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The Role of Iodine During Pregnancy and Its Consequences on Neonatal Thyroid Hormones - A Review

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Abstract
Deficiency of Iodine has numerous adverse effects in humans, known as iodine deficiency disorders, due to inadequate thyroid hormone production. Globally about 2 billion people are affected by iodine deficiency and the most visible sign is endemic goiter resulting in brain damage causing mental retardation, reduced somatic growth and motor function in children. Environmental factors that interfere with the thyroid metabolism play an important role in causation of autoimmune thyroid diseases and the knowledge of these factors influencing thyroid dysfunction can help in understanding and interpreting the results of such studies in a better way. Assessment of iodine include urinary iodine concentration, goiter, newborn TSH, and blood thyroglobulin. Iodine status in pregnancy remains unclear whether iodine intakes are adequate, leading to calls for supplementation of iodine during pregnancy. In most countries, the strategy applied to control iodine deficiency in populations, is monitored carefully by universal salt iodization, the most cost effective ways to contribute to social and economic development. Hence, optimal intake and knowledge of iodine may minimize the amount of thyroid dysfunction in vulnerable populations. This review was an attempt made to summarize the current knowledge on iodine status and its importance during pregnancy.

Keywords
Dietary supplements; Iodine; Infants, Newborn; Pregnancy; Sodium chloride, Dietary; Thyroid hormones.

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INTRODUCTION
Pregnancy phase involves numerous hormonal and metabolic changes. Progression of gestation requires increased output of hormones by the maternal thyroid gland on reaching equilibrium [1]. Security of food and nutrition is a fundamental right at both individual and population level leading to the progress and development of a society and nation. Deficiencies of iodine, iron, folic acid, vitamin A and zinc are the leading five causes of micronutrient deficiencies which comprises a global public health problem [2]. Majority of the neural processes linked to the nutrients have been studied in human as well as animals for its consequences and prevention [3]. Severe iodine deficiency, causes both maternal and fetal hypothyroidism. Adequate supplementation of iodine given during early pregnancy prevents maternal and neonatal goitrogenesis. Therefore,

present review summarizes the insight of iodine and its association with the maternal and neonatal thyroid functioning.

METHODS

A literature review was carried out of studies involving the iodine status during pregnancy and its impact on neonatal thyroid functioning, along with the dietary factors contributing and affecting the iodine status. To identify the articles keyword-based search strategy was adapted and applied to several widely used internet search engines, to the MEDLINE database. There was no restriction in date. It was further improved by a hand-search of reference lists of selected articles.

PREVALENCE OF IDD

Despite improvement in iodine intake globally, 1.88 billion people of the global population are estimated to have insufficient intake of iodine. About 41 million newborns a year remain vulnerable from the enduring consequences of brain damage coupled with iodine deficiency. However, only restricted number of countries has completed urinary iodine concentration (UIC) surveys in pregnant women and women of reproductive age at national or sub-national level and thus, there is lack of data to estimate the regional or global prevalence of low iodine intake in these important target groups. In India, the population at risk of iodine deficiency disorder (IDD) due to insufficient iodine intake is as shown in Table 1. The USI remains the only and the most important source of dietary iodine for the Indian population. The WHO Global database on iodine deficiency reported median UIC (mUIC) in children in Bengaluru urban was 185 µg/l [4]. However, there is limited data on the mUIC concerned with pregnant mothers and their neonates.

As per the surveys conducted by Indian council of Medical Research (ICMR), Central and State Health Directorates and Medical Institutes from 1950s have demonstrated that IDD is public health problem in all the states and union territories in India. In India among 325 districts surveyed, 263 districts are IDD endemic, which states that IDD prevalence was above 10% in the population whereas in pregnant women the prevalence of IDD was 22.9% and 9.5% in Delhi and Himachal Pradesh respectively [5]. In India, household access to iodized salt is 92% among whom 71% consumed adequately iodized salt the other 9% consumed salt with no iodine. Wide regional variations with urban areas being 83.2% and rural 66.1% was observed. Variations among different states like Chhattisgarh (31.6%), Karnataka (35.5%) and Jharkhand (41.4%) coming under low coverage states while Manipur (98.3%), Meghalaya (98%) and Nagaland (97.1%) being high coverage States was reported [6].

