NUTRITION AND DEVELOPMENT

Consequences and Impact of Malnutrition

Nutrition is the building block of healthy, secure lives and thus, the foundation for development. It is that common thread that cuts across every developmental sector (economic, health, education), thus a fundamental pillar of human life, health and development across the entire life span. It supports and influences every stage of life, at every level of being and essential to all the body systems. Nutrition is essential for human & national development. Undernutrition remains one of the world’s most serious but least addressed socioeconomic and health problems as there’s a high burden of stunting, wasting, underweight, overweight, IUGR, acute and severe malnutrition, micronutrient deficiencies, hunger, etc.

Health: Malnutrition weakens the body and opens it up to the attacks of illness.

Education: Malnutrition impedes (hinder) brain development and affects lifelong learning.

Malnutrition impacts negatively on physical growth and development, morbidity (diseases) ie increases the menace and aggravates diseases. It also increases mortality. Subsequently, it constrains (reduces) children’s ability to fulfill their potential and contributes to intergenerational transmission of poverty via the mechanism of poor school and economic performance especially among young girls.

Nutrition plays the most critical role in a person’s life during a very narrow window of time – the first 1,000 days of life. The quality of nutrition during those 1,000 days can help determine the lifelong fate of any individual, and by implication, the nation. There is growing evidence that maternal body size is strongly associated with the size of newborn children. Undernourished women tend to become shorter adults, and thus are more likely to have small children. Undernutrition in pregnant women is also one of the causes of adverse pregnancy outcomes such as miscarriage, still birth, and intrauterine growth restriction (IUGR). Children born with low birth weight (LBW) are more susceptible to recurrent infections whose severity is also closely linked with child nutritional status. Emerging evidence points to the fact that children
who are undernourished in the first two years of life and who put on weight rapidly later in childhood and in adolescence are at high risk of diet related non-communicable diseases (DRNCD) such as diabetes, hypertension, arthritis, gout, certain types of cancers, and heart disease among others.

Impact on Economic Development

Economic analyses of the costs of malnutrition have examined specific micronutrient deficiencies as well as stunting. For example, an estimated 3.4% of global GDP is lost to the effects of anaemia on childhood cognitive development and educational attainment. Iron deficiency in adults has been estimated to decrease national labour productivity by 5 to 17%. And up to 10% in lost productivity and earnings has been attributed to stunting. These figures are especially pertinent in terms of future development goals, since nearly one-third of all children in the developing world are currently underweight or stunted. There are massive economic and social consequences to the high rates of undernutrition in Nigeria. Billions in GDP are lost each year due to the pernicious cycle of undernutrition. Annually, Nigeria loses over US$1.5 (22 billion naira) in GDP to vitamin and mineral deficiencies. Due to VAD alone, 25% of our children grow up with lowered immunity, which leads to frequent illness and poor health. Analysis by the Micronutrient Initiative shows that unless we take effective action to prevent and control VAD, over 80,000 Nigerian children will die annually. These estimates are corroborated by a recent study by the World Food Programme (WFP) and the Economic Commission for Latin America, which estimated the economic losses due to undernutrition in seven nations at a staggering 6% of annual GDP.

Effect cuts across different life stages

Adopted from the ACC/SCN-appointed Commission on the Nutrition Challenges of the 21st Century
NUTRITION AND MENTAL DEVELOPMENT

The brain depends on food for energy


The Brain

![Brain Diagram]

Parts of the brain

- **Cerebrum**
  - **Prosencephalon (forebrain)**
    - Telencephalon
      - Cerebral hemispheres
        - Basal ganglia
        - Hippocampus
        - Amygdaloid nucleus
    - Diencephalon
      - Thalamus
      - Hypothalamus
      - Metathalamus
      - Subthalamus
  - Mesencephalon (midbrain)
  - Rhombencephalon (hindbrain)
    - Metencephalon
      - Pons
      - Cerebellum
    - Myelencephalon (medulla oblongata)

The brain weighs 1300 - 1400 g and is made up of about 100 billion neurons. It is the “most complex living structure on the universe” according to the Society for Neuroscience. The brain makes us who we are.

