

# Call For The Nutritional Requirements For The Cognitive Development Of The Younger Children During And After The Covid-19 Pandemic: A Review For Parents

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## Abstract

The present review highlights the importance of nutrition and cognitive development in younger children (preschoolers; 2-5 years) during and after the Covid-19 pandemic. Since the onset of the pandemic studies has reported the importance of nutrition particularly during the pandemic and on the other hand studies have also discussed the role of cognitive development during a pandemic. This is the first article which combines the importance of nutrition in relevance to the pandemic and the cognitive development of younger children. The explanation proposed in the manuscript presents an important guideline for parents to raise their children during and after the onset of the pandemic. Further, the manuscript provides an explanation of various types of nutritional importance for the cognitive development of children and recommends food sources high in vitamins and micronutrients. The manuscript also recommends the daily dosage requirements and symptoms of delayed development in children due to the pandemic.

**Key words** Nutrition, cognitive development, vitamins, micronutrients, and neuronal development.

## Introduction

Since the pandemic started, waves have been witnessed where the severity and infectious rates have been recorded differently. The startle spread of coronavirus (CoV) 2 (SARS-CoV-2) acute upper respiratory syndrome in early 2020 has upsurged as a pandemic (Gralinski & Menachery, 2020). Depending on the severity and infectious

rates countries have imposed restrictions differently. It has been documented that children and young adults have milder to moderate forms of infection compared to adults. Many efforts have been made to deliver a vaccine to protect adults against this contagious virus which tends to spread rapidly (Zhou et al., 2020). Most of the country's adult population are now vaccinated and continuous attempts are being made for

preventive and curative measures to understand the epidemiological factors associated with the mutated versions and the widespread of the virus (Park, Cook, Lim, Sun & Dickens, 2020; Bousquet et al., 2020). Children under the age of 5 years are still not vaccinated and researchers are trying to establish a vaccine to protect younger children (less than 5 years) against the virus. Children are at risk of contracting moderately to severe symptoms which may be fatal. Therefore, the nutritional requirement could prove a protective layer to reduce these fatal symptoms over time.

The covid-19 pandemic is compromising the nutritional requirements across the globe mainly the younger children in low-middle income populations (United Nations, 2020). Many countries have imposed strategic restrictions on combating the pandemic including social distancing, schools and closure of nurseries, country or state/province lockdowns have impacted the food production, transportation and the sale and distribution of nutritional and affordable foods as a consequence families have been surviving on compromised nutritional alternatives. Many families are also suffering from pandemic-induced economic slumps as they scrap to access the required food services (Robertson et.al, 2020). This has imposed physical as well as psychological hurdles to healthy eating and contributed to an obesogenic environment for all ages (Di Renzo et al., 2020; Muscogiuri, G., Barrea, L., Savastano, S., & Colao, 2020).

Understanding the core of nutritional requirements and evidence-based recommendations referring to the risk of covid 19 is critical. Nutrition can act as a protective shield to protect children from the symptoms of covid - 19 is still debatable. Therefore, this review tries to make an attempt for the parents to understand

the importance of nutrition which should be included on daily basis in children's diet for better growth and cognitive development and to reduce the onset of frequent upper respiratory symptoms, and viral infections such as covid-19.

The paper also draws special attention to parents to keep the track of cognitive development of children during restricted mobility while covid-19 cases are rising or living in a new normal (post covid). Nutrition is important to ensure cognitive development for children's well-being in the new normal era of the Covid-19 pandemic. Papers from the year 1985 till 2022 (a few pioneer studies have been included as well from 1975, 1968) have been reviewed. Herein, a comprehensive and non-systematic search from the four databases was made (Scopus, Google Scholar, SciELO, and PubMed). A total of 321 manuscripts were considered for reading. Original data, review articles, national and regional perspectives, government websites and commentaries were included. 220 manuscripts were excluded as these papers were not related to children, covid-19 pandemic/upper respiratory infections, cognitive development, and nutrition. 101 manuscripts were included after reading the abstract and the entire manuscript. The section below discusses the relationship between cognitive development and nutrition.

