Relationship between nickel allergy and diet

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ABSTRACT

Nickel is a ubiquitous trace element and it occurs in soil, water, air and of the biosphere. It is mostly used to manufacture stainless steel. Nickel is the commonest cause of metal allergy. Nickel allergy is a chronic and recurring skin problem; females are affected more commonly than males. Nickel allergy may develop at any age. Once developed, it tends to persist life-long. Nickel is present in most of the dietary items and food is considered to be a major source of nickel exposure for the general population. Nickel content in food may vary considerably from place to place due to the difference in nickel content of the soil. However, certain foods are routinely high in nickel content. Nickel in the diet of a nickel-sensitive person can provoke dermatitis. Careful selection of food with relatively low nickel concentration can bring a reduction in the total dietary intake of nickel per day. This can influence the outcome of the disease and can benefit the nickel sensitive patient.

Key Words: Allergy, Diet, Food, Nickel

INTRODUCTION

Nickel was first isolated by the Swedish chemist Cronstedt in 1751. It is the twenty-second most abundant element and the seventh most abundant transitional metal with an atomic number of 28 in the periodic table with an atomic weight of 58.71. It has five naturally occurring isotopes. It is a tough, silvery-white heavy metal and is highly resistant to attack by air and water. It occurs in igneous rocks, as a free metal and together with iron; it is also a component of the earth core. Nickel also occurs in living organisms, mainly in plants. Nickel forms numerous alloys with other metals. Its alloy with iron, nickel steel, is extremely tough and corrosion resistant.

Most of the nickel produced world-wide is used for the manufacture of stainless steel, which is mostly used to produce food processing equipment and containers. It is also used to manufacture fashion jewelry, machinery parts, coins; finely-divided nickel is used as hydrogenation catalyst.

NICKEL ALLERGY

Nickel produces more cases of allergic contact dermatitis than all other metals together. Nickel sensitivity is more common in females than males. The prevalence of nickel sensitivity varies from 4–13.1% in different countries.[1,2] Among women in general population, today the prevalence is around 10%[3] and it is increasing. All age groups are affected; prevalence may be high in some occupational groups, for example, hairdressers, in whom the prevalence rate may be as high as 27-38%.[4] Women are more commonly sensitized by nonoccupational contacts such as ear piercing with ordinary needle and use of fashion jewelry that contains free nickel, while males are mostly sensitized by occupational exposure.

The degree and pattern of nickel allergy varies:

(a) Some people develop dermatitis from even brief contact with nickel-containing items, while others develop allergy only after many years of skin contact with nickel. A "secondary rash" due to spread of dermatitis[5] to distant regions is rarely observed at present.

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(b) Some people develop hand eczema, often many years after primary sensitization. It may be due to the chronic contact with nickel containing detergent, nickel-plated items, nickel-containing coins, etc.
(c) Some patients develop vesicular type of hand eczema following the ingestion of nickel in diet.[6] Such hand eczema flares up when such patients are treated with oral nickel sulfate.
(d) Rarely, patient with nickel sensitivity may present with baboon syndrome[7] – a generalized rash with particular involvement of buttock, anogenital area, flexures and eyelids. Baboon syndrome is thought to be a pattern of systemic contact dermatitis. Cases of erythema multiforme and vasculitis have been reported following nickel ingestion.[8,9]
(e) Chronic urticaria, a type 1 hypersensitivity response, has been attributed to dietary nickel; but this is extremely rare.[10]

Relation of atopy and nickel dermatitis

It is generally believed that contact dermatitis is less common in persons with atopic dermatitis (AD) than in normal persons. This is because patients with AD are not readily sensitized by repeated application of dinitrochlorobenzene (DNCB). However, recent studies have shown that the poor response to DNCB occurs only in severe AD and most of the atopics respond to contact allergens similar to the normal population during the remission period.[11]

Studies have shown that atopics are more likely to develop occupational dermatoses.[12] In a review, Coenraads and Diepgen[13] found that skin atopy at least doubles the risk of hand eczema in occupations where it is a common problem. Nickel dermatitis of hand of occupational origin is common amongst the atopics. This type of dermatitis is commonly observed in atopics working with the metal- and nickel-plating industry. However, the pattern of dermatitis is rarely diagnostic.

