines. Ethn Dis 1991;1:171-87.

Oppenheimer SJ. Iron and its relation to immunity and infectious disease. J Nutr 2001;131:616-35.

Oski FA, Honig AS, Helu B, Howanitz P. Effect of iron therapy on behavior performance in non-anemic iron deficient infants. Pediatrics 1983;71:877-80.

P

Padilla AM. Acculturation: Theory, models and some new findings. Boulder, CO: Western Press, 1980.

Pelto G. Ethnographic studies of the effects of food availability and infant feeding practices. Food Nutr Bull 1983;6:33-43.

Pelto G. Intra-household food distribution patterns. Malnutrition: Determinants and consequences. Curr Top Nutr Dis 1984;10:285-93.

Pennington C. The Tarahumar of Mexico. Salt Lake City, UT: University of Utah Press, 1963.

Pérusse L, Bouchard C. Genotype-environment interaction in human obesity. Nutr Rev 1999;57:S31-8.

Pootrakul P, Skikne B, Cook J. The use of capillary blood for measurements of circulating ferritin. Am J Clin Nutr 1983;37:307-10.

Preziosi P, Hercberg S, Galan P, Devanlay M, Cherouvrier F, Dupin H. Iron status of a healthy French population: Factors determining biochemical markers. Ann Nutr Metab 1994;38:192-202.

Proos LA. Anthropometry in adolescence; secular trends, adoption, ethnic and environmental differences. Horm Res 1993;39:41-8.

R

Rasmussen, KM. Is there a causal relationship between iron deficiency or iron-deficiency anemia and weight at birth, length of gestation and perinatal mortality? J Nutr 2001;131:590-603.

Reed BA, Habicht JP. Sales of food aid as sign of distress, not excess. Lancet. 1998;351:128-30.

Reyes S. Mortalidad materna en México. México, D.F.: Intituto Mexicano del Seguro Social, 1994:28-44.

Rivera-Dommarco J, Shamah-Levy T, Villalpando-Hernández S, González-Cossío T, Hernández-Prado B, Sepúlveda J. Encuesta Nacional de Nutrición 1999. Estado nutricio de niños y mujeres en México. Cuernavaca, México: Instituto Nacional de Salud Pública, 2001.

Roche AF, Davila GH. Differences between recumbent length and stature within individuals. Growth 1974;38:313-20.

Romano A. El Centro Coordinador Indigenista de la Tarahumara. Los Centros Coordinadores Indigenistas. México, D.F.: Instituto Nacional Indigenista, 1992.

Romney AK, Weller SC, Batchelder WH. Culture as Consensus: A theory of Culture and Informant Accuracy. Am Anthrop 1986;82:313-38.

Romney AK, Batchelder WH, Weller SC. Recent applications of Consensus Theory. Am Behav Sci 1987;31:163-77.

Royston R, Armstrong S. The status of women and maternal mortality. In: World Health Organization (WHO), ed. Preventing maternal mortality. Geneva: WHO, 1989:75-106.

S

Sandström B, Lönnerdal B. Promoters and antagonists of zinc absorption. In: Zinc in Human biology. Mills CF, ed. Devon, UK: Springer-Verlag, 1989:57-78.

Sauberlich HE. Detection of folic acid deficiency in populations. In: Broquist HP, Butterworth CE, Wagner, ed. Folic Acid: Biochemistry and Physiology in Relation to Human Nutritional Requirement. Washington, D.C.: National Academy of Sciences, 1977:198-208.

Schenck HV, Falkensson M, Lundberg B. Evaluation of "Hemocue", a new device for determining hemoglobin. Clin Chem 1986;32:526-29.

Schloz B, Gross R, Schultink W, Sastroamidjojo S. Anemia is associated with reduced productivity of women workers even in less physically-strenuous tasks. Br J Nutr 1997;77:47-57.

Scott J, Weir D. Folate/vitamin B_{12} interrelationships. Essays in Biochemistry, 1994;28:63-72.

