Asia Pacific J Clin Nutr (1996) 5(3): 186-190

Trace element nutrition in developing countries

M Abdulla[1], AH Khan[2] and MF Reis[3]

1. *Department of Clinical Pharmacology and Therapeutics, Hamdard University, New Delhi-110062, India*
2. *Punjab Medical Center, 5 Gulberg Road, Lahore, Pakistan*
3. *LNETI-ICENDEEN, 2685 Sacavem, Portugal*

Trace element status in humans is often poorly established in developed, let alone developing, countries. There have been assumptions about inevitable adequacy, especially for ultra-trace elements, like chromium, with varied diets. However, new pressures on trace element adequacy are emerging, like developments in food technology with the new formulated foods and element pollutants (toxic metals) with potential interactions with essential elements. Improved, more sensitive methods for trace element measurements in foods and biological specimens, functional indices of trace element status, with application to nutritional epidemiology, and the pursuit of clinical trials, should allow appropriate revision of current views. This process is likely to more consequential in developing countries.

Key words: trace elements, developing countries, toxic metals, functional indices, nutritional epidemiology, clinical trials, IAEA, UNESCO

Introduction

During the past few decades, considerable progress has been made in the field of trace elements. Impressive developments have taken place in the clinical, biochemical, immunological and nutritional areas related to trace elements. Rapid improvements in analytical technology, and sophisticated instrumentation introduced during the last three decades, have helped to disclose the presence of most of the naturally-occurring trace elements in living systems and their food chains. At present, at least 21 elements represented in the periodic table have been found to be essential for animal and human life[1,2]. This number is likely to be increased in future with improvements in our knowledge concerning the role of trace elements in vital metabolic reactions. In spite of the impressive progress that has been made in the field of trace element nutrition in the past, the biological role and the minimum requirement of many trace elements are still hypothetical. Since the minimum requirement of some of the essential trace elements, such as selenium and chromium, is so low it is generally believed that a purely nutritional deficiency of these elements rarely occurs in man. The latest developments in food technology have enabled the food industry to offer the general public in affluent countries an enormous choice of food products during the last couple of decades. This trend is extending to even the developing countries. The increased consumption of refined food-stuffs may in due course result in marginal deficiency of essential trace elements[2-4]. Recent studies indicate that such a trend has been noted in developed countries[5,6]. Certain groups including children, pregnant and lactating women, the elderly and drug abusers may be more vulnerable to such deficiencies than the population in general.

The nutritional importance of trace elements has grown rapidly during the last three decades, mainly due to a better understanding of their biological functions. Except for iodine and iron, whose essentiality for man was recognised almost a century ago, the role of some of the other important trace elements in human metabolism has been established only during the last few decades. In deficiency states, essential trace elements are bound to lead to health problems. Iron deficiency anaemia and goitre due to iodine deficiency are good examples. In terms of people afflicted, especially in the developing world, such conditions are close to that of individuals suffering from protein-energy malnutrition. Several other pathological conditions in man are also associated with trace element deficiencies.

Both deficiency of essential elements and toxicity of heavy metals are fairly common in many countries of Asia, Africa and Latin America[7,8]. In order to assess the nutritional importance of trace elements, it is relevant to consider the factors regulating their metabolism. Actual intake levels and bioavailability are two key factors that are nutritionally important. Barring occupational exposure, the food chain remains the major pathway through which the trace elements enter the human body. Only limited information is available at present concerning the dietary intake of trace elements from prepared meals. Nevertheless, in developing countries, trace element problems have a low priority as a public health issue. The information that is available in many developing countries concerning dietary intakes is often unsatisfactory since it is based on conventional techniques involving food tables[2,9,10]. Only direct analysis of the actual food consumed during a 24-hour period can provide the true dietary intake of essential and toxic trace elements. Currently, most countries in the developing world follow the recommendations that are accepted in affluent countries.

Methodology

As mentioned earlier, the information concerning the true intake of trace elements from prepared meals can only be obtained by analysing directly the actual food consumed during a 24-hour period. In practice, this is an expensive and arduous technique, especially for a poor population group. For the study of trace element intakes in large population groups, computation from an account of the food type and quantity consumed, using standard food tables, remains the most practical and cost-effective method[11]. The trace element intake data estimated from dietary surveys, however, will always be dependent on the quality of pooled samples of food to represent an average for a country or area. Therefore, food tables prepared in one country are usually not appropriate for use in another. Moreover, the data in the food tables are often based on the analysis of raw food materials. The concentration of trace elements in many foodstuffs is often low, and difficult to measure, and thus data may not be available for a number of important trace elements such as chromium and selenium. The food tables available in different regions of the same country may differ with regard to trace element concentrations due to differences in the methods of sampling and food analysis. Despite these problems, many developing countries have made an attempt to provide some basic information concerning the daily intake of a few trace elements. Some measure of the validity of dietary intakes can be made by the independent investigation of urine nitrogen and electrolytes, comparing 24-hour excretion during both the survey period and a non-collection period[9,12].