IODINE REQUIREMENTS

FAO/WHO has recommended sufficient amount of iodine in-order to prevent the brain damage or thyroid function disorders which is caused due to deficiency of iodine during pregnancy, lactation and the first two years of life. The recommendation by the WHO for adequate daily iodine intake for men and women (non-pregnant and non-lactating) is 150 µg/d and 250 µg/d for pregnant and lactating women, [7]. In the early 1980s based on median breast milk iodine concentration the iodine intake for infants recommended by WHO is 90 µg/d. In children aged between 1.5-2.5 years the median iodine intake was 63.5 µg /d. Due to lack of studies on assessing iodine requirements for young children between 1–8years an estimated average intake of 65 µg/d was set [8]. WHO recommends 90 µg and 120 µg of iodine per day for preschool children aged between 0-59 months and for school children aged between 6-12 years respectively (Table 2) [7].

ROLE OF IODINE IN THE BODY

Iodine is very necessary for the production of thyroid hormones. It is absorbed completely in the stomach and duodenum. The iodate in the iodized salt, is reduced to iodide in the gut and about more than 90% is absorbed in healthy individual. The clearance of iodine from circulation is by thyroid varies with iodine intake and it is constant by kidney. Around 15-20 mg of iodine is in the thyroid of healthy adult body. During chronic iodine deficiency the iodine content of thyroid fall below 20 µg, but in iodine sufficient areas approximately 60 µg of iodine is trapped by the thyroid per day in-order to balance the losses and maintain thyroid hormone synthesis. The half-life of plasma iodine in the blood is approximately 10hours, but it is shortened during conditions like hyperthyroidism or iodine deficiency [9]. The mammary gland secretes iodine which is concentrated in the breast milk for the new born during lactation. The thyroidal adaptations to low dietary iodine intake is modified by triggering the increased secretion of thyroid stimulating hormone (TSH) by the pituitary. If iodine intake falls around 100 µg/d, TSH secretion is increased due to which plasma inorganic iodide clearance increases by thyroid through stimulation of sodium iodine symporter expression [10]. In children and adults with moderate to severe iodine deficiency the circulating pattern of thyroid hormones comprises of elevated TSH, low serum thyroxine (T4) and normal or high normal tri-iodothyronine (T3) [11]. It remains largely unclear, that variability in the countenance in

deficiency of iodine from one locality to another is accounted by the diet, environment or the genetic factors which needs exploration [12].

DIETARY SOURCES AND INHIBITORS OF IODINE

Most foods and beverages have low native iodine content. The commonly consumed foods provide 3-80 µg of iodine per serving. Marine plants and animals have high iodine content as these marine sources concentrate iodine from seawater. Most of the countries use iodized salt for cooking and at the table which accounts for additional iodine. Iodine loss is minimized by boiling, baking and canning method [13]. The amount of iodine in food is influenced by iodine containing compounds used in livestock feed, irrigation and fertilizers. The native iodine content in dairy products increases by the use of iodophores in cleaning milk cans and teats, erythrosine widely used in foods, pharmaceuticals and cosmetics a red coloring agent has high amount of iodine. Water purifying tablets, medicines and skin disinfectants are some of the other sources of iodine [8].

