Selenium: Essential in Health and Disease

Selenium – Data from India
To Our Readers

The focus of the current issue (31) of the CRNSS Update Series “Nutrition in Disease Management” is on selenium – a very important antioxidant that has been shown to be protective against several chronic degenerative diseases. The first is a review article from the prestigious Faculty of Medical and Health Sciences at the University of Auckland, New Zealand, which draws our attention to the importance of selenium as an essential micronutrient in both health and disease. The review describes various issues pertaining to selenium such as the metabolic pathway of selenium, the settings wherein organic and inorganic selenium can be used and the situations in which selenium deficiency can occur. This is followed by a brief description of analysis of selenium content of different foods carried out at the well-known National Institute of Nutrition, Hyderabad, India that also discusses the locational and varied differences within India.

Please register early for the IBCON PEDGASTRO 2006 (the first Indo-British Conference of Pediatric Gastroenterology, Hepatology and Nutrition – details on Pages 15 and 16), which has a separate single day registration for the Nutrition Plenary Session and the Nurses’ and Dieticians’ Symposium which discusses issues pertaining to nutritional support.

Dr Sarath Gopalan
Executive Director, CRNSS
and Editor
Selenium: Essential in Health and Disease

Ines Hardy, MRPharmS and Gil Hardy, PhD
Faculty of Medical and Health Sciences
University of Auckland
New Zealand
i.hardy@auckland.ac.nz

INTRODUCTION
Selenium is an essential trace element and a key constituent of a large variety of functional proteins or enzymes. Levels of this important micronutrient are low in most European soils and volcanic areas of the world such as New Zealand. Sub-optimal levels are consequently present in many diets. It has recently been established that the human selenoproteome contains 25 selenoproteins. Integration of selenium is determined genetically and occurs via the 21st amino acid selenocysteine (SeCys). All known selenoproteins, except for selenoprotein P, contain single SeCys residues in their active centre, which are essential for their function.

The enzyme glutathione peroxidase (GSHPx) exists as four different types that occur ubiquitously in the body. GSHPx degrades peroxides before they decompose into cytotoxic hydroxyl free radicals. Another essential group of enzymes are the deiodases which convert the pro-hormone L-thyroxine (T4), secreted from the thyroid gland, into the active thyroid hormone 3,3’,5-Triiodine-L-thyroxine (T3). Thioredoxin reductases play an essential role in the regulation of the cellular redox state via the thioredoxin system, which is also coupled with glutathione status. Dysfunction of the thioredoxin-thioredoxin reductase system leads to cell death.

The preservation of the intracellular redox equilibrium serves, amongst other things, as protection against toxicity from endogenous and exogenous oxidising agents. Selenium is furthermore involved in DNA biosynthesis and there is strong evidence that low intakes are associated with high DNA instability and suboptimal DNA repair, while enhancing pro-inflammatory conditions that increase the risk of cancer1.
Selenoprotein P is secreted mainly from the liver and accounts for up to 70 per cent of plasma selenium. It has both a storage and transport function and probably also acts as an antioxidant, due to its high content of SeCys and cysteine. It can also bind heavy metals such as mercury in selenide complexes. Selenoprotein P is potentially the best parameter to assess selenium status but it is not yet available as a routine laboratory analysis. Other selenoproteins are found in testes and sperm as well as in prostate epithelium, which points to the essential function of selenium in spermatogenesis and reproduction. In male mammals it has already been shown that selenium deficiency leads to infertility. Selenoproteins are also found in the ovaries, adrenals and pancreas

SELENIUM REQUIREMENTS IN EUROPE

The British and German RDA recommend a daily intake of 30 to 70 µg selenium, in contrast to the current recommendation in the USA of 55 µg per day. These are recommendations that partly derive from the actual intake in the population and state the amount of selenium necessary to avoid symptoms of deficiency. European selenium intake is now approximately 30 µg/d in women and 42 µg/d in men with about 20 per cent of women and men consuming less than 25 µg/d, prompting many scientists to consider the official recommendations to be too low for modern diets and lifestyles.