## **I Cognitive Development and Nutrition**

Cognitive capabilities are defined as the set of higher mental functions superimposed by the brain which includes learning and memory, attention, perception etc. (Bhatnagar & Taneja, 2001). Cognitive development is an important milestone in younger children which could be predictive of school achievements later in life span (Tramontana, Hooper & Selzer, 1988; Clark, Pritchard & Woodward, 2010; Engle, 2010). Higher and successful

education has been linked to better job opportunities, higher socioeconomic status, nutrition, physical activity, and a better lifestyle (Florence, Asbridge & Veugelers, 2008). Therefore, it's important that special attention be given to the nutritional requirements of younger children for better and complete cognitive development. Nutrition is important for neurocognitive development such as cognitive neuronal tracks, DNA synthesis, and neurotransmitters important development markers in younger children's brain development (Bhatnagar & Taneja, 2001; Lozoff & Georgieff, 2006; Zimmermann, 2011). The brain develops rapidly at a younger age than the rest of the body because, at the age of 2, the brain reaches to 80% of the weight of the adult brain which makes nutrition very salient for younger children's cognitive and neurocognitive development (Benton, 2010; Bryan, Osendarp, Hughes, Calvaresi, Baghurst & Van Klinken, 2004; Lenroot & Giedd, 2006).

## **2 Importance of nutrition and cognitive development during and post covid-19**

A diet rich in nutrition helps children with their overall well-being and strength, and a healthy diet helps them to be active and explore the environment around them. Proper nutrition is also a key to a healthy immune system which may prevent obesity and the risk to develop chronic diseases. The human brain requires more energy than any other organ in the body (approximately 20% of the total diet intake). Children's brains are rapidly developing, children require good calorie intake for their developmental requirements. Many higher-order cognitive functioning such as memory, attentiveness, and learning is directly affected by the food that has been consumed. Healthy eating habits in children may yield long-term developmental benefits. Without a healthy diet, children might not be able to concentrate

better which is required for achieving the developmental milestone.

The review aims to highlight the importance of vitamins and micronutrients which can play an important role in activating the immune system to improve resistance to viral respiratory tract infections (RTI; covid-19 is one of those; Vlieg-Boerstra et al., 2022). The European food safety authority considered many vitamins and minerals important for the proper functioning of the immune system to be consumed in adequate amounts as a prevention shield for RTIs.

The current reviews present the importance of nutrients which have important boosting immune functioning for the prevention of RTI's and it's an important step to recognize these nutrients to be adapted in children's daily health diet consumption are listed and defined below.

### **2.1. Vitamin D3**

Vitamin D3, which is usually derived from UV radiation from the sun and from fortified foods such as milk and cereals, has an important role in elevating the metabolic absorption of calcium and phosphorus that results in healthy bones, especially for children in the early stages of bone development. Pneumonia is one of the leading causes of child death worldwide (Mancino, Cristiani, Pierangeli, Scagnolari, Nenna, Petrarca, et al., 2020). Some studies have identified that vitamin D helps to strengthen the immune system, and its deficiency may pose a significant risk for developing acute respiratory tract infections such as pneumonia (BourBour, Mirzaei Dahka, Gholamalizadeh, Akbari, Shadnoush, Haghghi & Taghvaye-Masoumi et al., 2020; Zhou, Luo & Qin, 2019; Panfili, Roversi, D'Argenio, Rossi, Cappa & Fintini, 2021). Recent intervention suggests that adequate levels of vitamin D could serve as a preventive measure against COVID-19 which is highly linked with respiratory tract infections (Panfili,

Roversi, D'Argenio, Rossi, Cappa & Fintini, 2021; Alipio, 2020). When children are living in the era of COVID-19 it is advisable to have vitamin D supplements in the diet, especially in countries where children have less exposure to sunlight. Research has identified vitamin D as a potential marker that stimulates the body's immune system response for the treatment or prevention of COVID-19, both in adults and children both (Panfili, Roversi, D'Argenio, Rossi, Cappa & Fintini, 2021). Children and adults who limit their exposure to sunlight should receive a daily supplement varying between 200 IU to 2,000 IU depending upon the Vitamin D concentration in serum which varies between 25 nmol/l to >100 nmol/l (Bouillon, 2017). Higher dosage can be recommended depending upon the concentration levels of Vitamin D3 in the serum.