Goiterogens, are the dietary substances that interfere with the thyroid metabolism and augment the effect of iodine deficiency. Cruciferous vegetables which include cauliflower, cabbage, broccoli, turnips, kale contain glucosinolate, correspondingly cassava, lima beans, linseed, sorghum and sweet potato contain cyanogenic glucosides which may be metabolized to thiocyanates, compete with iodine for thyroid uptake [12]. Groundnut were also reported to be goitrogenic. Smoking is also associated with higher serum levels of thiocyanates which may compete with iodine uptake and reduced iodine levels in breast milk. The flavonoids present in soy and millets may impair TPO activity and use of soy based products without added iodine can produce goiter and hypothyroidism in infants [14]. The deficiency of vitamin A, selenium and iron can aggravate the iodine deficiency. Deficiency of iron reduces heme-dependent TPO activity in thyroid and impairs thyroid hormone production. Children with goiter having iron deficiency anemia reduces the efficacy of iodine prophylaxis where the supplementation of iron improve the efficiency of iodized salt and iodized oil [12]. In areas of borderline iodine deficiency, pregnant women are highly vulnerable to iron deficiency anemia and poor maternal iron status predicts both higher TSH and lower T_4 concentrations [15]. The composition of dietary fat influences the secretion of TSH, hepatic deiodinase activity, thyroid peroxidase (TPO) activity and T3 binding to nuclear receptors. Dietary high fat lard intake induced thyroid dysfunction with increase triglyceride levels, decreased total T4 and free thyroxine (fT4) levels along with increased serum TSH levels in male Wistar rats. Consumption of green tea at high doses can impair thyroid function by decreasing T3, T4, TPO and deiodinase activity and increase TSH levels, in rats fed with green tea extract [14].

IMPORTANCE OF IODINE AND THYROID FUNCTION DURING PREGNANCY

A key component of thyroid is iodine which is very essential for healthy growth, development of the offspring's during pregnancy. In addition, an adequate level of iodine during pregnancy is essential for fetal neurodevelopment and mild iodine deficiency is associated with developmental impairments [16].

Iodine deficiency during pregnancy produces an increase in prenatal mortality and low birth weight which can be prevented by providing supplementation to the mothers in latter half of pregnancy (Fig.1). Many epidemiological studies have reported that hypothyroxinemia, during early gestation, affects the neurological development of the new born in the long term. Other full-scale clinical studies have confirmed a connection between maternal thyroid insufficiency during gestation and low neuropsychological development in neonate. The most severe neurologic injury resulting from thyroid deficiency is endemic cretinism initiated by iodine deficiency. Study conducted by Zhang et al. reported that supplement of iodine during early stage of pregnancy could improve migration of the cell cerebral cortex and neurodevelopment of offspring, [16]. Sukkhojaiwaratkul et al. recorded that maternal iodine supplementation improved iodine nutrition in their breastfed infants. Improvement of iodine status during pregnancy was indicated by the trend toward declining in cord serum TSH values after iodine supplementation [17]. The study by Pretell, confirmed that at delivery the maternal and cord T4 values in the iodine deficient group were significantly lower than the normal. A direct relationship between the severity of iodine deficiency, as established by the urinary iodine excretion, and the T4 values was demonstrated in both mother and fetus [18].

Study conducted in Belgian pregnant women had shown that the serum TSH concentrations increased progressively in more than 80% pregnant mothers caused by increased concentrations of human chorionic gonadotropin (hCG), although these levels also remain within the normal range, it is accompanied by increase serum Tg which is in-turn directly related to increase in TSH. Therefore, this situation of chronic thyroid hyper-stimulation increases the thyroid volume by 20-30% during

gestation which is twice high in conditions of normal iodine supply. Limited data is available on thyroid function during pregnancy in populations with severe iodine deficiency [19].

CONSEQUENCES OF IODINE INSUFFICIENCY AND EXCESS

Deficiency of iodine being one of the most important factors where at least 200 million children aged less than 5 years fails to reach their potential in cognitive and socio-emotional development along with other causes [17]. However, there is no data on mortality or cognition from mild to moderate iodine deficient and iodine sufficient regions. Longitudinal studies measuring TSH levels and levels of both free thyroid hormones in pregnant and non-pregnant women from areas where iodine intake is adequate are limited and usually include a small number of participants, and they rarely include data on UIC [20]. The acceptable upper limit of iodine intake is controversial. Approximately until 36 weeks of gestation fetal thyroid does not acquire the capacity to suppress the acute Wolff-Chaikoff effect. Hence excess intake of maternal iodine nutrition could potentially cause congenital hypothyroidism [21]. In one of the study conducted by Nohr found that supplementation of iodine could cause TSH of cord blood to be 27.3% during pregnancy than those without iodine supplementation, and concluded that fetal thyroid is more sensitive to the hampering effect of iodine than is usually predicted [22]. Pregnant females from a region with high mUIC and high supplement coverage showed lowest levels of serum-fT4. More than adequate or excess levels of iodine are considered unsafe especially in susceptible populations like the elderly, fetuses and neonates with recurring thyroid disease.