Figure 1: Average selenium concentrations in European countries
**SOURCES OF SELENIUM**

Selenium enters the mammalian food chain via the soil but uptake is dependent upon high pH and soil porosity. Most plants take up the trace element in a linear fashion but other ‘accumulators’ follow a concentration gradient. After ingestion, dietary selenium is returned to the soil as trimethyl selenonium ions in urine and as elemental selenium and metal selenides in faeces. These inert forms are converted back to selenite and selenate by soil bacteria. Brazil nuts are the best dietary sources of selenium, followed by liver, kidneys and cooked fish. Cereals, green vegetables and beans are important sources but their content reflects the variability of soils. Other nuts, citrus fruits and dairy products also contribute to dietary intake.

It is often not possible to achieve adequate selenium intake from the diet alone without supplementation because most foods have low selenium content. Requirements are increased in different stress situations and in many diseases, so a general intake recommendation always represents a compromise and can never correspond to individual needs. Average serum or plasma selenium concentrations in European countries are all appreciably lower than typical levels (114 µg/l) recorded in the USA Nutritional Prevention of Cancer Study and the level for optimal glutathione peroxidase activity (95 µg/l) determined by New Zealand researchers.

![Figure 2: Simplified representation of selenium metabolism](image-url)
How much selenium a person needs is therefore determined by the quantity necessary to reach the optimal blood level. Numerous studies point to the fact that it should be approximately 160µg/l in whole blood and 135µg/l in serum\textsuperscript{10,11}.

**SELENIUM DOES NOT EQUAL SELENIUM**

Selenium preparations are divided into those containing organically bound selenium and those containing inorganic selenium. They differ in their metabolic pathway, indication and regulatory status.

**SELENIUM PREPARATIONS**

Organic selenium preparations are usually yeast-based. Their selenium is approximately 80 per cent selenomethionine (SeMet) and 20 per cent unidentified selenium compounds\textsuperscript{12}. SeMet and SeCys are amino acids found in dietary protein. Organic preparations fall under food supplement regulations so contain amounts of selenium recommended for the daily supplementation of healthy individuals (50-100µg) and are freely available (usually as selenium yeast tablets).

Inorganic selenium preparations contain sodium selenite (Na\textsubscript{2}SeO\textsubscript{3}) or sodium selenate (Na\textsubscript{2}SeO\textsubscript{4}). Products such as Selenase\textsuperscript{®} containing sodium selenite are Prescription Only Medicines licensed by the UK regulatory authorities for proven selenium deficiency that cannot be compensated for by increased dietary intake.

**METABOLIC PATHWAY**

SeMet and sodium selenite are equally well absorbed through the intestinal mucosa. The actual absorption rates for selenium are 92 per cent from sodium selenite and 98 per cent from SeCyst and SeMet. However, in contrast to the selenium absorbed from selenite, organic compounds are not immediately bioavailable. Selenoaminoacids are indistinguishable from their sulphur analogues, enter normal protein synthesis and are incorporated non-specifically into body protein. Selenium bound as SeCyst or SeMet remains unavailable for specific metabolism until catabolism of the amino acids by protein turnover, when the selenium is released as hydrogen selenide and becomes available for the synthesis of selenoproteins. This release is especially slow with SeMet. Thus incorporation into selenium-dependent enzymes is time dependent.

Under the action of reducing substances selenium from sodium selenite enters the hydrogen selenide pool immediately and becomes available for the specific synthesis of selenoproteins. Inorganic selenium is therefore immediately and completely bioavailable after absorption and can instantly be used for selenoprotein synthesis (e.g. into glutathione peroxidase). It is also eliminated from the body much more rapidly than organic preparations\textsuperscript{13}. The actual order of bioavailability is therefore: selenite>selenocysteine>selenomethionine.
WHEN CAN ORGANIC AND INORGANIC SELENIUM BE USED?
Organic selenium (as a food supplement) is suitable for healthy individuals to supplement their diet (50µg to 100µg/day). Higher doses are not recommended for long-term use. Inorganic selenium can be used both for supplementation as well as for the treatment of selenium deficiency in various diseases such as cancer, chronic inflammatory diseases and in intensive care. In these situations of severe depletion, an initial booster of 2000µg/day followed by a short course of 1000µg/day may be indicated.

WHY SELENITE SHOULD NOT BE TAKEN TOGETHER WITH VITAMIN C
Vitamin C reduces selenite (Se⁴⁺) to elemental selenium (Se⁰) producing a red precipitate and is itself oxidised in this reaction into an inactive form. If both substances do have to be taken together, it is recommended that selenite is taken on an empty stomach in the morning before any food, leaving an interval of at least one hour before taking vitamin C or any vitamin-containing foods or drinks. In low pH intravenous solutions, it is especially important to avoid mixing, but in well-buffered TPN mixtures above pH 5 interaction is negligible.

