Iodine Deficiency and Mental Performance: A Review

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ABSTRACT

Introduction
Iodine deficiency disorders (IDD) is responsible for a lot of adverse health effects and it is one of the most common causes of preventable mental impairment. Impaired cognitive function is an outcome of impaired neurodevelopment process during early pregnancy due to iodine deficiency.

Methods
A few cross-sectional studies found differences in mental performance between areas with high iodine found naturally in the environment (well water) and those with low iodine level, but other studies showed otherwise.

Results
Intervention studies with iodine also give variety of results ranging from significant improvement of mental performance to non-significant findings.

Conclusions
Malaysia faces with challenges in iodine supplementation among the population but it can be dealt with effectively if the programme is well executed and monitored.

Keywords
Iodine deficiency - Mental performance - Intelligence.
INTRODUCTION
Iodine deficiency disorders (IDD) is a serious global public health problem, where it has been estimated that 31.5% of school-age children (266 million) and 2 billion people among the general population have insufficient iodine intake. Programmes to control iodine deficiency such as salt iodisation, have been effective for decades. However, iodine deficiency remains a major threat to the health and development of populations around the world, particularly among preschool children and pregnant women in low-income countries.

Dietary intake with low iodine is the most common cause of preventable mental impairment worldwide, which prompted a global drive to eliminate iodine deficiency through highly effective strategies of salt iodisation and iodine supplementation. However, some national iodination programmes may have been ineffective in combating IDD because of widespread consumption of salt that has not been adequately fortified as well as by the presence of goitrogenic food sources being consumed in the environment.

MATERIALS AND METHOD
Indicator of Iodine Status
There are four indicators that are generally used in assessing iodine status; they are: i) urinary iodine concentration (UI), ii) goiter rate via thyroid size measurement, iii) serum TSH, as well as iv) serum thyroglobulin. However, urinary iodine (UI) is considered as the indicator of adequacy of the iodine intake of the population. A reliable and practical technique in measuring iodine excretion is to measure the UI to creatinine level (UI/ Cr) rather than measuring random spot UI concentration. Random spot sample is influenced by the day-to-day variability in iodine intake, water consumption of an individual, and in the amount of time it takes for iodine exposure to equilibrate. In iodine sufficient areas, there will be day-to-day and within-day variations but in areas where there is mild to moderate iodine deficiency, the UI concentrations will have day-to-day variations. However, it is also worth noting that urine iodine measurement fluctuates based on a person’s daily iodine intake and water consumption.

Effects of Iodine Deficiency
There are multiple adverse effects of iodine deficiency on human growth and development and iodine deficiency is still the most common cause of preventable mental impairment. Effects of iodine deficiency depend on the degree of the deficiency and at what stage of life it occurs. The effects of iodine deficiency based on life stages can be summarized as in Table 1.

Table 1 Effects of iodine deficiency by age group

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Health Consequences of Iodine Deficiency</th>
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<td>All Ages</td>
<td>Goiter, including toxic nodular goiter. Increased occurrence of hypothyroidism in moderate-to-severe iodine deficiency; decreased occurrence of hypothyroidism in mild-to-moderate iodine deficiency. Increased susceptibility of the thyroid gland to damage and thyroid cancer from iodine radioisotopes (e.g. from radioactive fall-out).</td>
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<td>Fetus</td>
<td>Abortion</td>
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<td></td>
<td>Stillbirth</td>
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<td>Congenital anomalies</td>
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<td></td>
<td>Perinatal mortality</td>
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<td>Neonate</td>
<td>Infant mortality</td>
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<td>Endemic cretinism</td>
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<td>Child and Adolescent</td>
<td>Impaired mental function</td>
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<td>Delayed physical development</td>
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<tr>
<td>Adults</td>
<td>Impaired mental function</td>
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<td>Iodine-induced hyperthyroidism</td>
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<td>Overall, moderate-to-severe iodine deficiency causes subtle but widespread adverse effects in a population secondary to hypothyroidism, including decreased educability, apathy, and reduced work productivity, resulting in impaired social and economic development.</td>
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</table>

Source: Zimmermann
Table 2 Relationship between iodine deficiency and mental performance

