

Original Article

Nutritional status evaluation and nutrient intake in adult patients with pulmonary tuberculosis and their contacts

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Abstract

Introduction: Malnutrition is a common status in patients with tuberculosis (TB). Because TB is disseminated through the sputum of infected persons, individuals who maintain relations with a TB patient are at high risk of infection; this risk is greater when contacts present an inadequate nutritional status. The aim of this work was to analyse and compare the nutritional status and macro and micronutrient intake of TB patients and their household contacts.

Methodology: A cross-sectional study was carried out in TB patients from Nuevo Leon, México, and their household contacts. Thirty-nine patients diagnosed with TB and 62 contacts were evaluated. Anthropometric evaluation was performed considering weight, height, body mass index (BMI) and waist-hip ratio (WHR); nutrient intake was evaluated by applying 24-hour dietary recalls.

Results: According to anthropometric assessment, the study population showed a greater trend towards being overweight and obese; 62% of TB patients and contacts had this type of malnutrition, while only 8% of individuals were undernourished. A greater tendency towards malnutrition was observed in the TB patient group.

Conclusions: TB patients and their contacts presented as overweight and obese. Both groups showed similar patterns in macro and micronutrient intake. Implications of deficiencies in the intake of these nutrients are discussed on the basis of their effects on individual health.

Key words: Tuberculosis; nutritional status; nutrient intake; TB-patients; household contacts.

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Introduction

Tuberculosis (TB) is a bacterial infection caused by *Mycobacterium tuberculosis* that primarily affects the lungs [1]. The main mechanism of bacterial spread and transmission is by air through the sputum of infected individuals [2]. Annually worldwide, TB causes approximately three million deaths and infects between one and two billion people [3]. The population infected with TB often is malnourished as indicated by decreases in the level of proteins, anthropometric indexes and micronutrient status [4]. Due to the mechanisms involved in disease transmission, people who are closely related to TB patients are at increased risk of infection; in addition, if the contact presents some type of malnutrition, the risk of infection increases because their immune system is weakened [1]. Household contacts are defined as individuals who maintain relations with a TB patient [5]. Some studies suggest that TB is related to low levels of micro-nutrients, such as zinc [6,7], vitamin A [1] and vitamin D [8]. Good

nutrition requires proper intake of macro and micro-nutrients [4]; however, the nutritional status and, therefore, the health of individuals could be influenced by several factors, such as socio-economic status, urban environment, eating habits, education and access to health services. Considering that the early diagnosis of inadequate nutritional status is necessary to prevent the contagion of the population that is in contact with TB patients [9,10], the objective of this research was to evaluate and compare the nutritional status and the macro and micronutrient intake of patients diagnosed with pulmonary TB and their contacts.

Methodology

Study Population

A cross-sectional study was performed in TB patients from Instituto Mexicano del Seguro Social (IMSS) Clinics of Nuevo Leon, México and their contacts. The research was conducted in 39 patients diagnosed with TB and 62 contacts in the age range

between 15 and 88 years. This study did not include women who are pregnant or breast-feeding, as well as anyone recovering from chronic illness or surgery. The study protocol was approved by the Research Ethics Committee of the Autonomous University of Nuevo León, School of Public Health and Nutrition, México. All subjects agreed to participate in the study, stating their agreement by signing the informed consent.

Anthropometric evaluation

An experienced nutritionist assessed the anthropometric data of participants in the study by determining the weight, height, body mass index (BMI) and waist-hip ratio (WHR). Subjects were weighed without shoes and lightly clothed using a Tanita electronic digital scales (Tanita Corporation of America, Inc., USA), while height was recorded using a conventional stadiometer (Seca 213, USA). Body mass index (BMI) was calculated by dividing body weight (expressed in kilograms) by the square of height (in meters): kg/m². Nutritional status was determined based on BMI cut off points by the World Health Organization (WHO): Global Database on Body Mass Index (BMI). Available from: <http://www.who.int/nutrition/databases/bmi/en/> [11]. Waist and hip circumferences were measured according to the WHO recommendations, using an insertion tape. Waist circumference was measured at the midpoint between the lower rib and the upper margin of the iliac crest, and the hip circumference was denoted as the widest circumference over the buttocks and below the iliac crest. WHR (i.e. the waist circumference divided by the hip circumference) was calculated with the values corresponding to waist and hip measurements [12].