WHAT IS THE RECOMMENDED DOSAGE OF SELENIUM?
The current WHO recommendation for the safe maximum long-term intake of selenium is 400µg per day. This is applicable for healthy individuals without symptoms of deficiency and not under conditions of increased stress. Individuals with very low selenium levels, consumptive diseases, chronic inflammation or infections, as well as disorders associated with excessive free radical production have not been taken into account by this recommendation and should be considered separately. The required and therefore tolerated dose is much higher in these cases (up to 1,000µg per day) and has to be established on a case by case basis. Selenium poisoning correlates to increased concentrations in blood and urine but is rare. Symptoms can occur from approximately 1,000µg per litre whole blood upwards. This corresponds to approximately 5,000µg selenium for an average size adult. The first signs are a garlic-like odour of the breath, tiredness, nausea, diarrhoea and abdominal pain.

HOW CAN SELENIUM BE MEASURED?
The body’s selenium status is usually measured in serum. However, the amount of intracellular selenium is more important. Assays should therefore be carried out on whole blood. The body’s overall status can then be extrapolated from the red cell content. An EDTA coated tube should be used for collection of the blood sample in order to avoid coagulation.
SITUATIONS IN WHICH SELENIUM DEFICIENCY CAN OCCUR

Long term parenteral nutrition
Since nutritional solutions usually contain little or no selenium, selenium deficiency can occur in patients who are fed exclusively via the parenteral route, without supplementation.

Dialysis
Patients whose renal function is so severely impaired that they require regular dialysis incur ongoing selenium losses. Supplementation with 500 µg sodium selenite three times per week after each dialysis session was beneficial in a year long study.

Pregnancy and lactation
Requirements for selenium, and other nutrients, are increased in pregnancy and lactation because selenium is also supplied to and metabolised by the child. Deficiency could harm the mother as well as the child.

Heavy metal poisoning
Selenium binds heavy metals in the body and thereby detoxifies them. However, the nutrient used for this reaction is then not available for the many other selenium dependent processes. This means that a relative deficiency can occur in heavy metal poisoning, even with concurrently large selenium intake.

Alcohol abuse
High alcohol intake leads to oxidative stress and ultimately liver damage. This is also associated with selenium deficiency and supplementation has been shown to have a positive effect on the clinical course of liver disease.

Vegetarians
Animal protein diets are usually high in selenium but for optimum intake of selenium much larger amounts of vegetable protein have to be consumed. Selenium deficiency is therefore possible with strictly vegetarian or vegan diets.

WHICH DISEASES CAN BE RELATED TO SELENIUM DEFICIENCY?

General immunosuppression
Because selenium-dependent enzymes carry out important tasks in the immune defence, deficiency can occur during colds and induce increased susceptibility to many other infections.
Cardiovascular diseases
The incidence of cardiovascular diseases can be related to significantly decreased selenium levels. Inflammatory processes are involved in the development of arteriosclerosis and markedly reduced selenium levels are found in patients with vascular disease 24, 25.

Chronic inflammatory diseases
Patients suffering from, for example Crohn’s disease, ulcerative colitis 26 or chronic inflammatory joint disease, usually have low selenium levels since chronic inflammation is associated with oxidative stress 27.

Autoimmune thyroid inflammation (Thyreoiditis)
In autoimmune diseases of the thyroid and other forms of thyroid inflammation, antibodies against the body’s own thyroid tissue are generated. Studies have shown that antibody levels and therefore inflammation and destruction of tissue are markedly reduced with selenium supplementation. This also has beneficial effects on overall well-being: physical and mental capacity, concentration and mood improvement, and there is a partial reduction in joint problems and allergies 28.

Diabetes mellitus
Diabetics undergo oxidative stress that can lead to life threatening secondary conditions such as heart disease. Concurrently they also exhibit low selenium levels. Clinical investigations demonstrate that early control and optimisation of selenium are of great importance for preventing diabetic complications 29. This is particularly relevant in older patients since selenium supply is found to decline with age.