THYROID HORMONES AND DEVELOPMENT OF FETAL BRAIN

For normal growth and development of the brain and central nervous system, thyroid hormones utilize iodine for their production. In early fetal development there is absence of nuclear receptors for thyroid hormones in the brain. The first stage of neurodevelopment relying on thyroid hormone depends on maternal fT4 and begins in the second half of first trimester. The fetal thyroid begins to produce hormones in the beginning of the second trimester. As gestation progresses the concentration of T4 in the fetus increases, since the gland does not fully mature until birth the reserves of fetal gland are low. Therefore, until birth the total fetal thyroid hormones are supplied by maternal thyroid hormones. Unsurprisingly low fT4 occurs in premature babies as they rundown the maternal supply which may cause developmental delay. Lack of dietary iodine causes the mother to be iodine deficient, and consequently the fetus, causing the mother to be euthyroid and fetus becoming hypothyroid with decreased synthesis and secretion of T4 and T3, and an increase in TSH concentration. Zoeller and Rovet suggested that initially in pregnancy, decreased thyroid hormones may cause problems in visual attention, processing, and gross motor skills, whereas lack of thyroid hormones in later stage of pregnancy results in added problems associated with visual skills, slower processing speeds, and fine motor skills. Therefore, these observational studies provide evidence that variation in maternal thyroid hormones influence normal development of brain. Further investigations are warranted, whether similar findings would occur in women with healthy thyroids who are iodine deficient. In conclusion, it is evident that low concentrations of maternal T4 can delay the fetal brain development [23].

IMPORTANCE AND CONSEQUENCES OF IODINE DEFICIENCY IN FETUS

Approximately 50% increase in maternal iodine requirements during pregnancy, is drawn from the significant iodine stores. Pathological changes such as goiter and hypothyroidism may be observed when little thyroidal iodine is drawn in-order to meet the increased iodine requirement which will adversely affect the maternal and fetal health [12].

Effects of mild-moderate iodine deficiency in mothers also have its repercussion on the fetus causing abnormalities in physical and intellectual development. There is limited data on the controlled trials of iodine treatment in mild-to-moderately iodine deficient pregnant mothers on infant or child development. Nevertheless, many measures are reported including maternal and newborn thyroid function as alternate markers of future infant brain development. In conditions of mild iodine deficiency, the serum fT4 concentrations decrease steadily and significantly during gestation whereas in case of neonate serum TSH concentrations and Tg were higher, this indicates that neonates are more sensitive than adults to the effects of iodine deficiency [24].

INDICATORS FOR THE ASSESSMENT OF IODINE STATUS

There are numerous accepted methods used in monitoring the iodine sufficiency in population. Median spot UIC, a biomarker for dietary iodine reflect intake of iodine of recent few days. Most of the iodine which is consumed is absorbed by the body and eventually gets excreted in the urine with some loss through feces. Though the concentration of urine of every individual vary every day, yet spot

or casual urine sample has been shown to be reliable biochemical marker of recent dietary intake. Hence due to this reason it was proposed that mUIC was the best indicator to assess iodine nutrition of pregnant, lactating women and young children less than 2-years-old in population surveys. Conversely, more studies are needed to support this statement. Additionally, this indicator should not be used for the purpose of individual diagnosis and treatment. The low median UIC indicates that the population is at the risk of developing thyroid disorder. The size of the thyroid reflects iodine nutrition over months or years and it can be determined through inspection and palpitation or to be more precise about the thyroid size ultrasonography is the objective method [25].