Hyposensitization with oral nickel

Studies have confirmed the role and benefit of hyposensitization with oral nickel in nickel allergy. It has been noted that oral tolerance to nickel sensitization can be obtained by feeding with nickel sulfate in nickel sensitive individual, and this has opened a new area of investigation for the treatment of nickel allergy. The suggested mechanism for oral hyposensitization in nickel-sensitive individual is the stimulation of the suppresser T-cell production by antigen excess.

In two controlled studies (each including 24 patients with contact allergy to nickel), where each patient was orally treated with 5.0 mg nickel sulfate once a week for 6 weeks, the degree of contact allergy, measured as patch test reactions before and after nickel administration, was noted to be lowered significantly.[14] In a different study,[15] where 30 nickel sensitive cases were treated with oral nickel sulfate in a dose of 0.1 ng/day following a low nickel diet, showed complete disappearance of the symptoms after 1 year of treatment in 29 cases; the remaining patient showed a partial alleviation of symptoms. Oral provocation tests with these 30 patients showed an overall increase of tolerance. Patch tests showed no variation in the 20 cases; a diminution was observed in 5 cases and the patch tests were negative in 5. Similar type of results were obtained by Bagot *et al*.[16]

SOURCE OF NICKEL

Nickel is a ubiquitous trace element, which forms approximately 0.008% of the Earth's crust and 0.01% of the igneous rock.[17] It occurs in soil, water, air and in the biosphere. The concentration of nickel normally encountered is as follows:[18]

Soil 5-500 μg/gram (may be higher locally)
Plant tissue 0.5-5 μg/gram (may be higher locally)
Animal tissue 0.1-5 μg/g
Fresh water 5-100 μg/litre

Land plant tissue contains four times more nickel than that of animal tissues.[19] This is because most of the human food that comprises both plants and animals acquire their nutrition from soil; therefore, the nickel content of food is strongly influenced by the concentration of nickel in the soil. The concentration of nickel in the soil varies from place to place. Some of the important factors that influence the concentration of nickel in soil are:[20]

(1) Type of soil
(2) Use of modern agricultural practices such as the use of synthetic fertilizers and pesticides
(3) Contamination of soil with industrial effluents and urban wastes
(4) Distance of the soil from the nickel smelters

It is noteworthy that even seasons can influence the concentration of nickel in plant tissues; it has been observed that nickel concentration increases in spring and autumn and

falls during mid summer.[21]

ROLE OF DIET IN NICKEL DERMATITIS

Nickel is present in most of the dietary items of humans and an average diet supplies 300–600 μg of nickel to the human body per day.[19] The presence of sufficient amounts of nickel in the diet of a nickel-sensitive person can provoke dermatitis. It has been observed that nickel sulfate when orally administered in the range of 600–5,600 μg as a single dose may provoke hand eczema.[22]

The hands are the most commonly affected sites for systemic nickel dermatitis. However, other body areas may be affected as well. There are reports of serious reactions such as erythema multiforme and vasculitis following oral challenge.[8,9]

The evidence for the role of dietary nickel in provoking/aggravating eczema is as follows:

- Flare of eczema and/or patch test sites upon oral nickel challenge.[6]
- Improvement of dermatitis on a low nickel diet.[23]
- Improvement of dermatitis by oral disulfiram, which chelates nickel and increases its excretion.[24]
- Improvement of dermatitis by oral disulfiram and low nickel diet.[25]
- It has been noted that children with orthodontic braces, who are therefore exposed to low continuous levels of ingested nickel, may have less subsequent nickel allergy.[26]

NICKEL IN FOODS AND BEVERAGES

Nickel constitutes approximately 0.008% of the Earth's crust, and the soil contains 40 ppm of nickel on average.[19] It is present in most of the dietary items. Food is the major source of nickel exposure for the general population. Major dietary source of nickel is plant food. Plant tissues contain more nickel than animal tissues. Therefore, the total dietary intake of nickel per day varies depending on the amount of consumption of plant and animal foods. The amount of nickel in foods may vary considerably from place to place. This is due to the nickel content of the soil that varies from place to place.