Table 1. Most commonly used techniques for the estimation of daily dietary intake of trace elements.

Techniques used	Comments/Sources of Error
A. Direct methods	
(a) Analysis of the weighed diets consumed during 24 hours	Accurate; expensive and time-consuming
(b) Analysis of pooled duplicate portions collected during 24 hours	Suited for small well-defined groups; chances of underestimation
(c) Analysis of diets prepared according to a market basket technique	Does not assess the variability of intake
B Indirect method involving standard food tables	
(a) Food balance sheets; per capita consumption	Not suited for the estimation of several trace elements; suitable for screening
(b) 24-hour and 7-day recalls	Chances of systematic errors; food tables may not have all necessary information
(c) Diet histories and related methods	Not ideal for the estimation of many trace elements; suited for average population intake
C Estimation through biological indicators	
(a) Whole body and plasma/serum	Does not indicate body status; poor correlation to intake levels
(b) Urine	Easy to collect; good for a few elements such as selenium, iodine, sodium and potassium
(c) Faeces	Not practical for large groups; excretion can be 80-90% for some toxic elements
(d) Hair and nails	Poor indicator of intake levels of most elements
(e) Specific cell lines	Can provide indirect information; expensive

Biological materials such as urine, faeces, blood, hair, nails and specific cell lines such as neutrophils have been extensively used in the past by many groups of workers for the indirect estimation of the dietary intake of trace elements[13-15]. None of them, however, reflects the exact intake levels. Nevertheless, with adequate correction factors, such methods can sometimes be used for a number of trace elements such as iodine and lead[16-18] although the results will only serve as markers for body status.

In general, the collection of accurate data on usual trace element intake by a population group is by no means a simple task. No single technique is ideally suited for the study of trace element intakes. All methods are capable of yielding reliable data if applied properly. The choice in any particular case needs to take account of the resources that are available, as well as other factors such as lifestyle, food supplies and distribution networks. In many cases, confidence in the results can be increased by applying not just to one technique but a variety of techniques based on different methodologies. Table 1 shows the summary of various techniques available for the estimation of dietary intake of trace elements and the sources of error.

Generally speaking, all the methods mentioned above have limitations. In order to make valid intake estimates, one should use a combination of techniques, depending upon the available budget and local resources. As long as the investigator is aware of the limitations of each method, it is still possible to produce intake data that can be used for purposes of comparison and recommendation, even in developing countries.

Choice of analytical techniques

A number of methods are currently available for the analysis of trace elements in foodstuffs. Sophisticated techniques such as neutron activation analysis, induced-couple plasma-mass spectroscopy (ICP-MS) and X-ray fluorescence spectrometry are seldom available in many developed and developing countries. Atomic absorption spectro-photometry is the commonly available technique in most countries of the developing world. With fairly easy modification, this technique can be used for the analysis of most of the important trace elements in food-stuffs[6]. Since the concentration of most of the elements of interest in freeze-dried dietary samples is much higher than that found in biological fluids, it is possible to obtain reliable data for a number of elements such as copper, chromium, selenium and zinc using this technique. By making use of the available standard reference materials, it is often possible to validate the results. However, for obtaining meaningful analytical results for 'ultra-trace' elements in food-stuffs, careful sample handling and rigorous methods in analytical quality control, including the use of clean rooms and suitable certified reference materials, are needed. It may take many years before the developing countries will be in a position to deal with ultra-trace element problems[19-22]. International agencies such as the International Atomic Energy Agency (IAEA) and the United Nations Educational, Scientific and Cultural Organization (UNESCO), are currently involved in various activities to promote trace element research in developing countries. The UNESCO institute in Lyon, France aims to have a reference laboratory in the near future to deal with the analytical problems related to trace element nutrition in both developed and developing countries[23].

Population explosion and environmental pollution

At the end of the 18th century, humankind numbered one billion. During the 19th century, the earth's inhabitants doubled and in the present century, the population has increased three-fold and if the same growth rate continues, the earth's carrying capacity will be saturated by the middle of the next century. In developed countries the population explosion has halted. Even in developing countries the average family size is likely to decrease as urbanisation and other factors cause a demographic transition. This process, however, may take several decades before it becomes significant. The population explosion began in the 17th century in the now industrialised countries. The inhabitants of the industrial countries today represent 25% of the world's population. Among the developing countries, India and China alone contribute one third of the world's population. Unlike China which has succeeded in curbing the population explosion along with the rapid achievements in science and technology, India has failed to do so. Within a few decades the population in India will be one billion or more.

