

**Neurological Impact of Zinc Excess and
Deficiency in Vivo***- A Review***ABSTRACT**

Zinc is an essential mineral that can cause pathological effects whether in excess or deficiency. Zinc is a component for over 250 enzymes and is required for cell growth, cell division, and cell function. Zinc is found in muscle and bones, with the prostate, liver, skin, and kidney having detectable levels of zinc. However, zinc in excess or deficiency can cause significant pathology in patients that include deleterious effects neurologically. Zinc in excess in vivo can focal neuronal pathology, while zinc deficiency can bring about mental lethargy, neuropsychiatric disorders, and reduced nerve conduction. Zinc is assimilated within the body by oral ingestion, dermal exposure, and pulmonary inhalation. Although not generally viewed as a cause of cancer, studies suggest that zinc is associated with progression of prostate malignancy. Toxic levels of zinc have been shown to induce lethargy, neurotoxicity, and gliotoxicity. High levels of zinc cause neuronal death in cortical cell tissue culture. Zinc is found to accumulate following the death of neurons in global ischemia. Therefore, zinc deficiency or excess is a significant clinical concern.

Keywords: zinc, toxic metals, vitamins, minerals

1. AN ESSENTIAL MINERAL

Zinc is an element found in-group 12 of the periodic chart and is a transition metal. Zinc is an essential mineral, one of 16, that includes [1]: calcium, phosphorus, potassium, sulfur, sodium, chloride, magnesium, iron, zinc, copper, manganese, iodine, and selenium, molybdenum, chromium, and fluoride. Zinc is an important mineral for many organisms and is known to be a component of for than 250 enzymes and a large number of proteins [1]. Thus, zinc is profoundly important for normal human health.

Of all the zinc found in the human body, almost 90% is located in the bones and muscles of individuals [1]. Oral consumption of zinc is followed by absorption in the small intestines, followed by dissemination in the body from the serum where it is bound to proteins [1].

Having noted the importance of zinc for human nutrition and health, it is necessary to address the reality that zinc deficiency and significant excess in the body results in pathological conditions. Zinc can express a strong role in neuronal death and participation in toxic events on the cellular level [1]. Zinc is believed to be associated with the regulation of apoptosis (death of cells that occurs as a normal and controlled part of an organism's development) at the cellular level [1].

Zinc is also found in the

2. ZINC IN THE HUMAN BODY

Almost 90% of the total amount of zinc found in the body (up to 3 grams total) is located in the bones and muscles [1]. Other tissue locations in which zinc is noted, includes the gastric intestines, brain, pancreas, skin, stomach, and kidney (see Figure 1) [2, 3]. Once in the serum, zinc is bound to proteins such as transferrin, α -microglobulin, and albumin [1].

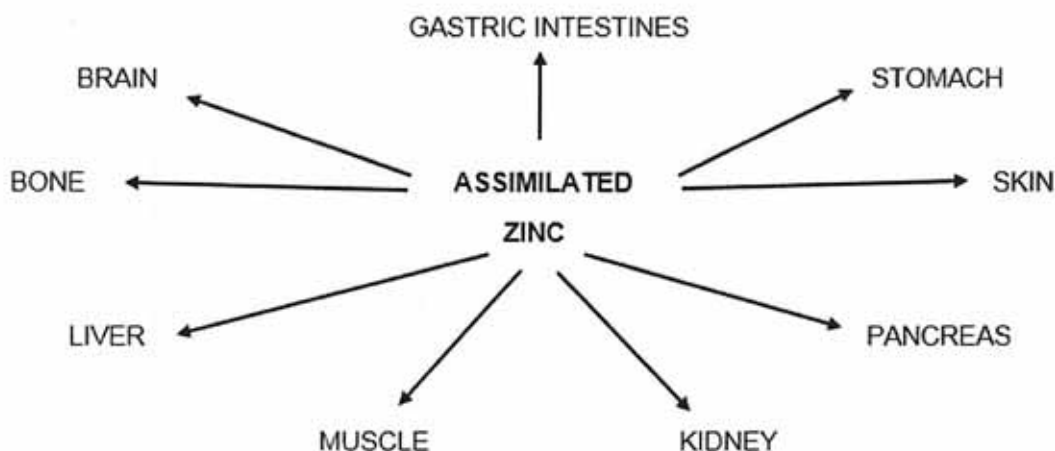


Fig. 1. Disposition of zinc in the human body. Zinc is found in numerous organs, including the brain, bones and muscle.

Within the cell itself, it is generally accepted that 50% of zinc present will be in the cytosol with somewhere from 30% to 40% contained in the nucleus [4]. The remaining balance is determined to be localized in the membranes [4]. In these locations, zinc plays an important role in nucleic acid and protein metabolism, as well as cell growth, function, and cell division [5]. Interestingly, the cellular zinc component is thought to play some role in homeostatic control that avoids the assimilation of excess zinc [1].