Scott J, Kirke P, Molloy A, Daly L, Weir D. The role of folate in the prevention of neural tube defects. Proc Nutr Soc 1994;53:631-6.

Scrimshaw NS, Gleason GR, ed. Rapid Assessment Procedures. Qualitative methodologies for planning and evaluation of health related programs. Boston, MA: International Nutrition Foundation for Developing Countries, 1992.

Shamah-Levy T, Villalpando S, Rivera JA, Mejía-Rodríguez F, Camacho-Cisneros M, Monterrubio EA. Anemia in Mexican women: A public health problem. Salud Publica Mex 2003;45:S499-S507.

Shrimpton R, Victora CG, de Onis M, Lima RC, Blossner M, Clugston G. Worldwide Timing of Growth Faltering: Implications for Nutritional Interventions. Pediatrics 2001;107:E75.

Secretaría de Salud (SSA). Programa Nacional de Salud. México, D.F.: SSA, 1990.

Secretaría de Salud (SSA). Atención de la mujer durante el embarazo, parto y puerperio y del recién nacido (Norma Oficial Mexicana NOM-007-SSA2-1993). México, D.F.: Diario Oficial de la Federación, 1993.

Secretaría de Salud (SSA). Mortalidad 1993-1998. México, D.F.: Dirección General de Estadística e Informática SSA, 1999.

Sepúlveda-Amor J, Lezana MA, Tapia-Conyer R, Valdespino JL, Madrigal H, Kumate J. Nutritional status of pre-school children and women in Mexico: results of a probabilistic national survey. Gac Med Mex 1990;126:207-26.

Shankar AH, Prasad AS. Zinc and immune function: the biological basis of altered resistance to infection. Am J Clin Nutr 1998;68:447S-63.

Shetty PS, James WP. Body mass index. A measure of chronic energy deficiency in adults. FAO Food Nutr Pap 1994;56:1-57.

Simopoulos AP. Genetic Variation and Nutrition. Nutr Rev 1999;57:S10-9.

Smith JC, Butrimovitz GP, Purdy WC. Direct measurement of zinc in plasma by atomic absorption spectroscopy. Clin Chem 1979;25:1487-91.

Smith CJ, Nelson RG, Hardy SA, Manahan EM, Benett PH, Knowler WC. Survey of the diet of Pima Indians using quantitative food frequency assessment and 24-hour recall. Diabetic Renal Disease Study. J Am Diet Assoc 1996;96:778-84.

Snow CF. Laboratory diagnosis of vitamin B12 and folate deficiency. Arch Intern Med 1999;159:1289-98.

Stabler SP, Lindenbaum, Allen RH. The use of homocysteine and other metabolites in the specific diagnosis of vitamin B-12 deficiency. J Nutr 1996;126:1266S-72.

Stephenson L. The impact of schistosomiasis on human nutrition. Parasitology 1993;107:107-23.

Stephenson L, Holland CV, Cooper ES. The public health significance of Trichuris trichiura. Parasitology 2000;121:73-95.

Stoltzfus R, Chwaya H, Tielsch J, Schulze L, Albonico M, Savioli L. Epidemiology of iron deficiency in Zanzibari schoolchildren: the importance of hookworms. Am J Clin Nutr 1997;65:153-9.

Stoltzfus R, Dreyfuss M. Guidelines for the use of iron supplements to prevent and treat iron deficiency anemia. Washington, D.C.: International Life Sciences Institute, 1998:11-7

Story M, Evans M, Fabsitz RR, Clay TE, Holy Rock B, Broussard B. The epidemic of obesity in American Indian communities and the need for childhood obesity-prevention programs. Am J Clin Nutr 1999;69:747S-74.

Sturrock K, Rocha J. A Multidimensional Scaling Stress evaluation table. Field Methods 2000;12:49-60.

T

Tanner JM. Growth at adolescence; with a general consideration of the effects of hereditary and environmental factors upon growth and maturation from birth to maturity. Oxford: Blackwell, 1962.

