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MATERNAL, INFANT, AND CHILDHOOD NUTRITION

Early Childhood Nutrition: Implications for Cognition and Long-term Health

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Introduction:

In modern society, the importance of maternal nutrition is well known, and information about what to eat, how much to eat, and what to avoid during pregnancy is widely available and easily accessible. Most women I know who have become pregnant have become very well versed in maternal nutrition in order to ensure a healthy pregnancy and the best possible outcome for their newborn. The best possible outcome is typically a "healthy *baby*", that is, a *baby* that is free of disease or disfigurement. The emphasis is placed solely on health (ie: being free from disease/disfigurement) in early infancy and not in the effects of nutrition on the child throughout their lifespan. Likewise, most mothers have been told that "breast is best" (whether or not it is their decision to breastfeed their child), but perhaps not necessarily for reasons related to long-term health and cognition. As a mother of 3, I recall being told about the benefits of breastfeeding as a means of forming a bond with the baby in addition to improved immune system function in the child. At the time, there was little, if any, conversation around other health or cognitive/behavioural benefits. Beyond pregnancy and breastfeeding, little public attention has been given to the impact of early childhood nutrition on their health and cognition *after* infancy. In my experience, emphasis later on is placed more on physical attractiveness than health, most likely because this is the emphasis that society has placed on us, the adults, and therefore we model this for our children. Indeed, in my case, the only conversations about eating a healthful diet I ever recall having with my own mother was for the purposes of maintaining a low body weight, ie: dieting. Given that the rates of obesity have increased to the point of epidemic, it is clear that this approach is not working, and perhaps emphasis and education about food should be shifted to focus on nutrition as a means of achieving long-term health and cognition. Prior to my career in the field of nutrition, I worked as a Psychometrist, performing psychological test batteries on college and university students for the purposes of determining whether a learning disability, ADHD, or other mental disorder may be present. Through this, I observed many students who were the same age, who had grown up in the same community, in the same schools, with largely similar socioeconomic statuses, who demonstrated such a large variability in cognitive

functioning, behaviour, and social skills, that it made me wonder what factors could have contributed to these differences in ability. As with any other health condition, there are typically many factors that can come into play; however, the role of nutrition cannot be overlooked as a potential preventative and protective factor. Throughout this essay, we will examine the impact of maternal, infant, and early childhood nutrition on long-term cognitive functioning and behaviour as well as physical health and development. Of note, only studies wherein socioeconomic status did *not* interact with nutritional supplementation will be included in this essay.

History of the Study of Childhood Nutrition:

Cicely William's 1933 description of "Kwasgiorkor" and her suggestion that its etiology could be found in a deficiency of protein began a period of intensive study and international concern. Kwashiorkor is a disease characterized by severe protein deficiency and bilateral swelling of the extremities. It causes fluid retention (edema) and a swollen, distended abdomen. The disease usually affects infants and children, most commonly from infancy through age 5 and is seen in very severe cases of malnutrition and third world countries (Benjamin & Lappin, 2022).

During the four decades following William's description of the disease, lack of protein was considered to be the major contributing factor in the diets of most malnourished and undernourished children in poverty-stricken countries. In 1959, Jelliffe coined the term "protein calorie deficiency", which included kwashiorkor, marasmus, and mild to moderate forms of protein calorie deficiency. Marasmus is another severe form of malnutrition, specifically protein-calorie malnutrition; however, the difference between marasmus and Kwashiorkor is that Marasmus is a deficiency in all macronutrients – proteins, fats, and carbohydrates. In 1974, the World Health Organization (WHO) estimated that there were nearly 100 million children from age 0-4 suffering from PEM in Asia, Africa, and Latin America (Bengoa, 2004). In the 1980s and 1990s, it was very common to see television commercials showing children from developing countries, emaciated but with distended bellies, whom you could sponsor to assist with providing

food and medicine. These children were likely suffering from Kwashiorkor and/or Marasmus, among other illnesses.

The theory associating protein calorie malnutrition to later deficits in cognition cognitive actually began in early 1900s; however, though most of the research took place mid-century, in the 1950s and 1960s. Detailed accounts of listlessness, apathy, and limited motor activity were provided of children suffering from severe malnutrition. With this discovery, it was logical to hypothesize that undernutrition also affected the brain given that its effects on major organs had been well known. Indeed, research from the 1960s showed that infants and young children with a history of severe malnutrition had lower scores on developmental scales, IQ tests, and test batteries assessing specific areas of intellectual functioning than same-aged children who were not malnourished (Pollitt, 1993).