Dietary assessment

Food intake was calculated applying a 24-hour dietary recall to patients and contacts to estimate the intake of energy, protein, carbohydrates, fiber, lipids, cholesterol, fat (saturated, monounsaturated, polyunsaturated), minerals as calcium, phosphorus, iron, magnesium, sodium, potassium, zinc and vitamins (retinol, ascorbic acid, thiamin, riboflavin, niacin, pyridoxine, folic acid and cobalamin). The 24-hour diet recall was carried out by a nutritionist on three different occasions during home visits of participants. Each 24-hour recall was conducted using a standardized protocol, with a complete list of all food and beverages consumed during the previous day and detailed descriptions of all the food and beverages consumed, including brand names and cooking methods.

An estimate of the amount of all foods and beverages consumed was recorded by household measuring and serving utensils like spoons, plates or cups. Food Processor Software® incorporating the Mexican food composition tables was used to calculate the nutrient intake from dietary recalls. For the calculation of the nutrient adequacy ratio, the nutrient recommendations for Mexican population [13] were used, applying the formula: (Patient food intake × 100) / Nutrient recommendations.

Other measures

In order to discover other factors that could influence the health of TB patients and their contacts, a structured sociodemographic questionnaire was included to obtain information regarding socio-demographics and lifestyle risk factors such as gender, age, kinship, perceived income, smoking, educational level, public services and access to health services of subjects.

Statistical analyses

Data analysis was performed using the statistical software packages MS Excel (Microsoft Corp, Redmond, WA, USA) or IBM SPSS Statistics Version 20.0. For the descriptive analysis of variables, means and standard deviations were calculated. The normal distribution of the quantitative variables was determined using the Kolmogorov-Smirnov test; *p* values > 0.05 were considered as variables with a normal distribution. Student's *t*-test or Wilcoxon's test was used to compare the macro and micronutrient intake of TB patients and their household contacts. Statistical significance was determined at *p* < 0.05. Data corresponding to each variable are expressed as the means ± standard deviation unless otherwise indicated.

Results

In the present study, there was a prevalence of males (69.2%) in the TB patient group, while in the contact group, females were prevalent (68%). In this population, 74% of TB patients and 86% of the contacts were 19 to 74 years old; 23% and 10% of TB patients and contacts, respectively, were > 65 years old; and 3% and 5% were < 18 years old. Regarding to socioeconomic factors, 12% of the study population survived with a salary less than or equal to the monthly minimum wage, corresponding to 2650.80 pesos (Mexican national currency), whereas 20.8% survived with two minimum wages per month, 30.9% with three minimum wages, 23.2% with 4 or more- minimal wages per month and 12.4% of the participants did not disclose

Table 1. Anthropometric assessment according to BMI in patients with tuberculosis and contacts.

	TB patients (n=39)		Contacts (n=62)		Both groups	
	Frequency	%	Frequency	%	Frequency	%
Underweight	6	15.4	2	3.2	8	7.9
Normal	15	38.5	15	24.2	30	29.7
Overweight	13	33.3	24	38.7	37	36.3
Obesity	5	12.8	21	33.9	26	25.7
Total	39	100	62	100	101	100

BMI, Body Mass Index: weight (kg)/ height (m²): <18.5 = underweight, 18.5 – 24.9 = normal, >25 = overweight y >30 = obesity; World Health Organization; *No significant differences were found between the characteristics of patients and contacts (p>0.05) for all comparisons using Student’s T test.