Viral infections
In viral diseases, a good selenium supply can be beneficial in two ways. Firstly, several studies show that an adequate supply of this trace element can protect against the outbreak or the progression of a viral disease and selenium deficiency can be a trigger for viral replication. This applies to certain viruses such as Cox sackie B, influenza and HIV. Secondly, viral diseases are associated with extreme oxidative stress. Thus selenium levels decline during illness but supplementation stabilises the patient’s immune defence 30, 31.

Cancer
Selenium levels are frequently low in individuals who will develop cancer, even before the onset of the disease. Several studies have shown that men with low selenium blood levels have a two to five fold higher risk of prostate cancer and daily supplementation appears to reduce this risk. Due to the many functions it has to perform in the body’s defence system, selenium reserves are often exhausted in cancer patients. The action of selenium appears to be partly as an
antioxidant in a protective role for immune cells as well as stimulating an increase of high affinity IL-2 receptors on the surface of activated lymphocytes which offers a basis for a reinforced T-cell response\textsuperscript{32}. The first clues to a tumour-protective effect came from large intervention studies in China where the incidence of primary liver carcinoma was reduced by 40 per cent over five years by daily selenium supplementation\textsuperscript{33}. The NPC study of 1,312 high risk patients receiving 200\(\mu\)g selenium or placebo daily over 4.5 years did not effect relapse rate but significantly reduced prostate cancer by 63 per cent, colon cancer by 58 per cent and lung cancer by 45 per cent\textsuperscript{7}. These spectacular results initiated the even larger SELECT study into selenium and/or vitamin E supplementation which is due to conclude in a year or two.

**CONCLUSION**

Selenium is a component of a variety of antioxidant and redox-state regulating enzymes and proteins. The most well-known – glutathione peroxidases, thioredoxin reductases and selenoprotein P – carry out their functions ubiquitously. Selenium deficiency has therefore an effect on all metabolic pathways that can be influenced by oxidation and constitute a limitation in the body’s reactive potential. Conversely an improved selenium supply would mean an increase of potential. Supplementation of 200-300\(\mu\)g/day improves micronutrient and antioxidant status in many clinical conditions, whilst short-term intravenous doses of 1000\(\mu\)g selenium as selenite has improved survival in critically ill septic patients\textsuperscript{34}.

Immune function is also sub optimal with decreased selenium levels. The importance of selenium for antioxidative defence is exemplified in its influence on gene expression. In deficient situations selenium-independent genes are switched on in order to maintain DNA repair, protection against oxidative stress and cell cycle control\textsuperscript{35}. The gene expression profile suggests that the cancer preventing properties of selenium can also be explained by the activation of genes involved in cell cycle regulation and oncogenesis\textsuperscript{36}.

The new field of nutrigenomics or ‘personalised nutrition’ seeks to optimise human diets for disease prevention based on identification of key single nucleotide polymorphisms (SNPs). Defining the relative frequencies of these key SNPs for known selenoproteins in a population of men at risk from prostate cancer may help us consider how the different genotypes respond to selenium supplementation and whether this may reduce the risk of cancer and other diseases.

**REFERENCES**


Selenium - Data from India

Adapted from - Abhay Kumar and Kamala Krishnaswamy
Selenium in Human Health: Nutrition News
National Institute of Nutrition (NIN)
Hyderabad, Volume 24, No. 2, April 2003

CEREALS AND MILLETS
Analysis of selenium content of different foods was carried out at the National Institute of Nutrition (NIN), Hyderabad using standard fluorimetric procedures. The selenium content of wheat from Hyderabad market ranged from 62 ng Se/g in the samples studied. Wheat being a good source of this nutrient has the highest bioavailability when compared to other foodstuffs. Rice a staples has 58 ng Se/g to 176 ng Se/g in the samples analysed. The low selenium content in rice may be due to the cultivation practices like waterlogged condition required for completing the life cycle of the crop. The selenium uptake under anaerobic condition of the soil is less documented. Millets like sorghum and bajra are a fairly good source of selenium for population subsisting on these foodstuffs. Ragi, though a millet, is a poor source of selenium when compared to other millets (Table 1).

PULSES
Pulses are a major source of protein in vegetarian diets. Some of the pulses consumed in India were analysed for the selenium content. Red gram and lentil have the maximum selenium content to this food group. Red gram is the major pulse consumed in this part of the country. But the contribution to total selenium in the diet may not be substantial as the quantity consumed is lower when compared to cereals particularly in rural areas (Table 1).