In a study conducted in UK, it was found that nickel (the mean concentration of nickel as mg/kg fresh weight) was present in the following amounts in various foods: in cereals (0.17); carcass meat (0.04); poultry (0.04); fish 0.08; eggs (0.03); green vegetables (0.11); other vegetables (0.09); potatoes (0.10); milk (<0.02); dairy products (0.02); nuts (2.5); fresh fruits (0.03); oils and fats (0.03), etc.[27]

A Korean study found significant nickel content in the following (mg/kg): a green tea bag contained 235.57; a black tea bag, 62.79; chocolate, 27.87; crisps, 12.70; wheat flour, 12.15; Welsh onion, 0.02; garlic, 0.016, milk, 0.004; egg, 0.002 and salt, 0.0.[28]

In another UK-based study of selected snack and convenience foods, the nickel content was found to be as follows (mg/kg): instant tea (7.8–12); instant coffee (0.62–1.3), roasted, salted cashews (4.1–4.7), custard (0.02–0.03), lentils (1.6–2.3), mixed nuts (0.99–5.29), dried peas (0.39–0.76), haricot beans (0.65–2.3), varieties of crisps (0.06-0.61).[29]

However, certain foods are routinely high in nickel content such as cocoa and chocolate, soya beans, oatmeal, nuts and almonds, fresh and dried legumes.[22]

The following list shows some common foods with higher nickel content.[30]

Food with high nickel content irrespective of the soil content

Whole wheat, whole grain, rye, oat, millet, buckwheat, cocoa, chocolate, tea, gelatin, baking powder, soy products, red kidney beans, legumes: peas, lentils, peanut, soya beans and chickpeas, dried fruits, canned foods, beverages, strong licorice, and certain vitamin supplements

Other foods containing considerable amount of nickel

Beer, red wine, mackerel, tuna, herring and shellfish, sunflower seeds, linseeds, hazelnuts, marzipan, walnuts, tomatoes, onion, raw carrots

The mean total dietary intake of nickel has been reported to be between 0.12–0.21 mg in UK,[27] 0.13 mg in Finland,[31] 0.17 mg in US[32] and between 0.207–0.406 mg in Canada.[33] The dietary intake of nickel in Denmark is comparatively higher and could reach over 900 μg/day, and this was due to the high intake of oatmeal and legumes, including soybean, nuts, cocoa and chocolate.[34]

Indian diets are rich in plant food in comparison to Western diet, which is rich in animal food, and therefore, it contains considerable amount of nickel. Cereals, pulses and vegetables constitute the main bulk of the Indian diet. Pulses comprise

varieties of gram, lentils, beans and peas, which have high nickel content. Vegetables used in Indian diets include green leaves, roots and tubers and other vegetables. Vegetables such as spinach, onion and garlic are very popular and are found to contain moderately high amounts of nickel.

Even the cows' milk, which is an essential part of majority of Indians' diet, is not free from nickel and its nickel content is approximately 0.03 ppm of nickel.[19] Tea is consumed throughout India; dried tea leaves used for beverage making have been found to contain 3.9–8.2 mg/kg.[35] Jaggery (a locally available form of sucrose, also known as "*Gu*" or Indian sugar), which is commonly eaten in rural India, is found to have nickel in the concentration of 0.011 mg/g of jaggery.[36] Coffee, which is very popular in South India, is found to contain nickel in the concentration of 43 μg per 100 g of coffee beans (roasted, ground).[37]

Cocoa beans, from which cocoa and chocolate are made may contain up to 10 mg/kg of nickel and are common constituents of fast-foods in India.[38]

High concentration of nickel is sometimes found in processed foods. This is free nickel, picked up from the stainless steel used in the manufacture of equipment and containers. In general, cooking in stainless utensils releases negligible amount of nickel; however, cooking acidic food in these utensils may increase the nickel content.