Cognitive Functioning and Behavior:

It is now well known in the scientific industry that macronutrient sufficiency is required for normal brain development. Early life macronutrient deficiency is associated with lower IQ scores, reduced academic achievement, and increased behavioral dysregulation (Granthan-McGregor, 1995). More specifically, neurodevelopment exists in a scaffolding-like process in which “the development of increasingly complex neural circuits (and the behaviors they support) relies on successful completion of previous stages of development” (Schwarzenberg et al, 2018). This means that optimal neurobehavioral development is only possible if all necessary factors are present at their biologically required times and that nothing is inhibiting these processes. Indeed, rapid changes in neurologic development begin as early as 18 days post-conception until the age of two, with the most active period occurring in the first 1000 days of life (Fox et al, 2010). During this time, crucial processes and structures occur that support later behaviors and provide a framework for behavioural development processes that occur later. This includes auditory and visual processing, learning and

memory, processing speed, motivation, and affect. It also includes functions of the prefrontal cortex such as attention, ability to multitask, and inhibition (Schwarzenberg et al, 2018).

We know, of course, that healthy neurodevelopment depends on a number of factors, such as interpersonal/family relationships, environment, and socioeconomics; however, the role of nutrition is equally as important. While conducting research for this essay, one study continued to be cited in nearly every research article I read. The study took place in rural Guatemala between 1969 and 1989. Investigators provided protein-calorie supplementation of different amounts to four different rural Guatemalan villages. Two villages were given a high-calorie, high-protein supplement, and the other two villages received a low-calorie, no-protein supplement with. Both supplements contained vitamins and minerals. These supplements were given to pregnant and lactating women as well children up to the age of 7. After a period of more than 10 years, researchers assessed village children between 13-19 years of age. They found that children who had been given the high calorie/protein supplement before the age of 2 had higher scores for knowledge, reading, vocabulary, and numeracy. They also had faster processing speed scores than children of the same age who received the low-calorie supplement. In summary, this study showed that early calorie/protein supplementation children at risk for macronutrient undernutrition improved cognitive outcomes over an extended period of life, well beyond the period in which they were provided with the supplement (Schwarzenberg et al, 2018).

Another study found that maternal supplementation during pregnancy and lactation was positively associated with infant birth weight and growth. Though no supplementation-related associations seemed to exist for newborns on performance on the Brazelton Neonatal Behavioral Assessment Scale, infant assessments at 6 months of age showed a positive association between supplementation and mental development. It did not show any differences in motor performance. At 15, 24, and 36 months; however, maternal supplementation was positively associated with both mental development and

motor performance on the same assessment as well as on a preschool battery of tests (DiGirolamo et al, 2020).

Many other studies have investigated the association between nutrition and cognition during preschool years, ages 3-7. Children's cognitive abilities were assessed using a large battery of tests, looking at skills such as language, short-term memory, and perceptual skills. They found that test performance was strongly linked with the child's physical size, head circumference and height specifically. Greater height and head circumference were associated with better perceptual abilities. Physical growth was associated with improved vocabulary and short-term memory, most notably in girls. Moreover, nutritionally deficient preschool children demonstrated low scores on high attention demanding tasks, which suggests that attention may also be linked to nutrition and cognitive performance (DiGirolamo et al, 2020).

Within the previously noted Guatemalan study, children provided with the high and low supplementation prenatally and from birth to four years of age were assessed at the ages of 6-8 years based on their abilities to respond to routinely stressful situations requiring problem-solving and to engage appropriately with peers. problem-solving situations and to interact appropriately with peers. High Supplementation children demonstrated more interest in exploring their environments, increased involvement in a competition, better frustration tolerance, greater motor control, and improved initiative-taking in group activities than their low supplementation counterparts. While engaging in free play, the high supplementation group demonstrated a happier overall affect, better social skills, and were less shy or anxious (Barrett et al, 1985). Additionally, severe malnutrition during the first 12 months of life was associated with lower levels of attention to novel stimuli (Klein et al, 1974). Research findings and suggest that behavioural impairments associated with poor early nutrition have long-term implications for the child's development. While we have spoken of the importance of adequate caloric and macronutrient intake, calories alone are not sufficient for healthy brain development. In addition to macronutrient intake, other nutrients that support brain development include zinc, iron, choline, folate, iodine, B vitamins, and vitamins A and D.

Failure to consume these key nutrients during this crucial period of neurodevelopment can lead to lifelong impairments in brain function, even if adequate nutrition is provided afterwards. For example, prenatal and early infancy deficiency in iron is associated with long-term neurobehavioral impairment. Even with iron treatment, these impairments may not be reversable (Lozoff et al, 2006). Significant maternal iron deficiency and/or poor maternal-fetal iron transport, which may be associated with hypertension or cigarette smoking in the mother, or conditions like maternal diabetes may lead to iron deficiency in the newborn and unfortunately with the associated long-term cognitive impairments.