their income. These data indicate that a higher percentage (62%) of TB patients and risk contacts live on a minimal income. There were no notable differences in the academic level of participants, with the exception of the percentage of TB patients and contacts that stated that they had not completed elementary school (51.3% and 30.7%, respectively). The rest of the participants stated different levels of study: Elementary School (12.8% and 17.3% for TB patients and contacts, respectively), Junior High School (25.7% and 33.8%) and High School (10.2% and 12.9%). With respect to the marital status of the participants, slight differences were observed. TB patients reported a civil status corresponding to single (25.6%) and married/free union (56.4%), while household contacts reported 38.7% and 54.8% for single or married/free union, respectively. A minor percentage of TB patients (12.8%) and contacts (3.2%) were divorced, and 5.1% and 3.2% of TB patients and contacts, respectively, were widowed. The progression of disease in patients was between 6 months and 2 years. Since diagnosis, TB patients have been in medical management as established through social security services.

Considering the recommendations made by WHO [14] and Fair *et al.* [15], and because 90.3% of the individuals considered as contacts in this study were

mostly relatives: 37% children, 12.9% brothers/sisters, 25.8% spouses, 14.5% father/mother, (the rest of the contacts (10%) were relatives: uncles or grandchildren), the contact group corresponds truly to "Household contact": a person who shared the same enclosed living space for one or more nights or for frequent or extended periods during the day with the index case during the 3 months before commencement of the current treatment episode [14].

According to anthropometric assessment, most of the study population showed poor nutrition, and only approximately 30% of TB patients and contacts showed a normal BMI. The study population showed a greater trend towards overweight and obesity; while only 8% of individuals were undernourished. Anthropometric assessment of TB patients showed a greater tendency towards malnutrition than contacts (Table 1). Patients and contacts showed a predominately normal WHR (51%); however, 43% of the study population presented android-type obesity (WHR above 0.85 for females and above 0.90 for males).

TB patients and household contacts showed a deficiency in energy consumption by approximately 19% and 15% nutrient intake, respectively. Both groups showed a greater consumption of proteins and lipids than carbohydrates. It is very interesting to note the gap in the consumption of these elements and total fibre

Table 2. Total daily intake of energy and macronutrients in TB patients and contacts.

Nutrients	TB patients (n=39)			Contacts (n=62)			P value*
	Mean	SD	Adequacy ratio (%)	Mean	SD	Adequacy ratio (%)	
Energy ¹	1862	537	81	1861	519	85	0.992 ^a
Proteins ²	69	22	122	69	22	136	0.994 ^a
Carbohydrates ²	230	63	66	228	63	70	0.882 ^a
Fibre ²	13	4	36	11	4	32	0.072 ^a
Lipids ²	75	30	97	76	31	103	0.972 ^a
Cholesterol ³	379	216	155	374	216	151	0.897 ^a
Fat							
Saturated ²	23	10	88	23	11	95	0.786 ^a
Monounsaturated ²	32	16	123	31	15	124	0.726 ^a
Polyunsaturated ²	8	4	31	9	5	36	0.860 ^b

SD, Standard Deviation; Adequacy ratio: ≤ 89.99% deficiency, 90-110% normal and ≥ 110.1% excess; Units expressed in kilocalories¹, grams² or milligrams³;

*Student’s T-test^a or Wilcoxon test^b were used.

intake, for which the adequacy percentage was 36% and 32% for patients and contacts, indicating a greater deficiency. In the fat consumption analysis, it was observed that lipid intake was very close to the percentage of adequacy (97% and 103%) in TB patients and contacts groups, respectively, whereas the intake of cholesterol, monounsaturated and polyunsaturated fats was similar in both groups. Full macronutrients intakes are presented in Table 2.

Table 3 shows the total daily intake of micronutrients in TB patients and contacts. Data indicate that patients with pulmonary TB had deficiencies in the consumption of some minerals, such as calcium, magnesium and zinc, according to the percentage of adequacy. The same trend was observed in the contact group. In the rest of the minerals analysed (phosphorus, iron, sodium and potassium), there were no differences between the values determined for both groups; of them, only potassium presented values below the daily requirement.