Brain development

The development of the brain and nervous system of the embryo begins shortly after conception and its rapid. The ectoderm - neural tube - spinal cord & brain are formed within 2-4 weeks. By the 3rd month, brain
& spinal cord connect with organs & muscles and between weeks 13-24 (2nd trimester), brain neurons formation are mostly complete. At birth (full term), brain has all the neurons it will need for life– An infant’s brain is 25% of its adult weight at birth. At 2 years of age, the brain is 75% of its adult weight and 90% by age 6 yrs. Total no of cells in adults is largely determined by end of 1st year of life.

Undernutrition (proliferative growth phase) slows rate of cell division & reduce no of cells. Malnutrition during lactation could lead to 15-20% reduction in no of cells. Undernutrition beyond 8 months could lead to reduced size of cells, reduced total cholesterol or phospholipids content (reduced no or length of myelin sheath = retarded dendritic branching)
Stages of Human Brain Development
Parameters of the brain by life stages

<table>
<thead>
<tr>
<th>Age</th>
<th>Body weight (kg)</th>
<th>Brain weight (g)</th>
<th>Body fat (%)</th>
<th>RMR (kcal/day)</th>
<th>B12Met (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Newborn</td>
<td>3.5</td>
<td>475</td>
<td>16</td>
<td>161</td>
<td>87</td>
</tr>
<tr>
<td>3 months</td>
<td>5.5</td>
<td>650</td>
<td>22</td>
<td>306</td>
<td>64</td>
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<tr>
<td>18 months</td>
<td>11.0</td>
<td>1045</td>
<td>25</td>
<td>590</td>
<td>53</td>
</tr>
<tr>
<td>5 years</td>
<td>19.0</td>
<td>1235</td>
<td>15</td>
<td>830</td>
<td>44</td>
</tr>
<tr>
<td>10 years</td>
<td>31.0</td>
<td>1350</td>
<td>15</td>
<td>1160</td>
<td>34</td>
</tr>
<tr>
<td>Adult male</td>
<td>70.0</td>
<td>1400</td>
<td>11</td>
<td>1800</td>
<td>23</td>
</tr>
<tr>
<td>Adult female</td>
<td>50.0</td>
<td>1360</td>
<td>20</td>
<td>1480</td>
<td>27</td>
</tr>
</tbody>
</table>

Conceptual framework on role of nutrition in mental development (Walker et al., Lancet 2007)
COGNITIVE DEVELOPMENT

Nutrition, genes & environment affect cognitive development. Micro- & macronutrients are essential in mental development. – Optimal brain development starts at conception and requires the adequate provision of nutrients that support neurogenesis. Brain structure/function are altered if essential nutrients are lacking or in short supply during development.

Undernutrition during pregnancy & 1st two years of life cause permanent/irreversible defect in brain development in the following ways;

- Affects somatic growth, structural & functional development
- Reduced cell no. (measured by DNA content) is affected by intrauterine and early postnatal malnutrition
- Synaptic connectivity is affected if malnutrition occurs between birth and 3 years of age

Nutrients with particularly large effects on early brain development

- Macronutrients
  - Protein-Energy
  - Lipids & Specific fats (e.g. LC-PUFAs)
- Micronutrients
  - Iron
  - Iodine (Thyroid)
  - Zinc
  - Copper
- Vitamins/Cofactors
  - B vitamins (B6, B12)
  - Vitamin A
  - Vitamin E
  - Folate
  - Choline

Nutrients and Growth Factors regulate brain development during prenatal and postnatal life. Rapidly growing brain is more vulnerable to damage and more amenable to repair following nutritional perturbations. Nutrient deficiencies may cause negative effects or no effects (head sparing). Nutrient overabundance/supplementation may produce positive, negative or no effects. What happens is based on…Timing, Dose and Duration