## **1.2 Vitamin C**

Research has identified vitamin C as one of the vitamins that should be included in one's daily diet. It is abundant in many fruits and vegetables that are easily available and affordable. Regular consumption of vitamin C boosts immunity (Calder, Carr, Gombart & Eggersdorfer, 2020). When the body is fighting an infection, white blood cells (leucocytes) are released. During the acute stage of the infection, especially for viral infections, blood cells start to decrease in number. Patients suffering from COVID-19 with acute respiratory tract infections have benefited from high dosages of vitamin C administered intravenously (in China and the USA; Abobaker, Alzwi & Alraied, 2020). Higher dosages of vitamin C have been linked to decreasing viral multiplication (Abobaker, Alzwi & Alraied, 2020; White, Freeman, Forrester & Chappell, 1986), and they have also been helpful in creating defense mechanisms against any kind of viral infection such as Covid-19, especially in children (Abobaker, Alzwi & Alraied, 2020). A higher incidence of frequent illness has been reported as

soon as preschoolers start going to nursery. Adequate consumption of vitamin C could help reduce the frequency and the span of upper respiratory symptoms and common cold in children (3 months to 18 years; Vorilhon, Arpajou, Vaillant Roussel, Merlin, Pereira & Cabailot, 2019). Food/natural sources found to be rich in vitamin C are citrus fruits such as oranges, kiwi, lemon, strawberries and grapefruit, tomatoes and cruciferous vegetables and white potatoes (Forastiere, Pistelli, Sestini, Fortes, Renzoni & Rusconi, et al., 2000). Even a little consumption of vitamin C is helpful in subduing wheezing symptoms in children (Forastiere, Pistelli, Sestini, Fortes, Renzoni & Rusconi, et al., 2000) and should be tracked and advised by parents (Hemila, Kaprio, Pietinen, Albanes & Helnonen, 1999).

## **1.3 Iron**

Many studies have highlighted the role of iron in boosting immunity. Iron is easily available in foods like leafy green vegetables, fortified cereals, red meat, and rice (Baker, Greer, Bhatia, Abrams, Daniels & Schneider, 2010). The food sources having a higher content of iron are nuts and dried food, whole meal pasta and bread, legumes, oats and tofu (Adetola, Onabanjo & Stark, 2020).

Iron deficiency is highly associated with the incidence of respiratory tract infections, and individuals prone to prolonged periods of iron deficiency are more likely to be affected by viral infections. Research has identified that inadequate levels of iron in children of all ages increase the risk for malaria and other infectious diseases, such as pneumonia (Calder, Carr, Gombart & Eggersdorfer, 2020). A recent study in China has demonstrated that children with decreased levels of iron were more susceptible to respiratory tract infections (Boretti & Banik, 2020). The advised iron dosage for children aged between 1–3 years is about 7 mg/day (Baker,

Greer, Bhatia, Abrams, Daniels & Schneider, 2010). Many studies have also highlighted the importance of iron for neurodevelopment in animals. Iron is one of the important minerals that help in the metabolism of neurotransmitters, creating a myelin sheath over axons and aiding the development of memory functions, especially during the growing years of younger children (Georgieff, 2008; Carlson, Tkac, Magid, O'Connor, Andrews & Schallert, et al., 2009; Tran, Fretham, Carlson & Georgieff, 2009). An iron-enriched balanced diet is advised for children to ensure their neurocognitive development and a strong immune system against viral infections such as COVID-19. Poor eating habits might be compensated by taking iron supplements on advice from practitioners.

#### **2.4 Vitamin B12 and Folate**

Vitamin B12 is abundant in animal-based products such as milk, fish, eggs, cheese, and meat. Lower- to middle-income groups may have restricted access to such products, especially in developing countries. More vegetarians are identified to be affected by vitamin B12 deficiency due to their dietary restrictions. The daily recommended dosage ranges, but for preschoolers 1–3 years old, it is about 0.9 mcg/day (reported by Herbert, 1968). Vitamin B12 is very important for human brain cells to function adequately, and prolonged deficiency in adults could result in memory loss, digestive issues, muscular pains, and fatigue.