The population explosion in developing countries has already perturbed the ecosystem of our planet. The industrial revolution has devastated the local, regional and global environment. Disturbances in the global heat balance are already a priority issue. Recent studies have already established a measurable increase in the current concentration of carbon dioxide in the atmosphere which is mainly due to an increase in the combustion of fossil fuels. Another important contribution from the industrial revolution is the dumping of heavy metals like lead, cadmium and mercury in the environment. In affluent countries, health authorities have succeeded in maintaining an acceptable level of these toxic elements in the environment during the last few decades. The concentrations of lead, mercury and cadmium have significantly decreased in the food chain of several West European countries. The reverse is the situation in many developing countries. The pollution problem is severe in the industrial cities of developing countries. The number of cars, buses, motorcycles and other vehicles has gone up significantly during the last few decades. Most of these vehicles operate on leaded petrol. In the major metropolitan cities, vehicle exhaust contributes to the major part of the air pollution. A recent study by the present authors concerning lead toxicity in developing countries indicated that the exposure levels of the general population the metropolitan cities in India and Pakistan are two to three times higher than those found in West-European cities[24,25]. Vulnerable groups in cities, such as children and pregnant women, are more at risk than the general population in the rural areas. The levels of lead in the blood of taxi and rickshaw drivers and of traffic police in Lahore are three times higher than that found in similar professional groups in Sweden[25]. Limited data available in developing countries indicate that the concentration of toxic metals in food grains and marine products is increasing[25]. It is well-known that high levels of toxic elements such as lead can interfere with the absorption of essential trace elements such as iron and zinc[25]. When the daily dietary intake of essential elements, such as zinc and iron, is already low in developing countries the presence of high levels of toxic metals can aggravate the situation further. it is unfortunate that the health authorities in developing countries are not concerned with the importance of trace element nutrition.

Other factors that influence trace element nutrition in developing countries

Apart from the problems of environmental pollution, the populations living in developing countries are exposed to recurrent respiratory and diarrhoeal infections, heat and humidity, prolonged lactation, and recurrent pregnancies. All these factors can influence trace element nutrition[7]. The trace element requirements in developing countries may differ from that of populations of industrialised countries. The biological availability of several essential trace elements may be influenced by inhibiting factors such as phytate, which is found in many food-stuffs of developing countries. When national recommendations are made in many developing countries the above-mentioned factors are not taken into consideration. The nutritional requirements of most trace elements in developing countries are likely to be higher than those established for affluent countries. In some of the developing countries, the average body areas of adults can differ from those of individuals in affluent countries and this again may influence the total requirements.

Available data on trace element intakes

One of the basic requirements of nutritional research concerned with trace elements is information on the intake levels from prepared meals consumed during 24 hours. From a public health point of view, it is important to assure that the intake of all essential trace elements is adequate in the average, normal daily diet of the general population. At the same time, the ideal diet should not contain more than the permitted levels of toxic heavy metals. It is thus essential to monitor periodically the trace element content of daily diets to assess the adequacy of the intake levels of essential trace elements as well as the toxic heavy metals. Barring occupational exposure, the food chain remains the major pathway through which the trace elements enter the human body. Information about daily dietary intakes based on sound methodology is scanty in developing countries. The limited data that are available in many developing countries mainly deal with a few elements such as iron and iodine. During the past couple of years, public health authorities in different parts of the world have started to take an interest in defining desirable levels of nutrient intakes for their populations[6,27]. Some of these efforts have been duplicated at the international level by bodies such as WHO and the Food and Agricultural Organization (FAO). The International Atomic Energy Agency (IAEA) is currently involved in an international research project dealing with the dietary intake of major and minor trace elements in several countries[8,26].

A statistical summary of adult dietary intakes of some of the important essential trace elements, based on the available literature during the last 30 years, is shown in Table 2. For most purposes, typical intakes are best represented by the median (50-percentile). For comparison purposes, the available results from the ongoing IAEA study are also shown as range[8].

Table 2. Dietary intake of essential trace element intakes per person per day.