3. ZINC ASSIMILATION, NEUROLOGICAL AND OTHER EFFECTS

The assimilation of zinc into the human body can be accomplished by three pathways. These three pathways are inhalation, oral ingestion, and absorption through skin [6]. The eventual effects as a result of each type of assimilation will be upon specific portions of the body in these pathways [6].

Although there are pathological results of excessive uptake or deficiency, the oral ingestion of adequate zinc in nutrition is important for normal health [1]. The oral consumption of excessive zinc will quickly bring about noticeable nausea, vomiting, abdominal pain, and eventual anemia [7]. Subsequent effects originating from the central nervous system will have lethargy and dizziness [7]. Other studies have shown that excessive oral ingestion will bring about overt symptoms such as fatigue and lethargy [8].

Pulmonary inhalation of continuous/excessive amounts has caused pathological issues. Inhalation of zinc in the form of industrial originated zinc oxide will cause shakes and chills, sometimes referred to as metal fume fever [9]. Galvanization is a process that can result in

cause

aerial exposure of zinc [1]. Particle sizes of less than 1 micrometer can effectively introduce troubling levels of zinc into the body, these exposures primarily from industrial settings [10]. Symptoms noticeable include fatigue, nausea, fever, chest pain, cough, dyspnea (difficult breathing), and muscle soreness [11].

Concerning assimilation through the dermal layers, it is known that zinc is a common component of various topical treatments of various conditions, including of wounds that cause breaks within the skin [12]. However, the extent of zinc absorption is influenced by the pH of the skin, chemical speciation, and amount of zinc applied from the medicament [13]. Overall, it is generally accepted that exposure to zinc by dermal pathway does not constitute a significant pathological risk [1].

Interestingly, the excess exposure to zinc derived from denture adhesives can induce copper deficiency leading to neurological symptoms involving walking and balance [14]. Unfortunately, recovery from these neurological symptoms looks to be limited in extent and efficacy [14]. Alarming, other investigators have reported even more severe results of excess zinc exposure from denture fixative creams that include neurological effects such as degeneration of the spinal cord, crippling nerve damage (human swayback disease), with bone marrow suppression [15]. The copper deficiency induced by zinc exposure in denture creams is shown to cause serious neurological disease [16].

Therefore, the assimilation of excess zinc as well as the deficiency thereof- induces various significant neurological related health maladies, these summarized in Table 1. These include lethargy, effects upon focal ability, and psychiatric conditions [1]. There are other notable health related risks associated with zinc assimilation.

Table 1. Effects Caused by Zinc Metal Deficiency and Substantial Excessive Presence

Condition/Pathology	
Zinc Metal Deficiency	Zinc Metal Substantial Excess
Reduction of Nerve Conduction	Mental Related Lethargy
Lethargy Due to Mental Effects	Reduction of Focal Activity
Pathology of Neurosensory Ability	
Pathology of Psychiatric Ability	

Certain metals have been associated with carcinogenicity (i.e. nickel, chromium) but zinc is overall not accepted to be a causative factor for cancer [1]. However, other studies of prostate adenocarcinoma, and particularly those monitoring the level of zinc in the surrounding tissues, indicate the potential involvement of zinc in the progression of prostate malignancy [17, 18].

Even though there are homeostatic mechanisms preventing zinc from achieving a level in the brain that would cause pathological results, there are cases where neurological symptoms follow zinc intoxication [1]. One case relates how a young male child induced lethargy and focal neurological reduction following 72 hours after ingesting as much as 12 grams of metallic type zinc [19]. Previous studies have shown that zinc can function as a neuromodulator [20, 21]. Other studies have demonstrated that zinc within the body could be a rapid and potent neurotoxin, as well as a gliotoxin [22, 23, 24]. Other substantial neural health issues will now be discussed.