At birth, B12 deficiency among mothers may be inherited by infants. The deficiency may persist if the infant is exclusively breastfed for 6 months (Stabler, 2013; Dror & Allen, 2008). The main causes of vitamin B12 deficiency in expectant women are malabsorption and poor nutritional appetite. As brain imaging studies discuss, many permanent complications occur among younger children if this deficiency is not treated in the

early development years, mainly delayed onset of neuronal myelination and degeneration of neuronal cells (Dror & Allen, 2008; Honzik, Adamovicova, Smolka, Magner, Hrubá & Zeman, 2010). Other symptoms may include a delay in growth and development, tremors, anemia, lack of energy, irritability, epilepsy, feeding difficulties, lethargy, comas, ileal resections, Imerslund-Gräsbeck Syndrome, and inflammatory bowel disease (Stabler, 2013). Early identification of vitamin B12 deficiency in children is vital for achieving better prognoses; if delayed, permanent disabilities may result. Many younger children have fully recovered after receiving an appropriate dosage of vitamin B-12 in the form of supplements/injections, which are prescribed by a practitioner. Recently a link has been established between adaptive immunity and low levels of vitamin B12 deficiencies (Batista et al., 2022). Severe vitamin B12 deficiency can also increase the risk of getting affected by severe viral infections (such as covid-19) because of the deficiency human body does not develop the capacity to fight viral infections (Kulkarni, Kinikar, & Jadhav, 2020). Vitamin B12 has important role in antibody production and metabolism to fight against such infections (Molla, Uzun, Koç, Yeşil & Bayhan, 2021). When younger children are not vaccinated against covid-19 (vaccination for younger children is still in process) then such deficiencies could be fatal. Parents should have early maternal screenings to ensure adequate brain-cell development right from conception and should pursue an infant screening soon after birth. During a time of viral infection such as covid-19, a diet rich in vitamin B12 is advised especially having vegetarian roots. It is also important that children having B12 deficiency should be taking supplements, especially during the time of covid-19 as guided by physicians.

#### **2.5 Zinc**

Zinc has been identified as one of the important micronutrients due to its antiviral properties which help in reducing the upper respiratory symptoms caused by Covid-19 infections (International Zinc Nutrition Consultative Group, 2004; Ekemen Keleş et al., 2022). An adequate amount of zinc has also been associated with adequate growth patterns in children, boosting immunity and strengthening the neurological development of children (Samad et al., 2021). Zinc is mainly found in the liver and muscles (intracellular) and slight variation in the peripheral organs may drastically affect the overall concentration. Metabolic changes in the human body are greatly associated with serum zinc levels. Studies have also reported that zinc is also helpful to inhibit the replication of SARS-CoV, hepatitis C virus, and even influenza (Suara & Crowe, 2004; Butterworth & Korant, 1974; Razzaque, 2020). Studies have also shown that children diagnosed with acute pneumonia (form of RTI's) were found to have lower zinc levels (Kumar, Jayaprakash & Kavitha, 2017) and lower zinc levels have been linked with sepsis and even death (Saleh, Abo El Fotoh, 2018). In another study children affected with acute RTI's were diagnosed with low serum zinc levels compared with children showing milder to moderate symptoms (Ibraheem, Johnson, Abdulkarim & Biliaminu, 2014; Nascimento Marreiro et al., 2022) and were affected more with Covid-19 infections (Wessels, Rolles, Slusarenko & Rink, 2022). 15 days recommended dosage for children younger than 6 months is 10 mg/day and 20 mg/day is for children older than 6 months (Santos, 2022) when children dealing with Covid-19 symptoms. The daily recommended dosage 5 mg/day for children below the age of 5 years, and 10 mg/day for children older than 5 years, which may also range from 20 to 25 mg/d as directed by a physician (Salgueiro, Zubillaga, Lysionek, Caro, Weill & Boccio, 2022). Red meat is to be recommended as a good source of zinc and maize, wheat cereal, wheat germ,

whole wheat bread, whole-wheat pasta, wild rice, refried beans, garbanzo beans, green beans, peas, soy-based meat substitute, peanut butter, sunflower seeds, pecans, and cashews are found to have the richer amount of zinc (Sandstead & Freeland-Graves, 2014; Gibson, Heath & Szymlek-Gay, 2014).

### 3 Discussion

Many studies have reported the importance of nutritional status associated with cognitive development of children especially in the early years. Children suffering from mild to severe nutritional deficiencies may have low body mass index (BMI) for their height and could reflect less performance than age matched normally nourished children (Dobbing, 1987; Simeon & Grantham-McGregor, 1990).