Proteins and mental health

Protein/amino acids affect brain functioning & mental health. There are eight essential amino acids (EAAs). A complete/high-quality protein contains EAAs in adequate amounts. Proteins are necessary for DNA, RNA synthesis and maintenance and growth factor synthesis (Neurotrophins or neurotrophic factors are the protein substances, which play an important role in growth and functioning of nervous tissue). Proteins are also important for neurotransmitter production (substances in the body that carry signal from one nerve cell to another) e.g serotonin and dopamine. Serotonin is derived from the amino acid L-tryptophan, and variations in the amount of this amino acid in the diet (tryptophan-rich foods include milk and turkey) can affect the amount of serotonin produced by the neurons. Physiological functions attributed to serotonin include a role in the regulation of mood and behavior, appetite, and cerebral circulation. Neurotransmitter dopamine is made from AA tyrosine, neurons that use dopamine as a neurotransmitter are called dopaminergic neurons. Parkinson’s disease is caused by degeneration of the dopaminergic neurons. Parkinson’s disease is the second most common neurodegenerative disease (after Alzheimer’s disease) and
is associated with such symptoms as muscle tremors and rigidity, difficulty in initiating movements and speech, and other severe motor problems.

Proteins are also important for Structural proteins, i.e., axons, dendrites and synapse formation (A synapse is the functional connection between a neuron and a second cell). The amino acids glutamic acid and to a less degree, aspartic acid, function as excitatory neurotransmitters in the CNS. Glutamic acid (or glutamate) is the major excitatory neurotransmitter in the brain, producing excitatory postsynaptic potentials (EPSPs) in at least 80% of the synapses in the cerebral cortex.

Where precursor AA is not available, levels of affected neurotransmitter in the brain will fall affecting functioning and mood. Lack of tryptophan/serotonin leads to low mood and aggression. Diseases causing buildup of some AAs leads to brain damage & mental defects. Phenylalanine in phenylketonuria can cause brain damage & mental retardation.

**Energy and Mental development**

Human brain is metabolically active ≥23% RMR. Brain energy (ATP) utilization is high in fetus and neonate. Impaired glucose regulation cause impaired cognition while improved regulation leads to cognitive improvements. Dietary carbohydrates enhance cognition in subjects with poor memories. Glucose is the Brain's fuel (~80g daily) and its supply affects memory & mood. Overnight and morning fast leads to decreased glucose supply, memory & attention. When breakfast is skipped, there is decreased energy-in terms of levels, cognition and problem solving ability. Energy deprivation causes non-essential functions shut/slow down. In prolonged starvation, the brain adapts & utilize fatty acids &ketone. For example, hypoglycemia is the most frequent cause of coma in insulin-treated patients and is believed to account for 3 to 4 percent of deaths in this population. Symptoms of hypoglycemia include dizziness, shakiness, hunger, irritability, sweating, and heart palpitations. Mental confusion may prevent a person from recognizing the problem and taking such corrective action as ingesting glucose tab-lets, juice, or candy. If hypoglycemia occurs during the night, patients may be completely unaware of its presence. Severe hypoglycemia or a delay in treatment can cause irreversible brain damage.

**PEM and Mental Health**

Energy and/or protein deficiency causes deficits in cognition. Stunting is associated with delayed neuro-sensory integration, low IQ and school achievement. Stunted children (0-24 months) had lower test scores than non stunted children (Modified for SES factor, school type and some other factors)

Head Circumference: Poor nutrition contributes to microcephaly. Low birth weight causes about 40-60% reduction in brain cells– School performance positively correlate with body weights & heights, Performance on psychological test positively related to dietary practice.

**Lipids and Mental Health**

Dry weight of the human brain is predominantly lipid making up to 22% of the cerebral cortex and 24% of white matter. Lipids play several roles: Cell membranes, Myelin and Synapse formation. Lipids also maintain neurotransmitter levels.

Body fat is approximately 15-16% of body weight at birth, this increases to 25-26% in the first 12-18 months of postnatal growth and decreases to 15% by early childhood. High body fatness allow infants to accommodate the growth of brains by having a ready supply of stored energy and phospholipids.