Element	Global data median (range*)	IAEA data range	Unit
Chromium	50 (20-285)	59-106	μg
Copper	15 (0.6-5.8)	1.1-2.0	mg
Iodine	190 (50-1050)	50-260	μg
Iron	13 (5.1-47)	8.1-30.0	mg
Selenium	61 (8-1340)	34-133	μg
Zinc	10 (4.2-19)	8.3-14.0	mg

*Minimum (0 percentile) and maximum intake (100 percentile)

As may be observed from Table 2, the observed dietary intakes (both global as well as IAEA data) of chromium, copper, iodine, iron, selenium and zinc are, in general, compatible with the current recommended safe and adequate intake levels. There are, however, exceptions for some elements such as iodine, iron and zinc. Generally speaking, the observed global data indicate some evidence of significant nutritional deficiencies in certain population groups for these elements. Previously only the deficiency of two elements, namely that of iron and iodine have been recognised as being of widespread public health significance from a nutritional standpoint. Now, genuine concern arises as to the necessity of adding zinc to this list, especially in those population groups in developing countries[28,29] whose diets contain complex substances that limit the bioavailability of zinc (see previous section). In addition, high levels of lead in the environment may further aggravate the situation. It is important to collect reliable data on trace element intake in developing countries in order to assess the adequacy of trace element nutrition.

Table 3 shows the intake of some of the important toxic metals, again showing the global data along with the results from the IAEA study for comparison. Although median intake levels of all the toxic elements shown in Table 3 are under the provisional tolerable intake (PTI) values, the mean intake of some heavy metals vary significantly in some countries. In certain parts of Italy and Portugal, the intake of mercury and lead is much higher than the PTI levels[30]. The total lead intake in some countries also has been found to be high[31]. In some developing countries, as mentioned earlier, the exposure to lead can be very high. The number of petrol-driven (leaded petrol) vehicles has increased significantly during the last couple of decades. Consumption of illicit liquor and contamination of food through storage in glazed clay utensils are other sources of lead. Although heavy metal toxicity has a very low priority as a public health problem in developing countries, it is an important issue that needs to be considered seriously by them in the future. Once again, it is essential to collect reliable data concerning the intake of toxic elements in developing countries.

Table 3. Dietary intake of toxic metals.

Element	Global data median (range*)	IAEA data range	Unit
Aluminium	4.4 (2.2-17)	3.0-17.0	mg
Arsenic	41 (3-330)	3-160	μg
Cadmium	14 (8-200)	8-25	μg
Lead	51 (7-515)	21-160	μg
Mercury	4.1 (0.7-76)	3-76 μg	

*Minimum (0 percentile) and maximum intake (100 percentile)

In summary, there are a number of issues that need to be addressed in developing countries regarding trace element nutrition. These include: (a) studies leading to the identification of areas where essential trace element deficiencies and toxicities from toxic metals are common, (b) analysis of trace elements in individual foods and in water supplies, to provide greater reliability when assessing the trace element intake by indirect methods, (c) studies of relationships between biochemical parameters for the diagnosis of marginal deficiency of trace elements, and (e) the impact of pollution on the bioavailability of trace elements.

Trace element nutrition in developing countries

M Abdulla, AH Khan and MF Reis

Asia Pacific Journal of Clinical Nutrition (1996) Volume 5, Number 3: 186-190

發展中國家的微量元素營養

人類微量元素的狀況在發達國家常很難確定，更不用說發展中國家了．人們假定從各種食物中能獲取足夠的微量元素，特別是象鉻這樣的極端微量元素．然而，獲得足夠的微量元素的壓力正在呈現，如食品技術的發展產生的新配方食品及元素污染(有毒金屬)對必需微量元素的潛在的干擾．改進的、更敏感的食品及生物樣品微量元素測定方法，微量元素功能指數，營養流行病學的應用及臨床試驗追踪，將對目前的觀點進行適當的修訂．這一過程對發展中國家更多的是一個間接的過程．