SPICE AND CONDIMENTS
Spices and condiments are a food group which are used for culinary purpose in the diet. The contribution of selenium to the daily requirement is lower when compared to other two food groups mentioned previously. Mustard is a good source of selenium among the spices analysed (Table 1).
Table 1: Selenium content of Foodstuffs

<table>
<thead>
<tr>
<th>Foodstuffs</th>
<th>Se Content (ng/g)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean ± SD</td>
<td>Range</td>
<td></td>
</tr>
<tr>
<td><strong>CEREALS AND MILLETS</strong></td>
<td>32 - 91</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rice</td>
<td>99 ± 43</td>
<td>58-176</td>
<td></td>
</tr>
<tr>
<td>Wheat</td>
<td>170 ± 69</td>
<td>62-263</td>
<td></td>
</tr>
<tr>
<td>Maize</td>
<td>85 ± 60</td>
<td>32-170</td>
<td></td>
</tr>
<tr>
<td>Sorghum</td>
<td>189 ± 69</td>
<td>91-287</td>
<td></td>
</tr>
<tr>
<td>Bajra</td>
<td>127 ± 78</td>
<td>146-391</td>
<td></td>
</tr>
<tr>
<td>Ragi</td>
<td>68 ± 50</td>
<td>24-155</td>
<td></td>
</tr>
<tr>
<td><strong>PULSES</strong></td>
<td>28-391</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Red gram dal</td>
<td>225 ± 82</td>
<td>131-376</td>
<td></td>
</tr>
<tr>
<td>Bengal gram dal</td>
<td>161 ± 58</td>
<td>94-235</td>
<td></td>
</tr>
<tr>
<td>Green gram dal</td>
<td>95 ± 41</td>
<td>28-150</td>
<td></td>
</tr>
<tr>
<td>Black gram dal</td>
<td>164 ± 84</td>
<td>68-265</td>
<td></td>
</tr>
<tr>
<td>Lentil</td>
<td>208±88</td>
<td>146-391</td>
<td></td>
</tr>
<tr>
<td>Cow pea</td>
<td>101±72</td>
<td>42-206</td>
<td></td>
</tr>
<tr>
<td><strong>SPICES</strong></td>
<td>2-423</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turmeric</td>
<td>45±12</td>
<td>26-62</td>
<td></td>
</tr>
<tr>
<td>Coriander seed</td>
<td>132±12</td>
<td>117-145</td>
<td></td>
</tr>
<tr>
<td>Mustard seed</td>
<td>201±152</td>
<td>92-423</td>
<td></td>
</tr>
<tr>
<td>Fenugreek seed</td>
<td>63±16</td>
<td>50-86</td>
<td></td>
</tr>
<tr>
<td>Red chili powder</td>
<td>79±6</td>
<td>57-98</td>
<td></td>
</tr>
<tr>
<td>Pepper</td>
<td>17±17</td>
<td>2-35</td>
<td></td>
</tr>
<tr>
<td>Cumin</td>
<td>120±130</td>
<td>21-286</td>
<td></td>
</tr>
</tbody>
</table>

**LOCATIONAL AND VARIETAL DIFFERENCES**

The selenium content of foodstuff depends on the soil selenium levels, variety and other agronomic practices. The major factor, apart from the foodstuffs in the diet, is the location of the cultivation which determines the selenium content of the foodstuffs. Rice from Nalgonda District of Andhra Pradesh has very low levels of selenium. Another area located in the same revenue district showed higher level of this nutrient but lower than the foodstuffs from the twin cities of Hyderabad and
Table 2: Locational differences in Se content of different foodstuffs

<table>
<thead>
<tr>
<th>Foodstuffs</th>
<th>Twin cities</th>
<th>Nalgonda</th>
<th>Suryapet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice</td>
<td>82.6 (6)</td>
<td>22.7 (10)*</td>
<td>70.5 (3)</td>
</tr>
<tr>
<td>Sorghum</td>
<td>212.7 (4)</td>
<td>201.5 (4)</td>
<td>—</td>
</tr>
<tr>
<td>Green gram dhal</td>
<td>97.6 (5)</td>
<td>127.0 (5)</td>
<td>—</td>
</tr>
</tbody>
</table>

Values are median values. Figures in parentheses are number of samples analysed.