**Fatty acids function in Brain development**
Essential fatty acids (EFAs) play a crucial structural role in brain tissue, myelin sheaths and in cell membranes (myelin sheath is a thick lipoprotein sheath that insulates the myelinated nerve fiber) Brain proteins are fixed by the genetic code but the fatty acid composition of brain phospholipids respond to the diet. EFAs (n-3-long-chain polyunsaturated (LCPs)) fatty acids are important for brain development (fetal and postnatal periods). N-3 and n-6 LCPs function in neuronal growth, synaptic processing of neural cell interaction, and regulating cell differentiation and growth.

One of the most important contributions of nutrition to mental health is the maintenance of the structure and function of the neurons and brain centers coordinating communication within the body and between the body and the environment. Sixty percent of the brain's dry weight is fat, and under optimal conditions 25% of this fat is docosahexaenoic acid (DHA), an omega-3 fatty acid. Omega-3 (n-3) fatty acids appear to be the type of fat preferred by the brain and nervous system. Each of the three n-3 fatty acids have been studied with regard to mental health, and each has been found to have unique, important, and non-interchangeable contributions to overall brain and nervous system functioning. Alpha-linolenic acid (ALA) is also known to chemists as 18:3 (n-3), with a chain length of 18 carbons long and three bonds that are unsaturated. Pure ALA has been found to have many health benefits, especially in the inhibition of inflammatory processes associated with cardiovascular disease, autoimmune disease, diabetes, and bowel disease. Its secondary benefit is that it can function as a precursor for the n-3 fatty acids eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). However, this conversion is low even in the most optimum nutritional conditions, and a diet lacking a variety of vitamins and minerals (common in persons with mental health diagnoses) further limits this conversion. Most experts in the area of nutrition and mental health do not recommend a reliance on ALA as a source of DHA or EPA. N-3 fatty acids are essential in brain development and functioning. Docosahexaenoic acid (DHA) (4.6mg DHA per day) is specialized for photosignal transduction and processing in the cerebral cortex.

DHA is the brain's building block. When provided with a choice of different fatty acids, the brain appears to prefer DHA. This fatty acid provides structure to neurons and is an anchor point for neurotransmitter receptors. Eicosapentaenoic acid (EPA) (20:5 n-3) is primarily found in fish. In addition, under conditions of tissue DHA (22:6 n-3) saturation, DHA can "retroconvert" into EPA. This process is so named because under normal conditions, conversion from EPA into DHA is the more common biochemical process.

DHA is also primarily found in fish. Fish do not synthesize DHA; they obtain DHA in their diets by eating marine algae. Humans benefit from the fact that this DHA is stored in the muscle tissue of the fish that they consume. It is also possible to purchase supplements of DHA obtained from marine algae. Unlike many essential nutrients, obtaining and retaining DHA and EPA depend not only on adequate intake but on important lifestyle and "macro" nutritional choices. It is often what is eaten in addition to DHA and EPA that determines whether overall essential fatty acid levels are adequate. Simply taking a supplement may not be enough.

Lipids deficiency & effect on Mental Development

Deficiency of n-3 fatty acids can modify membrane proteins’ ability to bind ligands & activate enzymes. It can also alter receptor activity and affect antigenic recognition, signal transduction, lateral mobility within the lipid bilayer and lead to increased excitability.

Reports from publications

• Omega-3 deficiency causes poor scores on tests for visual and cognitive performance among infants (Bryan et al., 2004)
Maternal fish intake during pregnancy is associated with children’s mental development up to 14 years (Lederman et al., 2008; Oken et al., 2008; Mendez et al., 2008; Gale et al., 2008; Budtz-Jorgensen et al., 2007; Hibbeln et al., 2007)

Positive association between fish, n-3, or total PUFA intake and cognitive outcomes among 4-16 yr old children (Kirby et al., 2010, Theodore et al., 2009; Kim et al., 2009; Zhang et al., 2005, Freire et al., 2010)

Iodine and Thyroid hormone production and regulation

IDD is the most frequent preventable cause of mental retardation globally

Consequences of Iodine deficiency

- Preventable brain damage & mental retardation (Delange, 2000)
- Permanent reduction of Intelligent Quotient by as much as 13.5 points
- Reduced cognition and achievement
- Low visual-motor performance, motor skills, perceptual and neuromotor abilities & low scores in intelligence tests
- 3% Cretinism, 10% Moderate to severe mental retardation and 87% Mild intellectual impairment occurs in children born to iodine deficient women.