關鍵詞：微量元素，發展中國家，有毒金屬，功能指數，營養流行病學，臨床試驗，IAEA，UNESCO

References

1 Underwood EJ (1977): In Trace elements in human and animal nutrition, 4th ed, New York: Academic Press.
2 Abdulla M. (1986): Inorganic chemical elements in prepared meals in Sweden. PhD Dissertation, University of Lund, Sweden, 6-98.
3 Mertz W. (1970): Some aspects of nutritional trace element research. Fed. proc 29, 1483-1488.
4 Mertz W. (1981): The essential trace elements. Science 213,1332-1338.
5 Abdulla M. (1983): Public health/clinical significance of trace elements. In Nutritional adequacy, nutrient availability and needs, ed J Mauron, 338-355. Basel, Boston, Stuttgart: Birkhauser.
6 Abdulla M, Parr RM & Iyengar GV. (1993): Trace element requirements, intake and recommendations. In Essential and toxic trace elements in human health and disease, ed AS Prasad, 311-328. New York: Wiley-Liss.
7 Solomons NW. (1990): Trace element requirements and needs. In Proceedings of the 2nd meeting of the International Society for Trace Element Research in Humans, ed H Timita. Tokyo: Springer-Verlag.
8 Parr RM, Abdulla M, Aras NK et al. (1990): Dietary intakes of trace elements and related nutrients in eleven counties: preliminary results from an IAEA co-ordinated research program, Proceedings, 7th international symposium on trace elements in man and animalsTEMA-7 ed B. Momcilovic, 3,13. Zagreb: IMI.
9 Abdulla M, Jagherstd, M Kolar, K et al. (1983): Essential and toxic inorganic elements in prepared meals 24-hour dietary sampling employing the duplicate portion sampling technique. In Trace element analytical chemistry in medicine and biology, P Bratter & P Schrammel, 75-86. Berlin, New York: Walter de Gruyter.
10 Parr RM, Crawley H, Abdulla M et al: Human dietary intake of trace elements: A global literature survey mainly for the period 1970-1991, WHO document on trace element requirements and recommendations. In press.
11 Van Staveren WA & Burema J. (1985): Food consumption surveys: Frustrations and expectations. Naringforsking, 29(2), 38-43.
12 Isaksson B. (1980): Urinary nitrogen output as a validity test in dietary surveys. Am J Clin Nutr 33, 4-12.
13 Varo P, Althan G, Ekholm P, Aro A, Koivistoinen P (1980): Selenium intake and serum selenium in Finland. Am J Clin Nutr 48, 324-329.
14 Whitehoues RC, Prasad AS, Rabbani P & Cossack ZT. (1982): Zinc in plasma, neutrophils, lymphocytes, and erythrocytes as determined by flameless atomic absorption spectrophotometry. Clin Chem 28, 475-480.
15 Bingham S. (1982): Recent developments in dietary methodology. In Euronutrition report 1 eds, J. G. A. J. Hautvast & W. Klaver, 196-222.
16 Abdulla M, Jagerstad M, Melander et al. (1979): Iodine, Scand J Gastroent 14(1), 185-190.
17 Schutz A. (1979): Cadmium and lead. Scand J Gastroent 14(52), 223-231.
18 WHO (1977): Environmental health criteria 3 - Lead.
19 Iyengar GV (1987): Reference values for the concentrations of As, Cd, Cr, Cu, Fe, I Hg, Mn, Mo, Ni, Pb, Se and Zn in selected human tissues and body fluids. Biol Trace Ele Res 12, 263-295.
20 Iyengar GV & Woittiez JRW. (1988): Trace elements in clinical specimens: evaluation of literature data to identify reference values. Clin Chem 34, 474-481.
21 Iyengar GV, Wolf WR & Tanner JT. (1988): Multipurpose biological reference materials. Frez Z Anal Chem 322, 549-551.
22 Iyengar GV. (1989): Elemental analysis of biological systems, Vol.1. CRC Press, Boca Raton, FL.
23 Chazot G. (1993): Summary report on UNESCO global network for trace element research. Int J Toxicol Occup Environ Health 20(1),9-16.
24 Manser WWT & Khan A. (1989): Blood levels of copper, zinc and lead in patients with pediatric disorders and of lead in sections of the Karachi population. In Metabolism of minerals and trace elements, eds M Abdulla, H Dashti, B Sarkar, H Al-Sayer & N Al-Naqeeb, 23-28. London: Smith-Gordon.
25 Khan AH, Abdulla M & Schutz A: Lead levels in the blood of general population in Lahore and Delhi. In preparation.
26 Parr RM. (1993): Nutritional aspects of trace elements in developing countries. Int J Toxicol Occup and Environ Health, 2(1),1.
27 Parr RM. (1990): Global Trace element intake. In Proceedings of the Second ISTERH meeting, ed H Timita. Tokyo: Springer-Verlag.
28 Prasad AS. (1991): Discovery of human zinc deficiency and studies in experimental human model. Am J Clin Nutr 53, 403-412.
29 Prasad AS. (1988): Clinical spectrum and diagnostic aspects of human zinc deficiency. In Essential and toxic trace elements in human health and disease, ed AS Prasad, 3-54, New York: Alan R Liss.
30 Reis MF, Abdulla M, Parr RM et al. (1994): unpublished.
31 Kumpulainen JT, Parr RM, Abdulla M et al. (1992): Intake of toxic elements: a study of 14 countries. Third meeting of the international society for trace element research in humans (ISTERH), Stockholm, Sweden, May 25-29, 1992: Abstract.