Iron deficiency (anemia) is commonly occurring in younger children, its occurrence rates may reach up to 50% in underdeveloped countries associated with poverty, parasitic infections and malnutrition-related diseases (DeMaeyer & Adiels-Tegman, 1985). Children have shown overall low developmental scores than those with accepted or mild deficiency values (Lozoff, Jimenez & Wolf, 1991; Walter, 1993; Simeon & Grantham-McGregor, 1990), iron food supplements is a must for children's long term developmental index. The relationship between anemia and susceptibility rates in children are under investigation because human immunity which is driven by a community plays an important role (Oppenheimer, 2001; Mertens & Peñalvo, 2021). It is recommended that; adequate intake of iron may ensure long term developmental benefits for children while living in the environment of highly contagious diseases such as covid-19.

Many studies have identified the role of vitamin B12 and folate important for children cognitive development (Louwman et al, 2000) and even a

milder form of deficiency may have a huge impact (Refsum et al., 2001). Vitamin B 12 is mainly found in animal products, and this could be the reason why this deficiency has been found in abundance in Indonesians and Indians (Setiawan, Giraud & Driskell, 2000; Refsum et al., 2001). Vitamin B folate (B12 and B6) share the same similar metabolic properties and may have a compromised development of central nervous system (CNS). B vitamins folate, B12, and B6 share a metabolic pathway that might have acute and long-term effects on the CNS. Therefore, B vitamins are important for cognitive development and performance especially during childhood. Vitamin B family is important for regulating inflammation when body is fighting infections such as covid-19 (Suardi, Cazzaniga, Graci, Dongo & Palestini, 2021). The vitamins regulate the production of antibodies for maintaining innate immunity while body is fighting infections (Maggini, Pierre & Calder, 2018). It is advised that parents should consider a rich diet in B vitamins for the acceleration of active immunity for fighting such diseases in children and vegetarians should have a special focus on food enriched such as eggs, cheese, butter and milk products (Haryanto, Suksmasari, Wintergerst & Maggini, 2015; Watanabe, Yabuta, Tanioka & Bito, 2013).

Vitamin D3 has also proven to be important for the regulation of neuronal growth patterns in children for cognitive health. The vitamin is crucial for brain development in early years and the genesis of autism spectrum disorder (Staal, 2016) and also important for the expression of the nerve growth factor in children's genes and development of glial cells (Chabas et al., 2013). It has also been reported that, Vitamin D is involved in genes expression and it's also important for the calcium and phosphate metabolism required for pathological and physiological processes (Autier, Boniol, Pizot & Mullie, 2014). This further explains that vitamin

D plays a critical role in maintaining mental health and its suboptimal level (less than 25(OH) in serum) may be predictive of underdevelopment cognitive development (McCann & Ames, 2008). Fostering the levels may be predictive of good mental and bone and joint development in children (Föcker et al., 2017). Vitamin D may be helpful in establishing protective immunity against RTT's in children and intake of required supplements may reduce the severity of the infection (Doğan et al., 2022). Vitamin D and Zinc levels were found to be lower in children contracted with Covid-19 pandemic (Elham et al., 2021). Deficient levels of these serum may cause a disruption in mucosal epithelial cells making individuals more vulnerable for contracting covid-19 (Tezer & Demirdağ, 2020). Some studies have shown that children showed milder symptoms for covid -19 than adults (Henry, Lippi & Plebani, 2020; Dufort et al., 2020 ). It is important to maintain a healthy lifestyle and dietary habits to boost individuals' immunity to fight against such infections (Urashima et al., 2010). It is advised that parents should provide a good exposure to sunlight to their children in the morning times for a good absorption of Vitamin D and to maintain the daily recommended dosage for children better immunity and cognitive development during and post covid -19 pandemic.