122
123 Previous studies have shown that an exposure to zinc at a level of 300 μM to 600 μM , for as
124 little as 15 minutes, can induce extensive neuronal death in tissue culture of cortical cells
125 [25]. Zinc has been shown to be active in neuronal damage, participates in action during
126 membrane depolarization following acute brain injury to increase its neurotoxicity [26]. This
127 membrane depolarization causes an increase of zinc to act as a neurotoxin [27].
128
129 Other studies have described zinc as a necessary component of excito-toxic cascade
130 following seizures, ischemia (inadequate blood supply to an organ, especially the heart
131 muscles), and head related trauma [28, 29].
132
133 Damage to the brain regions out of broad ischemia to hippocampal CA1, thalamus,
134 neocortex, and striatum have shown zinc accumulation among dying or dead neurons [30].
135 This event has also been shown to occur in the hippocampal hilar region [30]. The fact that
136 this event described above can be prevented by intraventricular injection of zinc chelator
137 calcium-EDTA (Edetate Calcium Disodium) supports the assertion that zinc accumulation
138 leads to neuronal cell death [31].
139
140 Previous studies have associated zinc to a oxidative stress type induction to neuron cell
141 damage [32]. Inclusive is a study showing zinc-induced neuron cell death occurring with
142 increased levels of reactive oxygen species occurring within neurons [33]. Seen as a support
143 for this scenario of zinc action on neurons, the zinc-induced cell death is decreased by
144 introduction of anti-oxidant agents [34].
145
146 A zinc-induced apoptosis event in neurons can take place by a pathway triggering caspase
147 activation (and apoptosis) by induction of p75^{NTR}-associated death executor and neutrophin
148 receptor p75^{NTR} [35, 36].
149
150 The release of intracellular zinc will initiate neuronal apoptosis [37, 38], with accompanied
151 cell swelling and destruction of intracellular organelles [39, 37]. Altogether, these studies
152 suggest that zinc-initiated neuronal cell death encompasses both apoptotic and necrotic
153 mechanisms (cell injury, which results in the premature death of cells) [29].
154
155 Previous studies have shown the likelihood that zinc is involved in certain neurodegenerative
156 diseases [40]. The improper regulation of zinc homeostasis and zinc may play a substantial
157 role for the onset and progression of Alzheimer's disease [40].
158
159 Other unfortunate cases include the fatal accidental ^{over}dose of zinc to a neonate following
160 confusion of amounts of micrograms to milligrams [41]. A study conducted in Nepal showed
161 that zinc phosphide occurred in 6.5% of all poison cases occurring in 2004 [42]. Also, acute
162 intravenous zinc poisoning occurs from poor administration of parenteral nutrition with
163 intravenous injection [43].
164
165 In addition to pathological conditions described above, symptoms from zinc deficiency such
166 as growth retardation, skin changes, poor appetite, mental lethargy, taste abnormalities,
167 slow wound healing have been noted in even moderate zinc deficiency [44]. The condition of
168 zinc deficiency is aggravated by low dietary intake, alcohol abuse, malabsorption, and
169 chronic renal disease [1, 44]. Zinc deficiency is seen to be widespread and has a destructive
170 impact on neuronal development, as well as immunity of the patient [1].
171
172 Therefore, it is seen that endogenous zinc can be substantially involved with cytotoxic
173 actions in individual cells. Studies have shown that zinc has a notably activity in cell death
174 occurring in the brain [1]. However, zinc is considered to be one of the essential minerals for

human health. The dual role that zinc plays in human health and clinical pathology deserves further study. To understand the role zinc plays in pathological events is important, in order to determine a remedial course of treatment. Therefore, the investigation will continue and elucidate important facets of zinc in the human body.

4. CONCLUSION

Endogenous zinc is known to important involvement within cytotoxic activity within individual cells. Zinc excess is shown to induce lethargy and focal neuronal reduction. Zinc deficiency is shown to induce lethargy, neurosensory pathology, neuropsychiatric disorders, and reduction of nerve conduction. Oral ingestion of toxic levels of zinc will produce symptoms of dizziness and lethargy. The inhalation of zinc can bring about shaking, fatigue, and fever. Although zinc acts as a neuromodulator, endogenous zinc can be a potent and rapid neurotoxin. At 300 μ M levels, zinc will extensively destroy cortical cells in tissue culture. Neurons exposed to zinc will initiate apoptosis. The activity of zinc in the human body has significant implications for normal health. Zinc in excess or deficit will cause pathological conditions which should be rapidly diagnosed by clinicians. Further study of the biological activity of zinc is warranted.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

CONSENT

Not applicable.

ETHICAL APPROVAL (WHERE EVER APPLICABLE)

Not applicable.

REFERENCES

1. Plum LM, Rink L, Haase H. The essential toxin: impact of zinc on human health. *Int J Environ Res Public Health*. 2010;7:1342-65.
2. Bentley PJ, Grubb BR. Experimental dietary hyperzincemia tissue disposition of excess zinc in rabbits. *Trace Elem Med*. 1991;8:202-7.
3. He LS, Yan XS, Wu DC. Age-dependent variation of zinc-65 metabolism in LACA mice. *Int J Radiat Biol*. 1991;60: 907-16.
4. Llobet JM, Domingo JL, Colomina MT, Mayaya E, Corbella J. Subchronic oral toxicity of zinc in rats. *Bull Environ Contam Toxicol*. 1988;41:36-43.
5. Vallee BL, Falchuk KH. The biochemical basis of zinc physiology. *Physiol Rev*. 1993;73:79-118.
6. Toxicological Profile for Zinc. Agency for Toxic Substances and Disease Registry Division of Toxicology and Environmental Medicine: Atlanta, GA, USA, 2005.