Both patients and contacts had low intake levels of retinol, ascorbic acid, niacin, pyridoxine and folic acid; however, there was an excess in the consumption of thiamine, riboflavin and cobalamin in both groups (Table 3). Intake levels of vitamin A (retinol) were deficient in TB patients and contacts with values of 86% adequacy in both groups. Similarly, levels of ascorbic acid in TB patients and contacts were low; even though the statistical analysis indicated that there were no differences in the intake values between both groups, their adequacy percentage was 78% and 60% for

patients and contacts, respectively. Likewise, pyridoxine (vitamin B6) levels were below the nutritional recommendations, reaching values of 31% and 34%, for patients and contacts groups. With respect to folic acid intake, both TB patients and contacts showed a lack of intake; their percentage of adequacy reached values of 57% and 52%, respectively.

Discussion

Frequently, TB disease is associated with factors such as gender, age, education, disposable income, civil status, public services and access to health services. In our study population there were no differences in such factors, when the population was separated in TB patients group and contacts group. It has been suggested that there is an association between TB and low income [16] due to the costs of treatment. A common characteristic is that people living in rural areas have low income with respect to those who live in urban areas. Moreover, it has been reported that in the states and economical regions of Mexico with lower income, the number of registered TB cases is greater for men than for women, indicating that such differences correspond not only to biological or epidemiological characteristics but also to socioeconomic and cultural aspects and access to health systems [17]. However, it has been observed that people with little or no formal education are socially, geographically and/or economically marginalized and present with a compromised health status associated with TB morbidity and mortality [17]. In the present study, only

Table 3. Total daily intake of micronutrients studied in TB patients and contacts.

	TB patients (n=39)			Contacts (n=62)			P value*
	Mean	SD	Adequacy ratio (%)	Mean	SD	Adequacy ratio (%)	
Minerals¹							
Calcium	837	341	77	831	370	79	0.944 ^a
Phosphorus	865	314	125	844	293	121	0.762 ^a
Iron	17.6	8.9	187	15.7	5.0	142	0.681 ^b
Magnesium	159	56	42	149	49.3	45	0.392 ^b
Sodium	892	624	179	868	545	175	0.920 ^b
Potassium	1765	686	89	1650	561	83	0.677 ^b
Zinc	6.37	3.4	66	6.07	2.9	72	0.662 ^a
Vitamins²							
Retinol	696.4	853	86	631	926	86	0.550 ^b
Ascorbic acid	64.96	63	78	46.33	32	60	0.563 ^b
Thiamine	1.28	0.55	112	1.23	0.39	110	0.878 ^b
Riboflavin	1.35	0.45	112	1.28	0.48	113	0.273 ^b
Niacin	13.1	6.13	87	12.2	4.92	85	0.519 ^b
Pyridoxine	1.01	0.48	69	0.90	0.39	66	0.267 ^a
Folic acid	226	93.62	57	207	125.6	52	0.127 ^b
Cobalamin	6.68	9.43	280	5.82	9.26	243	0.609 ^b

SD, Standard Deviation; Adequacy ratio: ≤ 89.99% deficiency, 90-110% normal and ≥ 110.1% excess; Units expressed in milligrams¹ or micrograms²;

*Student's T-test^a or Wilcoxon test^b were used.

subjects living in the Monterrey City Metropolitan area were included. In general, the economic income average of the population living in this area is not below the minimum wage, in agreement with what was declared by the participants. Because monetary income is associated with the education level of the people, it is possible that this effect could explain why almost half of TB patients (51.3%) reported that they had not completed elementary school.