<table>
<thead>
<tr>
<th>Country</th>
<th>Study Title, Publication Year</th>
<th>Subjects</th>
<th>Study Design</th>
<th>Outcomes measured</th>
<th>Tool Used to assess Cognition</th>
<th>Main Results</th>
<th>Reference</th>
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<tbody>
<tr>
<td>Malaysia</td>
<td>Iodine deficiency and its correlation with mental performance among the schoolchildren in Saro, Satun: a preliminary study, 2003</td>
<td>25 schoolchildren aged 7-12 years</td>
<td>Cross sectional study</td>
<td>Mental performance</td>
<td>TONI-2 (Test of Nonverbal Intelligence)</td>
<td>School children who have higher content of iodine in the water supply perform better at school as compared to other isolated areas.</td>
<td>Zalha et al.17</td>
</tr>
<tr>
<td>Bangladesh</td>
<td>Biochemical hypothyroidism secondary to iodine deficiency and its association with poor school achievement and cognition in Bangladeshi children, 1999</td>
<td>769 grade 1 and 2 children from severely iodine deficient areas</td>
<td>Matched cross sectional study</td>
<td>School achievement Cognitive and motor functions</td>
<td>Wide Range Achievement Test (WRAT)</td>
<td>The thyroid group had better scores in reading and spelling (p &lt; 0.001) and mathematics (p = 0.03) as compared to hypothyroid group. The euthyroid group had significantly better scores in the French learning test (p = 0.01), but there was no group difference in any of the other cognitive or motor tasks.</td>
<td>Farida et al.16</td>
</tr>
<tr>
<td>Mexico</td>
<td>Iodine deficiency and its association with intelligence quotient in schoolchildren from Colima, Mexico, 2004</td>
<td>403 children from public and private schools</td>
<td>Cross sectional study</td>
<td>Intellectual quotient</td>
<td>Raven's Progressive Matrices</td>
<td>IQ deficiency 4.26 times greater in those with moderate iodine deficiency (p = 0.06)</td>
<td>Grenda-Lecastenoy</td>
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<tr>
<td>Spain</td>
<td>Intelligence quotient and Iodine intake: A cross sectional study in Children, 2004</td>
<td>921 school children from 6th grade 1, 5 and 8</td>
<td>Cross sectional study</td>
<td>Intellectual quotient</td>
<td>Raven's Progressive Matrices</td>
<td>The IQ was significantly lower in children who had urinary iodine levels below 100 mcg/1 liter (OR = 0.91, 95% CI = 0.88-0.94). An IQ below the 25th percentile was significantly related to urinary iodine levels below 100 mcg/liter (OR, 1.40; p &lt; 0.02) and thyroglobulin values above 15 mg/liter (OR, 1.52; p &lt; 0.03).</td>
<td>Santigo-Fernandez et al.17</td>
</tr>
<tr>
<td>Malaysia</td>
<td>Goitre prevalence and mental performance among Aborigines in Sarawak, 1996</td>
<td>806 Aborigines aged 4-60 years old</td>
<td>Cross sectional study</td>
<td>Mental performance</td>
<td>Raven's test</td>
<td>No significant correlation between thyroid hormone levels and mental performance score (r = 0.02, p = 0.8395)</td>
<td>Zalha et al.20</td>
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<tr>
<td>Albania</td>
<td>Iodine supplementation improves cognition in iodine-deficient schoolchildren in Albania: a randomized, controlled, double-blind study, 2006</td>
<td>310 primary schoolchildren aged 10-12 years old</td>
<td>Double-blind intervention trial</td>
<td>Cognitive and motor performance</td>
<td>Raven's Coloured Progressive Matrices</td>
<td>Iodine treatment was associated with highly significant improvement in test scores on Raven's Coloured Progressive Matrices, rapid search, symbol matching, symbol search, and rapid object naming (p &lt; 0.0001).</td>
<td>Zaimann et al.18</td>
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<td>Portugal</td>
<td>Psychomotor development of children from an iodine-deficient region, 2011</td>
<td>40 pregnant mothers, 86 children at age 3 months, 12-18 months, and at 24 months</td>
<td>Cohort</td>
<td>Child's level of development in the cognitive and motor behavior domains</td>
<td>Bayley Scale of Infant Development, converted to Mental Development Index (MDI) and Psychomotor Development Index (PDI)</td>
<td>Children born from mothers with F14 level &lt;25% and 25% (OR = 2.1) had no significant influence, but with mild-to-severe delay.</td>
<td>Consoli et al.11</td>
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<tr>
<td>Malaysia</td>
<td>The supplementation of iodine to infants and children in iodine-deficient areas in endemic goitre areas: the impact of therapy 1998.</td>
<td>311 at baseline, 252 at first visit, 256 during second, 239 during third and 244 during the fourth visit</td>
<td>Quasi-experimental trial</td>
<td>Mental performance after supplementation with 100 mcg sodium iodide.</td>
<td>Raven's Progressive Matrices</td>
<td>Significant increase in mental performance after 1.5 years of intervention</td>
<td>Zalha et al.19</td>
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Iodine Deficiency and Mental Performance

Iodine is an important micronutrient that involves growth and development and it is an essential component of the thyroid hormones, thyroxine (T<sub>4</sub>) and triiodothyronine (T<sub>3</sub>). Normal neurodevelopment requires appropriate amount of T4. It is initially provided by the mother and, after mid gestation, by the maternal and fetal thyroids. Major impact of thyroid hormones seems to occur during fetal life especially before the onset of fetal thyroid function, and it was also noted that iodine has its most significant effect if consumed by expectant mothers in sufficient amount during the early period of pregnancy. Iodine deficiency during pregnancy and infancy may impair growth and neurodevelopment of the offspring and increase infant mortality. It can also cause stillbirths, abortions, and congenital abnormalities.