*P < 0.05%

Table 3: Varietal differences in Se content (ng/g) of rice

<table>
<thead>
<tr>
<th>Variety</th>
<th>Mean ± Sd</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sona Masuri</td>
<td>119±45 (3)</td>
<td>60-176</td>
</tr>
<tr>
<td>Bapatla</td>
<td>99±45 (4)</td>
<td>71-166</td>
</tr>
<tr>
<td>Hamsa</td>
<td>51±19 (3)</td>
<td>26-69</td>
</tr>
<tr>
<td>Phalguna</td>
<td>42±13 (3)</td>
<td>30-56</td>
</tr>
<tr>
<td>Suwarna</td>
<td>41±25 (3)</td>
<td>20-72</td>
</tr>
</tbody>
</table>

Figures in parentheses are number of samples analysed.

Secunderabad. These data suggest that locational differences are an important component in estimating the dietary intake of at least some nutrients (Table 2).

The variety of crop and agronomic practices too determine the choice of the cultivator. The verity chosen may be a better assimilator of a particular nutrient as an inherited trait in its development. This characteristic feature may contribute to the total dietary intake of any nutrient. Table 3 shows the variation that can be expected while assessing the nutrient intake in the study population from dietary data.
ANNOUNCEMENT

IBCON-PEDGASTRO 2006

(THE FIRST INDO-BRITISH CONFERENCE ON PEDIATRIC GASTROENTEROLOGY, HEPATOLOGY AND NUTRITION)

Date: October 26-28, 2006
Venue: India Habitat Centre, New Delhi

Nurses and Dietitians Symposium – October 28, 2006 (Parallel Session)

Registration Fees for Nurses and Dietitians Symposium
(for Indian Nationals):
- Till May 31, 2006 - Rs. 500 (Rupees Five Hundred Only)
- After May 31, 2006 - Rs. 750 (Rupees Seven Hundred and Fifty Only)
- Spot Registration - Rs. 800 (Rupees Eight Hundred Only)

This does not apply to registration for the main conference.

The IBCON-PEDGASTRO 2006 is unique because unlike many conferences conducted in India where foreign nationals are either invited delegates or faculty (guest speakers), the British Society of Pediatric Gastroenterology, Hepatology and Nutrition (BSPGHAN) is co-hosting the Conference with India and our colleagues from the UK are actively involved in organising this conference which is as much their conference as is ours. In fact, the initiative was taken by our colleagues in the United Kingdom who suggested that it would be an excellent idea to conduct their meeting
in India. It is expected that approximately 600 delegates will be attending the conference.

The IBCON-PEDGASTRO 2006, the first of its kind, will include a Nurses and Dietitians Symposium on October 28, 2006 which will focus on issues related to principles, product availability, delivery and challenges related to enteral and parenteral nutrition administration. The Symposium is expected to serve as a forum for a useful exchange of ideas and information regarding practical issues involved in administration of both enteral and parenteral nutrition.

For further information regarding IBCON-PEDGASTRO 2006, please contact:
Prof. A.K. Patwari
Organising Secretary
E-mail: akpatwari@gmail.com

For further information regarding Nurses and Dietitians Symposium, please contact:
Dr. Sarath Gopalan
Co-organising Secretary
E-mail: crnssindia@gmail.com


**Governing Body of CRNSS**

Dr S. Padmavati  
President  
Director, National Heart Institute, New Delhi

Dr C. Gopalan  
Member  
President, Nutrition Foundation of India, New Delhi

Dr Prema Ramachandran  
Member  
Director, Nutrition Foundation of India, New Delhi

Dr Kamala Krishnaswamy  
Member  
Senior Emeritus Scientist,  
National Institute of Nutrition, Hyderabad

Dr S. Janaki  
Member  
Consultant Neurologist, New Delhi

Ms Malini Seshadri  
Treasurer  
Freelance Writer and Company Secretary, Chennai

Mr Rakesh Bhargava  
Member  
Managing Director & CEO, Fresenius Kabi India Limited

Dr Sarath Gopalan  
Executive Director  
Consultant, Clinical Nutrition and Paediatric Gastroenterologist  
Pushpawati Singhania Research Institute, New Delhi

---

**CRNSS** is a Registered Society under the Societies Registration Act of 1860. This Update Series is published by CRNSS four times a year. The latest information and advances in the area of nutrition, special systems in the management of diseases are presented for the benefit of medical practitioners and dieticians.