Troiano RP, Frongillo EA, Sobal J, Levitsky DA. The relationship between body weight and mortality: a quantitative analysis of combined information from existing studies. Int J Obes Relat Metab Disord 1996;20:63-75.

Turnlund JR, King JC, Keyes WR, Gong B, Michel MC. A stable isotope study of zinc absorption in young men: effects of phytate and cellulose. Am J Clin Nutr 1984;40:1071-7.

U

United Nations Administrative Committee on Coordination/Sub-Committee on Nutrition (UN ACC/SCN). How nutrition improves: State-of-the-Art Series Nutrition Policy Discussion Paper No. 15. Geneva: UN ACC/SCN, 1996.

United States Department of Agriculture (USDA). Nutrient Database for Standard Reference: Agricultural Research Service. Release 13. Nutrient Data Lab Home Page. URL http://www.nal.usda.gov/fnic/foodcomp, 1999.

V

Valencia ME, Bennett PH, Ravussin E, Esparza J, Fow C, Schulz LO. The Pima Indians in Sonora, Mexico. Nutr Rev 1999;57:S55-8.

Viteri F. Prevention of Iron Deficiency. In: Howson CP, Kennedy ET, and Abraham Horwitz A, eds. Prevention of Micronutrient Deficiencies: Tools for Policymakers and Public Health Workers. Committee on Micronutrient Deficiencies. Board on International Health. Food and Nutrition Board. Insitute of Medicine. Washington, D.C.: National Academy Press, 1998:45-102.

W

Walsh CM, Dannhauser A, Joubert G. The impact of a nutrition education programme on the anthropometric nutritional status of low-income children in South Africa. Public Health Nutr 2002;5:3-9.

Walter T. Effect of iron deficiency anemia on cognitive skills in infancy and childhood. In: Hallberg L, Asp N, ed. Iron nutrition in health and disease. London: John Libbey, 1996:219-29.

Weller SC, Romney AK. Systematic Data Collection. Thousand Oaks, CA: Sage, 1988.

Weller SC, Mann NC. Assessing rater performance without a gold standard using Consensus Theory. Med Decision Making 1997;17:71-9.

White LL, Ballew C, Gilbert TJ, Medlein JM, Mokdad AH, Straus KF. Weight, body image, and

weight control practices of Navajo Indians: findings from the Navajo Health and Nutrition Survey. J Nutr 1997;127:2094S-8.

World Health Organization (WHO). Diet, nutrition and the prevention of chronic diseases. Geneva: WHO, 1990.

World Health Organization (WHO), United Nations Children's Fund (UNICEF), International Council for the Control of Iodine Deficiency Disorders (ICCIDD). Global prevalence of iodine deficiency disorders. Micronutrient deficiency information system working paper No. 1. Geneva: WHO, 1993:7.

World Health Organization (WHO). Physical Status: The use and interpretation of anthropometry. Geneva: WHO, 1995.

World Health Organization (WHO). Trace elements in human nutrition and health. Zinc. Geneva: WHO, 1996:72-104.

World Health Organization (WHO). The world health report 1997: Conquering suffering, enriching humanity. Geneva, WHO, 1997:51.

World Health Organization (WHO), United Nations Children's Fund (UNICEF). Iron Deficiency Anemia: Prevention, assessment and control. Geneva, WHO, 1998.

World Health Organization (WHO). Nutrition: Alleviating protein-energy malnutrition. Internet site accessed on December 2003 at http://www.who.int/nut/pem.htm

World Bank. World Development Report 1993: Investing in Health. Washington, D.C., World Bank, 1993:75.

Worwood M. Ferritin. Blood Rev 1990;4:259-69.

Y

Yip R, Johnson C, Dallman PR. Age-related changes in laboratory values used in the diagnosis of anemia and iron deficiency. Am J Clin Nutr 1984;39:427-36.

Z

Zittoun J, Zittoun R. Modern clinical testing strategies in cobalamin and folate deficiency. Sem Hematol 1999;36:35-46

Avhandling för avläggande av Medicine doktorsexamen i internationell hälsa (medicinska fakulteten) presenterat vid Uppsala Universitet 2004.