LOW NICKEL DIET

Nickel is a ubiquitous trace metal, and it is a fact that nickel cannot be completely avoided from diet; however, the careful selection of food with relatively low nickel concentration can bring a reduction in the total dietary intake of nickel per day. This can influence the outcome of nickel dermatitis. Studies have confirmed the benefit of low nickel diet in the management of nickel eczema. However, it should be understood that the dermatitis will not clear completely during the diet period; however, it is likely to lead to fewer and milder flare-ups. While planning a low nickel diet, the dietary habits of the patients should be considered to encourage the acceptability of the diet. Following points must be taken into consideration while drafting a low nickel diet:

1. Avoid all foods that are routinely high in nickel content such as cocoa, chocolate, soya beans, oatmeal, nuts, almonds, fresh and dried legumes.
2. Avoid all drinks and vitamin supplements with nickel and canned food. Nickel dissociate from the alloy of the can and thus increase the total nickel content of the canned food.
3. Animal tissues generally contain less nickel in comparison to plant tissues. Meat, poultry and eggs are suitable for low nickel diet. Except for a few varieties of fishes that show high concentration of nickel such as tuna, herring, shellfish, salmon and mackerel, other fishes can be used for low nickel diet.
4. Nickel content of milk is low; therefore, milk and its products such as butter, cheese, curd and cottage cheese (paneer) can be consumed.
5. Nickel content of cereals is low. Foods prepared from rice (polished), refined wheat or corn (corn flakes, macaroni, etc.) are allowed.
6. Vegetables such as potatoes, cabbage and cucumber can be used. However, vegetables such as onion and garlic, which are very popular in our country, should be used in moderation. Green leafy vegetables are an inseparable part of Indian food; if desired, they may be taken sparingly due to the possibility of high concentration of nickel. Mushroom can be used.
7. Among the fruits, one may partake bananas (in moderation), apples (up to 3–4 times a week) and citrus fruits (up to 3–4 times a week).
8. Tea and coffee are very popular in India; in weaker concentration, these beverages can be taken in moderation (up to 2 cups a day).
9. While cooking, the following things have to be considered:
   (a) Nickel-plated utensils should not be used and should be replaced. Acidic food should not be cooked in stainless steel utensils as the acids may lead to the dissociation nickel from the the utensils and it may increase the nickel content of the food.
   (b) The initial water flow from the tap in the morning should not be drunk or used for cooking as nickel may be released from the tap during night.

METABOLISM OF NICKEL

The average dietary intake of nickel is approximately 300–600 μg/day. Nickel is poorly absorbed when ingested in typical diets. Only 1–10% of the ingested dietary nickel is absorbed;[19] the mechanism of absorption is unclear. Following absorption, nickel is transported in blood bound to serum albumin. Nickel is not significantly accumulated by any tissue in the body, although the thyroid and adrenal glands have relatively high nickel concentrations in comparison to other tissues. Most of the absorbed nickel is excreted by the

kidneys as low-molecular weight complexes. Nickel is also lost through sweat and bile.

REQUIREMENTS OF NICKEL IN DIET

A daily dietary requirement of 25–35 μg of nickel has been suggested.[38] However, the role of nickel in biochemical functions is not clear.

Nickel is one of the commonest sensitizers all over the world. Once sensitized, the sensitization tends to persist for many years, often life-long. Therefore, nickel allergy shows a chronic recurring course. Different types of treatments have been recommended – wet dressing, topical steroids, systemic steroids, cyclosporine and other immunosuppressives, PUVA therapy, etc. The result of treatment of such nickel eczema is mostly unsatisfactory as the relapse rate is high. This is because humans are continuously exposed to nickel in the environment, be it at home or workplace. Articles with nickel can be avoided to a certain extent, thereby reducing the contact with nickel. However, this is not always helpful because nickel is present in most of the dietary items of humans. Unless this continuous supply of nickel is reduced, nickel eczema will continue to relapse, particularly the vesicular type of hand eczema. The careful selection of food with relatively low nickel concentration can result in the reduction in the total dietary intake of nickel per day. This can help to control nickel dermatitis. Therefore, a good knowledge of the presence of nickel in food is helpful for the management of nickel allergy.

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