Iron and Mental Health

Iron is an essential part of brain tissue. It is the component of cytochromes that make ATP. Deficiency & excess may cause permanent brain damage. Required to make neurotransmitters (dopamine, serotonin, norepinephrine). Iron contains enzymes necessary to make fatty acids in myelin and it essential for supply of oxygen.

Consequences of Iron Deficiencies

- IDA starves the brain of oxygen therby leading to fatigue & impaired mental functioning.
- Causes impaired working memory at 3.5 years after iron repletion

In infancy, it delays development of the central nervous system, causes poorer recognition memory in newborns and poorer school age neurodevelopment. It is also associated with behavior changes and delayed psychomotor development, abnormal neurologic reflexes/Slower nerve impulses transmission

Zinc

Aids transmission of nerve impulses and interacts with DNA (zinc finger proteins). It is needed for growth factor (IGF-1 and GH) synthesis, autonomic nervous system development, development of hippocampus (learning and memory) maintaining cell membranes and protecting cells from damage

Deficiencies in zinc have been associated with

- Neurological impairment, apathy, irritability, jitteriness, and fatigue
- Retardation of growth and development
- Reduced immunity/Increased risks of infections
- Reduced ability to concentrate and memorize
- Increased emotional responses to stress/impaired motor activity

Magnesium: Aids transmission of nerve impulses.
- Deficiency cause restlessness, nervousness and unsteadiness
**Manganese:** Involved in carbohydrate metabolism and brain functioning
– Deficiency is rare, cause abnormalities in brain function

**Copper:** Involved in iron metabolism and brain function
– Deficiency impairs brain functioning and immune system
– Lowered levels of neurotransmitters.

**Vitamins and mental health**

**B-Vitamins**
Involved in ensuring optimal mental development through action (metabolism) on other nutrients

- **Thiamin** – needed for glucose metabolism & make several neurotransmitters. – Deficiency ≡ Wernicke-Korsakoff syndrome (confusion, mental changes, abnormal eye movements, severe memory loss)
- **Niacin** - metabolism of carbohydrates, proteins, and fats. – Deficiency: Mental symptoms (irritability, headaches, loss of memory, inability to sleep, and emotional instability). – Severe deficiency = Pellagra (Dermatitis, diarrhea, dementia & death)
- **Vitamin B-6** - needed for most of the brain's neurotransmitters. – Deficiency characterized by mental changes: fatigue, nervousness, irritability, depression, insomnia, dizziness and nerve changes
- **Folic acid:** – Essential in stem cell division. – Deficiency associated with low serotonin level = Mental disorders (depression, mood, cognition and social functioning). Deficiency is also implicated in Anencephaly (irregular brain formation) and lifelong brain impairment
- **Vitamin B-12**— Essential for the development of the central nervous system (cognitive development) in early life. Maintains the myelin (coating) sheath on nerve cells. Inadequate myelin = nerve damage & impaired brain function. – Deficiency - irreversible nerve damage, dementia & brain atrophy. – B12 deficiency in early life reduced scores on cognitive tests in adolescence
- **Role of Choline in the Brain:** Essential nutrient for humans. Serves as substrate for neurotransmitter (acetylcholine). Likely has epigenetic effect (methyl donor). It promotes larger neuronal size, more dendritic arborization and greater neuronal signaling especially in hippocampus (learning and memory)
- **Vitamin E** deficiency causes changes in nerve tissues. It progresses to dizziness, vision changes & sensory changes. As an antioxidant, vitamin E has been used for treatment of neurological conditions (Parkinson's and Alzheimer's disease)