SAMMANFATTNING
Monárrez-Espino J. (2004). Hälsa och nutrition hos Tarahumara indianer i Norra Mexiko: Studier på kvinnor och barn.

Att tillhöra en infödd folkgrupp i Mexiko associeras oftast med ett dåligt hälsotillstånd, framför allt på grund av social isolering från det konventionella samhället. Tarahumara indianerna utgör inget undantag. De utgör den största gruppen av infödda i norra Mexiko och är en av de mest utsatta etniska minoriteterna i Nord Amerika. Det finns anledning att oroa sig för de rådande hälsovillkoren då mycket lite information finns tillgänglig för att underlätta utformandet och tillämpningen av program för att förebygga och handskas med de huvudsakliga hälsoproblemen som drabbar denna folkgrupp. Denna avhandling syftar till att försöka täcka upp delar av den informations brist som råder. I den presenteras och diskuteras resultaten från de studier, som inriktar sig på näringstillståndet hos tarahumara kvinnor och barn, genomförda mellan åren 1997 och 2002.

En studie i ett representativt distrikt med ett representativt urval av Tarahumara kvinnor i fertil ålder fann man högst prevalens av anemi bland de gravida kvinnorna som befann sig i sista trimestern (38,5 %) samt i gruppen ammande kvinnor under de 6 första månaderna efter förlossning (42,9 %), detta tillsammans med en hög prevalens av järnbrist. I denna studie utvecklades en metod för insamling av kapillära serum prover som droppades på filter papper för att därefter analysera serum ferritin halten vid avsides liggande sättningar**.** I samma studie fann man även att 52,5 % av de vuxna kvinnorna var överviktiga, vilket skulle kunna antyda om en "avindianiserings-process" av deras traditionella diet och aktivitets mönster. Detta fynd följdes upp i en senare studie som grundade sig på föreställningar om mat och kroppsform, genom att använda kognitiva antropologiska metoder. Att vara spansktalande framträdde som ett tydligt tecken på kulturförändring som skulle kunna sammankopplas med en ökning i prevalensen av övervikt och dess konsekvenser. En skolbaserad nutritions studie bland Tarahumara barn vid internatskolor visade brist på zink, vitamin B_{12}, järn och jod, dock var dessa fynd likvärdiga med uppmätta värden bland barn på den mexikanska landsbygden. Slutligen genomfördes en kvalitativ studie med avsikt att identifiera kulturellt accepterade maträtter och därigenom kunna omforma regeringens rådande sammansättning av livsmedelsbistånd, med syfte att mildra undernäringen bland unga Tarahumara barn.

Resultaten från denna avhandling ger relevanta data för en förbättrad utformning av interventionsprogram för att bekämpa och förhindra en del av de nutritions problem som drabbar Tarahumara indianerna. Dessa data skulle också kunna utgöra en referenslinje med vilken framtida förändringar kan jämföras med såvida liknande provtagnings rutiner används. Generellt, belyser resultaten vikten och utmaningen att uppnå modernisering på ett sätt som inte enbart förbättrar hälsoläget men som samtidigt upprätthåller och uppmuntrar till att behålla traditionella värderingar. Dessa utgör inte enbart grunden för Tarahumara samhället utan bidrar även därigenom i en del fall till en bättre kosthållning och bättre hälsa.

Joel Monárrez-Espino, Institutionen för kvinnors och barns hälsa. Internationell mödra- och barnhälsovård. Uppsala universitet. 751 85 Uppsala, Sverige.

Dissertation zur Erlangung des Doctor of Philosophy (medizinische Fakultät) im internationalen Gesundheitswesen, vorgelegt im Jahre 2004 an der Universität zu Uppsala.

ABSTRAKT
Monárrez-Espino J. (2004). Gesundheit und Ernährung der Tarahumara aus Nord-Mexiko: Studien zu Frauen und Kindern.