Thyroid hormone deficiency during the first and second trimesters of pregnancy would affect visual attention, visual processing, visuospatial skills and fine motor skills, whereas such deficiency during the second and third trimesters affects gross motor skills, memory and motor function. Deficiency during childhood reduces somatic growth and cognitive and motor function.

Cognitive impairment has been recognized to occur in individuals who were diagnosed with hypothyroidism, a medical condition that is also associated with iodine deficiency, regardless of at what age the condition developed. While congenital hypothyroidism found to cause attention deficit, hypothyroidism in adult can cause deficit in memory, psychomotor delay, as well as visuoperceptual and construction skill.

Studies have shown that populations affected by even mild iodine deficiency have their average cognitive capacity reduced, impaired school performance and lower intelligence quotient (IQ). A study carried out in Sarawak, Malaysia showed that school children who lived in a remote rural area where higher content of iodine in the water wells were found performed better at school as compared to other remote areas. Those who were euthyroid had better cognitive function as compared to those found to be hypothyroid. A study in Spain reported that there was a greater risk of children with urinary iodine levels less than 100 μg/liter to have IQ below the 25th percentile or even a clinically significant decreased in IQ showed an IQ of 70 or less.

Effects Of Iodine Intervention On Mental Performance

Several intervention studies were done to determine the effect of iodine supplementation on mental performance. Treatment with iodized oil was found to produce a marked and sustained improvement in iodine status and this resulted in improvement of mental performance in school children albeit small increase was seen. Supplement with thyroxine sodium among Orang Asli in Malaysia also found to have positive effects on mental performance.

Other studies however showed no significant association between iodine deficiency and mental performance. This can probably be explained that most of the studies of mental performance in children were unable to distinguish whether the effect of iodine deficiency is in utero or it is an effect from the current iodine status. As discussed earlier, significant effects on brain development by iodine happens during the early stage of pregnancy.

Malaysia Scenario And Challenges In Improving Iodine Deficiency

The findings from the National Iodine Deficiency Survey in 1996 lead to salt iodization programme in Sabah and Sarawak since 1999 but it was found that iodine deficiency was not a public health problem for Peninsular Malaysia. However, a more recent study showed otherwise where Orang Asli in Hulu Selangor were found to have moderate iodine deficiency with median UI of 45.1 μg/L as compared to the recommended level of at least 100 μg/L. The 2008 IDD National Survey also showed that almost 50% of the states in Peninsular Malaysia had median UI of less than 100 μg/L (1). Poor iodine consumption by the population could be the reason of this deficiency. Although worldwide, the number of households using iodised salt has risen from less than 20% to more than 70%, only 17.6% of Malaysians consumed iodized salt that contains the recommended level of ≥ 15 ppm and only 6.8% populations of Peninsular Malaysia consumed the recommended level.

Study of the distribution of iodized salt as well as on the accessibility of iodized salt and other iodine fortified foods might give a true picture of iodine consumption pattern among the Malaysian population. Besides poor dietary intake of iodine, high consumption of goitrogens such as tapioca roots and leaves has been associated with high prevalence of palpable goitre in the native population in Sarawak.

Another way of delivering iodine to the community was through the fitting of iodinator into the existing gravity-feed water supply in the villages. Water iodinator was used in Terengganu since 1997, but a study done in 2004 showed that although there was a significantly higher UI among school children where the school was fitted with water iodinator system, the consumption of the iodised water was very low where only 43.5% of the study subjects consumed it once a week. Hence, any programme in combating IDD should...
be reviewed and monitored regularly to ensure its success. A more vigorous campaign to instill awareness among the public about the adverse effects of IDD can possibly increase their compliance towards IDD intervention programmes.

CONCLUSIONS
Iodine deficiency is still a problem in many parts of the world despite the availability of iodination programmes in most countries. Factors such as inadequate fortification and unequal coverage of the programme should be looked into. Studying the local dietary habits might give a clue on what are the sources of iodine received and consumed by the local population as well as the type and amount of goitrogens in the local environment that can aggravate iodine deficiency. Tailoring programme based on local dietary consumption will be more beneficial to the target population especially in combating the adverse effects of iodine deficiency mainly on children’s mental performance.

REFERENCES


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