Blood constituents like the TSH and Tg serve as close observation for iodine nutrition. Deficiency of iodine lowers the circulating T4 and raises the serum TSH; hence the population with deficiency of iodine has high serum TSH concentrations than those with sufficient iodine. In neonates TSH is a valuable indicator of iodine deficiency. The TSH levels are elevated in iodine deficient population for the initial few weeks of life and this phenomenon is referred to as transient hyperthyrotopinemia [26]. TSH reference range is critical for diagnosis and treatment, hence the guidelines of American thyroid association in 2011 proposed and recommended the "Trimester-specific reference ranges: first trimester 0.1–2.5 mIU/L; second trimester 0.2–3.0 mIU/L; third trimester 0.3–3.0 mIU/L" [27].

STRATAGEMS TO PREVENT OR CORRECT THE DEFICIENCY OF IODINE

Optimal and sustained iodine nutrition especially during pregnancy and early childhood is essential for optimal maternal and child health (MCH). The primary strategy for all countries for elimination of deficiency of iodine in pregnancy remains USI. To address IDD, USI has been accepted globally as the main strategy and was endorsed by WHO/UNICEF in 1994. WHO/UNICEF/ICCIDD recommends that iodine is added at a level of 20–40 mg iodine/kg salt, depending on local salt intake [7]. Salt iodization remains the most cost-effective method of delivering iodine and improving cognition in populations with iodine deficiency. It has also been shown to improve the IQ of children born in iodine-deficient regions. A study from the Terai region of Uttar Pradesh reported the IQ of school children improved after the initiation of salt iodization program [28]. A recent estimate suggests that a one-point IQ improvement contributes to 0.11% growth in gross domestic product (GDP) at the national level. And hence, elimination of IDD, with an improvement of 13.5 IQ points, can potentially contribute to 1.5% growth in GDP [29].

Control of IDD has been a public health success story in India in 1962, and India was the first countries to launch the National Goiter Control Programme (NGCP) which was renamed as National Iodine Deficiency Disorders Control Programme (NIDDCP) in 1992. Improvement in iodine nutrition among pregnant women and children will improve the cognitive potential of millions of children, thus by improving our intellectual and financial productivity. The up-scaling and mainstreaming of IDD as a critical component of the MCH Programme will not only strengthen implementation of the NIDDCP Programme at the national and state levels but also lead to improvements in MCH [30].

Table 1: Estimated Burden of Pregnant Mothers and the Infants of Indian Population at Risk of IDD [2].

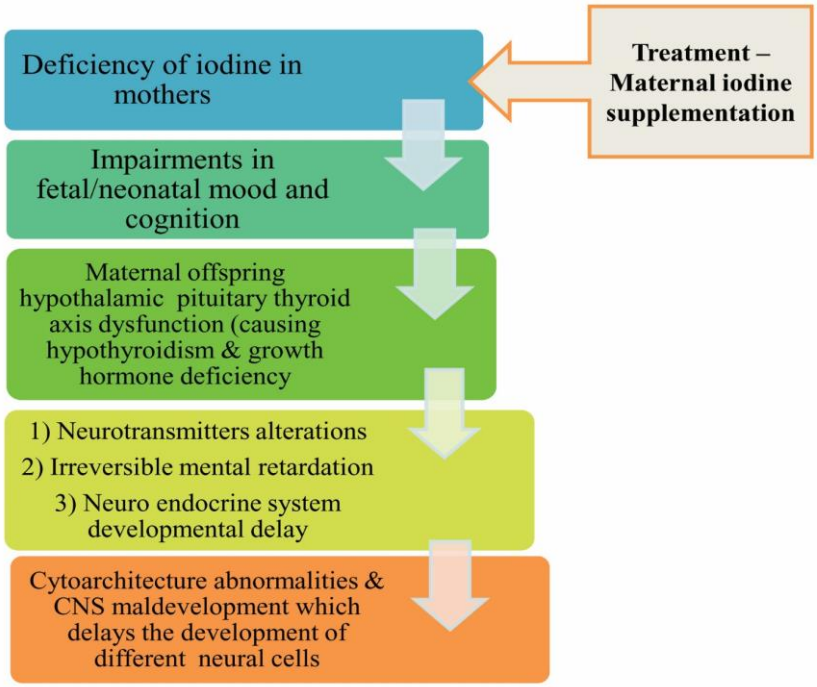
	Urban	Rural	Total	Unit
Total population	363.1	847.1	1210.2	millions
Infant population	6.5	19.5	26.1	millions
No. of pregnant females	7.4	22.7	30.4	millions
No. of newborn at risk of IDD	1.1	7.0	8.0	millions
No. of infants at risk of IDD	1.1	6.6	7.6	millions
No. of pregnant females at risk of IDD	1.2	7.7	8.8	millions

Table 2: Based on the Median or Range of UI Epidemiological Criteria from the WHO for the Assessment of Iodine Nutrition in a Population [7].