Die Zugehörigkeit zu einer eingeborenen Volksgemeinschaft Mexikos wird gewöhnlich mit einem schlechten Gesundheitszustand, aufgrund sozialer Isolation von der allgemeinen Gesellschaft, verbunden. Die Tarahumara-Indianer sind dabei keine Ausnahme. Sie stellen eine der größten Eingeborenengruppen im Norden des Landes dar und sind eine der ausgeschlossensten ethnischen Minderheiten in Nordamerika. Der Gesundheitszustand ist prekär, da sehr wenige Daten existieren, um die Gestaltung und Einführung von Programmen zur Prävention und Handhabung der, diese Menschen betreffenden, hauptsächlichen Probleme im Gesundheitswesen, zu ermöglichen. Diese Dissertation beabsichtigt, Teil dieses Informationsdefizits zu beseitigen. Sie präsentiert und diskutiert die Ergebnisse von im Zeitraum 1997 bis 2002 durchgeführten Studien, welche die Ernährung der Tarahumarafrauen und -kinder fokussieren.

Eine Umfrage mit einer repräsentativen Stichprobe von Frauen im gebärfähigen Alter, im größten Tarahumara-Bezirk, ergab das höchste Vorkommen von Anämie bei schwangeren Frauen im dritten Trimester (38,5%) und bei solchen, die während der ersten 6 Monate nach der Geburt stillten (42,9%), bedingt durch Eisenmangel. Bei dieser Studie wurde eine Feldtechnik für weit entfernte Gebiete entwickelt, um die Ferritin-Konzentration in Kapillar-Serum auf Filter Papier zu messen. Dieselbe Studie zeigte eine Übergewichtsprävalenz von 52,5% bei erwachsenen Frauen, was auf einen Prozess einer „Entindianisierung“ ihrer traditionellen Diät und Aktivitätsmuster zurückzuführen ist. Dieses Thema wurde bei einer späteren Studie herangezogen, bei welcher der Eindruck von Nahrung und Körperumfang mit kognitiven anthropologischen Methoden evaluiert wurde. Spanisch zu sprechen erschien als eindeutige Indikation für Akkulturation, welche mit einer Zunahme des Vorhandenseins von Übergewicht und seiner Folgen assoziiert werden könnte. Eine Studie zu Schulkindern in Eingeboreneninternaten zeigte Beweise für Zink-, Vitamin B_{12}-, Eisen- und Jodmangel, fand aber ähnliche anthropometrische Status wie bei ländlichen Mexikanerkindern. Schließlich wurde eine qualitative Studie durchgeführt, mit dem Ziel, kulturell akzeptierte Lebensmittel für die Neuentwerfung eines Warenkorbes zu identifizieren, um den Ernährungszustand von Kleinkindern zu verbessern.

Die Ergebnisse dieser Dissertation liefern relevante Daten für eine Verbesserung der Gestaltung von Programmen zur Bekämpfung und Prävention von Ernährungsproblemen, welche die Tarahumaras betreffen. Diese Informationen können auch als „Baseline“ benutzt werden, mit der zukünftige Veränderungen verglichen werden könnten, wenn ähnliche Stichprobenstrategien angewandt würden. Vor allem betonen die Ergebnisse, die Wichtigkeit und Herausforderung, eine Modernisierung zu erreichen, die nicht nur eine Verbesserung der Gesundheit mit sich bringt, sondern gleichzeitig auch, traditionelle Werte unterstützt, aufrechterhält und anregt, da diese Werte nicht nur die Grundlagen der Tarahumara- Gesellschaft sind, sondern in vielen Fällen zu einer besseren Diät und Gesundheit beisteuern.

Joel Monárrez Espino, Abteilung für Frauen- und Kinderheilkunde, Internationale Gesundheit bei Frauen und Kindern, Universität zu Uppsala, SE-751 85 Uppsala, Schweden.

Disertación para obtener el grado de Doctor en Filosofía (Facultad de Medicina) en Salud Internacional presentada en la Universidad de Uppsala en 2004.