The determination of nutritional status in exposed populations is considered as very important in the strategy to prevent TB infection [9]. In our study, both the prevalence of overweight and obesity was higher in contacts than in TB patients. Altogether, the prevalence of overweight-obesity in both groups reached values of 72.6% (contact group) and 46.1% (patient group). Important studies estimated that in the Mexican population, the prevalence of overweight-obesity ranges from 68% to 80% in the male and female populations, respectively [18-20]; in agreement, the values observed in the group of contacts were in this range, whilst in the group of patients, the percentage value found was almost half of that estimated for the general population. The results found in this study are consistent with other studies reporting that patients with active TB have a lower body mass index (BMI) than healthy controls. It is difficult to determine whether the presence of TB is due to poor nutritional status and, therefore, impaired immune status or, if this condition is the result of disease. A significant loss of body weight in TB patients has been described in the process of disease progression and treatment and, as a consequence, patients have a lower BMI [21-23]. Malnutrition in patients with TB may be caused by anorexia nervosa and/or hyporexia, because these disorders are characterized by the restriction of food intake resulting in the loss of body weight [24]. The waist circumference and WHR are considered as important parameters for a better anthropometric assessment [12,25]. Patients and contacts showed a predominately normal WHR; however, it is interesting to note that 43% of the study population presented an android-type obesity (abdominal obesity). This type of obesity is associated with factors that contribute to a greater risk of developing chronic diseases, such as cardiovascular complications, insulin resistance, type 2 diabetes, cancer and metabolic syndrome [20,25].

Previous reports show that deficiency of single or multiple nutrients can reduce an individual's resistance to infections [26]. On the other hand, malnutrition and tuberculosis are both problems mostly in developing countries; poor nutrition leads to protein/energy

malnutrition and micronutrient deficiencies that lead to immunodeficiency, increasing the risk for developing TB [27]. In our study, both TB patients and household contacts showed a deficiency in the consumption of energy, carbohydrates and fiber, and a greater consumption of proteins and lipids. Likewise, deficiencies in the consumption of micronutrients (minerals and vitamins) were present in both groups. We observed that in general, our population showed deficiencies in the intake of some minerals as calcium, magnesium and zinc. The importance of the uptake of minerals to protect from TB infection is well documented. Calcium plays an important role in the control of TB infection; several studies indicated that macrophages and monocytes have diminished ability to kill TB bacteria when levels of intra and extracellular calcium are reduced [28,29]. In addition, it has been shown that hypocalcaemia is very common in patients with TB [30]. Magnesium is a cofactor of many enzymes involved in biological processes and plays an important role in the immune response. Because it is a cofactor in the synthesis of immunoglobulins, it is involved in the adherence of immune cells, such as antibody-dependent cytotoxicity, and it participates in the IgM response and binding lymphocytes, such as T helper-B cell adhesion [31]. In our study, both patients and contacts had poor magnesium intake with their adequacy percentage less than 50%, making it necessary to increase their intake of foods rich in magnesium. On the other hand, zinc is associated with weight loss and recurrent infections due to dysfunction of the immune system affecting the growth and function of T and B cells, involved in the regulation of genes of lymphocytes, as well as in the development and normal function of neutrophils [32]. Therefore, this mineral is considered to play a fundamental role in the control and prevention of several infections, plus an essential role in vitamin A metabolism [33]. Ghulam *et al.* [6] reported that serum zinc levels are diminished in patients with pulmonary TB. This situation is similar to TB patients in this research, however, it is noteworthy that in our study, mineral intake was calculated using 24-hours reminder questionnaires; there was no measurement of serum levels, which would be important for future research.

Vitamin deficiencies are common in patients with tuberculosis [34,35]. In our study, the population corresponding to both groups, TB patients and contacts, presents deficiencies in vitamin A, ascorbic acid, niacin, folic acid, and pyridoxine intake. Regarding to vitamin A, some authors have found that severe TB was associated with vitamin A deficiency [36]. Such

deficiency is associated with poor nutrition, possibly as result of loss of appetite, intestinal malabsorption and/or urinary loss of vitamin A in TB patients. Although these factors could be responsible for the low intake of retinol in our population, we must consider that in the group of contacts (not TB patients), intake values were similar, which suggests that this could be attributed to poor eating habits of the population in this region. It is very important to note that scientific evidence shows that zinc deficiency is related to vitamin A deficiency [37], which can be explained by two mechanisms: the first is the oxidative conversion of retinol to retinal because this step requires the action of the zinc-dependent retinol dehydrogenase enzyme, and the second is the hepatic synthesis of the retinol binding protein because the mobilization of retinol in the liver requires a suitable concentration of zinc [38]. Considering prior research, it is possible that in addition to the results of inadequate intake of vitamin A observed in our population, there was a greater decrease in the levels of vitamin A in the study population due to the zinc intake in both study groups being below the daily recommendation. Vitamin C acts as a physiological antioxidant, protecting host cells against oxidative stress caused by infections and increasing the immune response against diverse viral and bacterial infections, including pneumonia and the common cold [39,40]. Additionally, it is reported that vitamin C supplementation is necessary to improve the health of TB patients and to prevent oxidative damage, including the toxic effects of anti-tuberculosis drugs [41,42]. Due to the role of this vitamin, it is extremely important that both TB patients and contacts with poor intake (as a preventive action) increase their consumption of foods rich in vitamin C to strengthen their immune system.