Zinc micronutrient is found in abundance in human body and it's important for the imputation of many metabolic pathways (Prasad, 2014). Zinc plays a dominant role in boosting immune system and the normal functioning of brain (Prasad, 2014). Zinc is the most pervasive metal ions found in human brain for the regulation of neurogenesis, neuronal activation and information processing and therefore, regulating cognitive and adequate brain functioning (Levenson & Morris, 2011). Few studies have shown that, changes in the zinc concentration has been intricately with different types of neuropsychiatric and neurodevelopment

disorders such as autism spectrum disorder and reading problems in children and Parkinson (Sensi, Granzotto, Siotto & Squitti, 2018; Sun, Liu, Ge, Wang, Wang & Li, 2017), alzahimers and mood disorders in adults (Sensi, Granzotto, Siotto & Squitti, 2018; Swardfager et al., 2013) and also cause neuronal brain damaged corresponding traumatic brain injury, stroke and seizures (Zhao et al., 2018). As per the World Health Organization (WHO) guidelines, zinc deficiency is the fifth leading cause of prevalence related to mortality in developing countries (WHO, 2002). To understand the role of zinc in SARS-CoV-2 is being studied intensively and people getting affected may temporarily lose the sensation of taste and smell for weeks studies also suggest that, zinc could be supplement for protecting from worsening covid and post covid symptoms (Gombart, Pierre & Maggini, 2020; Chavakis, May, Preissner & Kanse, 1999; Prasad, 2000; Foster & Samman, 2012). Zinc is also helpful in maintaining the correct balance and immune system and to reduce the illness caused by RTI's and Covid-19 pandemic. It is also advised to have supplements to reduce the RTI;s and other viral infections and to reduce the event of worsen the symptoms, especially for critically ill patients, elderly population and children (Cereda et al., 2022).

Vitamin C is considered as immunity supportive micronutrient and deficiency could result in severe upper respiratory contraction. The concentration levels is highly dependent upon the timing, doses and rout of administration. The deficiency of vitamin C could be considered as  $<23 \mu\text{mol/L}$  is common in the current times specially in the western world (Tveden-Nyborg & Lykkesfeldt, 2009; Lykkesfeldt, 2006). Vitamin C has been found crucial for fetus development and umbilical cord plasma. There are some cases reported when children suffering from vitamin C deficiency could face many challenges related to cognitive development in the early ages

(Villalpando et al., 2003). Inadequate levels of vitamin C may result in scurvy, a potentially fatal disease that is marked by bleeding swollen gums, prostration and livid spots.

In fact, the role of vitamin C deficiency and its effect on children brain or cognitive development has not been clearly defined in the literature. The role of vitamin C also excluding from other micronutrients as defined above is crucial. Vitamin C daily recommended dosage is 25mg for children between 1-3 years and 25 mg for children between 4-8 years. Since vitamin C plays an important role in boosting the immunity, so the daily dosage may change if the child has contracted upper respiratory diseases, viral infection, and pneumonia (Hemilä & Louhiala, 2013). Vitamin C is also helpful in decreasing the symptoms such as fatigue and pain when contracted with viral infection such as covid-19 (Vollbracht & Kraft, 2021). It is advised for the parents to provide a fresh and diet enriched in vitamin C including fruits and vegetables for developing immunity to fight against many viral infections and even covid-19.

#### **4 Conclusions**

It is advised for the parents to keep the track of cognitive development and nutritional requirements of the children on daily basis. It is important that the diet should be enriched with fresh fruits, vegetables eggs, milk, meats, and fish and variety or fruits and veggies to be consumed on daily basis (at least 5 varieties/day). If children are maintaining a vegetarian diet, then it's even more important that the subsite vegetarian food item should be added in their daily diet. It is also recommended to make six monthly visits to track the overall development of the children at least till the age of 5. Due to the limited amount of sun exposure, it is important that vitamin D supplements should be given on regular basis, especially in the countries where sunshine is limited. In India, younger children are massaged



at about 8:am in the sunshine, the ritual has a scientific reason because at that time maximum amount of Vitamin D3 can be absorbed by the body. If the child has a very healthy diet, then still it's not necessary that all the vitamins, minerals and micronutrients are absorbed, the absorption rate might be related less and still there are chances that the children is suffering from deficiency. Therefore, it is important that the levels of vitamins and micronutrients should be tested on six monthly or yearly basis. If children lack certain types of vitamins or micronutrients, then supplements should be given as per the direction of the practitioner.

Since children below 5 years are not vaccinated against covid-19, other vaccines should be provided timely basis as per the country's medical norms. A balanced diet is helpful in appropriate cognitive growth and development, especially in the younger years of development. In the future, many waves of covid-19 will be witnessed, and the frequency of the infection may change over the course of time. The advice suggested in the paper would be beneficial for the parents to raise their children in the ear of any upper respiratory symptoms such as covid-19 and even after.

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