RESUMEN

Monárrez-Espino J. (2004). Salud y Nutrición en los Tarahumaras del norte de México: Estudios en mujeres y niños.

La pertenencia a un grupo indígena en México se asocia frecuentemente a una salud pobre principalmente como resultado del aislamiento social de la sociedad Mexicana. Los Tarahumaras no son la excepción. Constituyen el grupo indígena más grande del norte del país y una de las minorías étnicas más marginadas de Norteamérica. A pesar de que sus condiciones de salud son precarias, existe muy poca información disponible que facilite el diseño e implementación de programas para prevenir y tratar los problemas de salud pública más importantes que les aquejan. Así pues, esta tesis tiene por objeto cubrir parte de esta falta de información. Presenta y discute resultados de estudios enfocados a la nutrición de mujeres y niños llevados a cabo entre 1997 y 2002.

Una encuesta en una muestra municipal representativa de mujeres Tarahumaras en edad reproductiva mostró la más alta prevalencia de anemia en las embarazadas en el tercer trimestre (38.5%) y las lactantes durante los primeros 6 meses después del parto (42.9%) paralelamente a una alta prevalencia de deficiencia de hierro. En este estudio, se desarrolló una técnica para la toma de muestras de suero capilar en papel filtro para medir los niveles de ferritina sérica en zonas remotas. Asimismo se encontró un 52.5% de sobrepeso en las mujeres adultas, sugiriendo un proceso de "deindigenización" de los patrones dietéticos y de actividad física tradicionales. Este tópico fue seguido en un estudio posterior sobre percepciones de la alimentación y apariencia corporal de la mujer Tarahumara utilizando métodos de antropología cognoscitiva. Hablar español emergió como un claro indicio de aculturación que podría estar asociado a un incremento en la prevalencia de obesidad y sus consecuencias. Una encuesta nutricional con niños Tarahumaras de albergues escolares mostró evidencia de deficiencia de cinc, vitamina B_{12}, hierro y yodo pero encontró un estado antropométrico similar al de otros niños mexicanos del medio rural. Finalmente, se condujo una evaluación cualitativa para identificar alimentos culturalmente aceptables para rediseñar una canasta de ayuda alimentaria con el objeto de aliviar la desnutrición infantil.

Los resultados de esta tesis ofrecen información relevante para el mejoramiento del diseño de intervenciones para combatir y prevenir algunos de los problemas nutricios que afectan a los Tarahumaras. De utilizarse estrategias muestrales similares, esta información podría además constituir el punto de comparación para evaluar cambios futuros. Pero sobre todo, los hallazgos apuntan a la importancia y el desafío para alcanzar una modernización que no solo mejore la salud de los indígenas, sino que además apoye, mantenga y promueva los valores culturales tradicionales, pues estos, además de conformar los cimientos de la sociedad Tarahumara, pueden en varios casos contribuir a una mejor nutrición y salud.

Joel Monárrez-Espino. Departamento de salud materno-infantil. Salud internacional materno-infantil. Universidad de Upsala. SE-751 85 Upsala, Suecia.

IMPRESIÓN gráfica
Printed in Mexico by Impresión Gráfica
Chihuahua, Chihuahua, México
2004

Acta Universitatis Upsaliensis

Comprehensive Summaries of Uppsala Dissertations
from the Faculty of Medicine

Editor: The Dean of the Faculty of Medicine

A doctoral dissertation from the Faculty of Medicine, Uppsala University, is usually a summary of a number of papers. A few copies of the complete dissertation are kept at major Swedish research libraries, while the summary alone is distributed internationally through the series Comprehensive Summaries of Uppsala Dissertations from the Faculty of Medicine. (Prior to October, 1985, the series was published under the title "Abstracts of Uppsala Dissertations from the Faculty of Medicine".)

Distribution:
Uppsala University Library
Box 510, SE-751 20 Uppsala, Sweden
www.uu.se, acta@ub.uu.se

ISSN 0282-7476
ISBN 91-554-5866-1