For the TB treatment, generally isoniazid is included in the first-line anti-tuberculosis medication (it has been used for more than 50 years). This drug is associated with hepatotoxicity risk and diseases such as hepatitis and peripheral neuropathy [43,44]. Additionally, it has been demonstrated that if isoniazid is given alone it will rapidly lead to drug resistance. This involves mechanisms such as increased activity of efflux pumps and/or the generation of spontaneous mutations in the *KatG* gene (that encoded the catalase-peroxidase enzyme, which acts as an isoniazid activator) [45]. Isoniazid has a competitive inhibition mechanism to pyridoxine, whose function is to serve as a precursor of pyridoxal phosphate and pyridoxamine phosphate, coenzymes that play an essential role in protein metabolism, synthesis of lipids and coenzyme A, and biosynthesis of synaptic transmitters [46]. There

is scientific evidence that the side effects of isoniazid can be prevented by the administration of pyridoxine [46,47], and simultaneous oral administration of pyridoxine with isoniazid in TB patients, or in children who have a poor nutritional history and pyridoxine deficit, prior to therapy with isoniazid, are recommended [48,49]. It is highly important to consider that 29% of TB patients in this study were using isoniazid as anti-TB treatment, and both TB patients and contacts showed a low vitamin B6 intake. Therefore, it is recommended that both groups increase their intake of vitamin B6, especially those in the TB patient group, in order to prevent possible side-effects of isoniazid treatment. Regarding folic acid intake, the adequacy ratio was ca. 50% in both study groups, although the different groups showed no significant differences in their consumption. It is important that both TB patients and contacts increase their intake of folic acid, because it has demonstrated that folic acid deficiency affects immune capacity through a mechanism that involves the reduction of circulating T lymphocytes, and thus, lowering resistance to infections (reviewed in Maggini *et al.*) [50].

In the current study, we observed that most participants presented a condition of overweight and obesity; however, this is inconsistent with their low energy and carbohydrate intake. Such inconsistency could be explained because our results were based on the last 24 hours of dietary nutrient recall. Therefore, for future research, biomarkers such as serum micronutrients or lipid blood profiles should be accurately measured so that the nutritional status of the participants can be accurately determined. Despite the limitations, the present study revealed that macro and micronutrient intake (specifically, vitamins and minerals) was deficient both in TB patients and in household contacts, and the results agree with data found in the literature. Considering the importance of nutrition on preventing the development of active TB, we recommend more investigations on human TB: with greater populations, studying long-term effects, and on different life stages and different types of populations. In addition, we suggest the establishment of strategies aimed at promoting a balanced diet among household contacts: people who have close contact with patients with infectious TB.

Conclusion

Based on the findings of this study, we concluded that both TB patients and household contacts present problems of poor nutrition. Most participants presented with a condition of overweight and obesity, similar to

that found in a large part of the Mexican population. In the same way, the present study revealed that macro and micronutrient intake (specifically vitamins and minerals) was deficient both in TB patients and in household contacts, placing this population at a great risk to TB infection.

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Authors' contributions

ECG designed the research protocol and the original analysis plan, secured the funding for the work, corrected and contributed to all versions of the manuscript; JLM designed and carried out the analysis, wrote the first draft and contributed to all versions of the manuscript; JHO and GIAM worked in the data analysis and contributed also to the later drafts; ZJS worked on the original idea for the study, revised the drafts and contributed to later drafts, before submission to Journal. All five authors approved the present manuscript.

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