UI (µg /liter)	Iodine intake	Iodine nutrition
School-aged children		
<20	Insufficient	Severe iodine deficiency
20-49	Insufficient	Moderate iodine deficiency
50-99	Insufficient	Mild iodine deficiency
100-199	Adequate	Optimum

200-299	More than adequate	Risk of iodine-induce hyperthyroidism in susceptible groups
>300	Excessive	Risk of adverse health consequences (iodine-induced hyperthyroidism, autoimmune thyroid disease)
Pregnant women	Insufficient	
<150	Adequate	
150-249	More than	
250-499	adequate	
≥500	Excessive	
Lactating women		
<100	Insufficient	
≥ 100	Adequate	
Children less than 2years of age		
<100	Insufficient	
≥ 100	Adequate	

Fig. 1. Schematic diagram of the interaction between the maternal iodine deficiency and CNS development [17].



CONCLUSION

Severe iodine deficiency during pregnancy causes cretinism and mental retardation. When iodine nutrition levels are sufficient, physiological adaptation takes place, when deficient pathological alterations occur. Even mild deficiency of iodine may be related with risk of overt and subclinical hypothyroidism, as well as autoimmune thyroiditis. To help control thyroid disorders, compared with clinical diagnosis and treatment, the iodine prophylaxis with periodic monitoring is an enormous cost-effective approach. If iodine prophylaxis programs are carefully monitored for both deficiency and excess of iodine the consequences affecting one third of the global population can be prevented.

CONFLICTS OF INTEREST

No potential conflict of interest relevant to this article was reported.

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REFERENCE:

1) Glinoer D., Pregnancy and iodine. Thyroid, 11(5): 471-481, (2001)
2) Pandav C.S., Yadav K., Srivastava R., Pandav R., Karmarkar M.G., Iodine deficiency disorders (IDD) control in India. The Indian journal of medical research, 138 (3):418, (2013)
3) Prado E.L. & Dewey K.G., Nutrition and brain development in early life. Nutrition reviews, 72(4): 267-284, (2014)
4) Dorea J.G., Iodine nutrition and breast feeding. Journal of Trace Elements in Medicine and Biology, 16(4): 207-220, (2002)
5) Jaikrishna N., Effect of iodine supplementation in Indian pregnant women on maternal and newborn thyroid function and cognitive development. Wageningen University 2015.
6) Harsha KR, Across India, women are iodine sufficient.
7) World Health Organization, United Nations Children's Fund, International Council for the Control of Iodine Deficiency Disorders. Assessment of iodine deficiency disorders and monitoring their elimination. 3rd ed. Geneva: WHO, 2007.
8) Trumbo P., Yates A.A., Schlicker S., & Poos M., Dietary reference intakes: vitamin A, vitamin K, arsenic, boron, chromium, copper, iodine, iron, manganese, molybdenum, nickel, silicon, vanadium, and zinc. Journal of the Academy of Nutrition and Dietetics, 101(3): 294, (2001)
9) De Groot L.J., Kinetic analysis of iodine metabolism. J. Clin. Endocrinol. Metab. 26:149–173, (1966)
10) Taki K., Kogai T., Kanamoto Y., Hershman J.M., Brent G.A., A thyroid-specific far-upstream enhancer in the human sodium/iodide symporter gene requires Pax-8 binding and cyclic adenosine 3′, 5′-monophosphate response element- like sequence binding proteins for full activity and is differentially regulated in normal and thyroid cancer cells. Mol. Endocrinol, 16: 2266–2282, (2002)
11) Delange F., Camus M., Ermans A.M., Circulating thyroid hormones in endemic goiter. J. Clin. Endocrinol. Metab, 34: 891–895, (1972)
12) Zimmerman B.M., Iodine deficiency Endocrine Reviews. 30(4): 376–408, (2009)
13) Chavasit V., Malaivongse P., Judprasong K., Study on stability of iodine in iodated salt by use of different cooking model conditions. J. Food. Comp. Anal, 15: 265–276, (2002)
14) Bajaj J.K., Salwan P. & Salwan S., Various Possible Toxicants Involved in Thyroid Dysfunction: A Review. Journal of clinical and diagnostic research, JCDR, 10(1), FE01–FE3, (2016). doi:10.7860/JCDR/2016/15195.7092
15) Zimmermann M.B., Burgi H., Hurrell R.F., Iron deficiency predicts poor maternal thyroid status during pregnancy. J. Clin. Endocrinol. Metab, 92: 3436–3440, (2007)
16) Zhang Y., Fan Y., Yu X., Wang X., Bao S., Li J., et. al. Maternal subclinical hypothyroidism impairs neurodevelopment in rat offspring by inhibiting the CREB signaling pathway. Molecular neurobiology, 52 (1): 432-41, (2015)
17) Wu G., Imhoff-Kunsch B., Girard A.W., Biological mechanisms for nutritional regulation of maternal health and fetal development. Pediatric and perinatal epidemiology, 26: 4-26, (2012)
18) Liberman C.S., Pino S.C., Fang S.L., Braverman L.E., Emerson C.H., Circulating iodide concentrations during and after pregnancy. Journal of Clinical Endocrinology and Metabolism, 83: 3545 –9, (1998)
19) Delange F., Iodine deficiency as a cause of brain damage, (2001)
20) European Thyroid Association. Annual Meeting of the European Thyroid Association. Masson; (1987).
21) Nøhr S.B., Laurberg P., Opposite variations in maternal and neonatal thyroid function induced by iodine supplementation during pregnancy. The Journal of Clinical Endocrinology & Metabolism, 85(2): 623-627, (2000)
22) Sun X., Shan Z., Teng W., Effects of increased iodine intake on thyroid disorders. Endocrinology and Metabolism, 29(3): 240-247, (2014)
23) Skeaff S.A., Iodine deficiency in pregnancy: the effect on neurodevelopment in the child. Nutrients, 3(2): 265-273, (2011)
24) Glinoer D., The regulation of thyroid function in pregnancy: pathways of endocrine adaptation from physiology to pathology. Endocrine reviews, 18(3): 404-433, (1997)
25) World Health Organization. Assessment of iodine deficiency disorders and monitoring their elimination: a guide for programme managers. 2007.
26) Williams F.L., Mires G.J., Barnett C., Ogston S.A., van Toor H., Visser T.J., Hume R. and with collaboration from the Scottish Preterm Thyroid Group. Transient hypothyroxinemia in preterm infants: the role of cord sera thyroid hormone levels adjusted for prenatal and intrapartum factors. The Journal of Clinical Endocrinology & Metabolism, 90(8), 4599-4606, (2005)
27) Li C., Shan Z., Mao J., Wang W., Xie X., Zhou W., *et al*., Assessment of thyroid function during first-trimester pregnancy: what is the rational upper limit of serum TSH during the first trimester in Chinese pregnant women. The Journal of Clinical Endocrinology & Metabolism, 99(1), pp.73-79, (2014)
28) Kochupillai N., Mehta M., Iodine deficiency disorders and their prevention in India. Reviews in Endocrine and Metabolic Disorders, 9(3): 237, (2008)
29) Jones G., Schneider W.J., Intelligence, human capital, and economic growth: A Bayesian averaging of classical estimates (BACE) approach. Journal of economic growth.; 11 (1):71-93, (2006)
30) Sareen N., and Pradhan R., Need for neonatal screening program in India: A national priority. Indian Journal of Endocrinology and Metabolism, 19(2): 204–220, (2015)

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