Likewise, obesity of the expectant mother affects the child's development and can lead to lower cognitive abilities, an increased risk of neurodevelopmental disorders, and has implications for immune function and ability to fight infectious diseases. The child may also be at an increased risk for diabetes and obesity (Godfrey et al, 2017). These physical impairments lead us to our next topic: long-term health.

Long-term Health:

When studying nutrition as it relates to health, there are a small number of topics that consistently arise in most areas of related research. One of these topics is obesity. In a society where nearly 75% of adults are overweight or obese (Fryer et al, 2020), there has been an increased public interest in diets and nutrition, primarily for the purposes of losing weight in adulthood. From a public health perspective, however, the interest in nutrition has grown as a means of preventing and treating chronic illness, which has become a global epidemic and huge economic burden. Over the past few decades, individuals have seen a significant increase in weight gain due largely to changes in eating habits and decreased physical activity. These changes have led to increased incidences of cardiovascular diseases and Type II Diabetes (Ley et al, 2014).

Cardiovascular disease is the world's leading cause of death. It is estimated that nearly 18 million people died from heart disease in 2019, which represents a whopping 32% of

all global deaths. CVD is also the leading cause of premature death under the age of 70, and in 2019, 38% of the 17 million premature deaths were caused by cardiovascular disease (World Health Organization, 2021). These statistics, although startling, are largely related to adulthood. There seems to a blind spot in relation to childhood nutrition, or perhaps we, as a society, feel that we will address it only when health problems present instead of preventing the problem. According to the Centres for Disease Control and Prevention, childhood obesity is a serious health problem in the US, where 19.7% or 14.7 million children and youth are considered obese. This can lead to serious health conditions such as hypertension, high cholesterol, breathing issues such as sleep apnea and asthma, Type 2 diabetes, and joint problems (CDC, 2022). The World Health Organization adds that obesity is responsible for 7-41% of certain cancers (Koletzko et al, 2017). Interestingly, WHO has indicated that there are few successful treatments for obesity and thus we should focus on prevention. While I agree with the latter, I do not agree that there are few successful treatments for obesity. I believe we are underusing and overcomplicating nutrition and physical activity as a simple and accessible means of treating obesity, and this starts with education. The current medical model, unfortunately, focuses more on reactive than proactive care, though this mentality does seem to be slowly shifting to one of integrative care, which would certainly be more effective. Prevention would be at the forefront of this modality. In a report titled “Ending Childhood Obesity”, a group of experts from WHO concluded that opportunities are available for prevention of obesity and associated health conditions throughout pregnancy, infancy, early childhood, and in adolescence (Koletzko et al, 2017). We will begin with pregnancy.

In a study entitled Early Nutrition project, over 2000 overweight pregnant women were randomly assigned to either standard care or to a comprehensive nutrition and lifestyle regimen which focused on limiting sugar and saturated fats and on increasing physical activity. In the group that received nutrition and lifestyle guidance, there was a substantial reduction in the number of infants born with a birth weight of about 4kg (~8.8lbs). This may be of significant clinical relevance, given that birth weight of above 4kg is associated with a doubled risk of later obesity (Yu et al, 2011). Another study

found that dietary and physical activity interventions lead to reduced maternal weight gain as well as reduced subscapular skinfold thickness when the infants were assessed at 6 months of age, in comparison to a non-invention group. This suggests that prenatal nutrition and physical activity may have an affect on later infant body fat (Koletzko et al, 2017).

There exists a considerable opportunity for prevention of illness and obesity in postnatal interventions as well. A large research project conducted in Germany found that breastfeeding is associated with a substantial reduction in the risk for obesity in school aged children, which was supported by many other observational studies. Koletzko et al. believed that the protective effect of breastfeeding may be due in part to the lower amount of protein found in breastmilk than in traditional infant formula. They hypothesized that that a too-high protein supply during infancy would exceed the body's metabolic requirements, thereby increasing plasma and tissue concentrations of insulin and IGF-1, inducing increased infant weight gain and body fat, in addition to increasing long-term risk of obesity (2017). This hypothesis was confirmed by a large clinical trial involving infants from 5 European counties. Among the more than 1000 children from whom BMI could be collected later at 6 years of age, only 3.5% of the previously breastfed children were found to be obese, compared to 10.5% in the children who had been fed traditional infant formula (2017).

Conclusion and Recommendations:

The importance of maternal, postpartum, and early childhood nutrition go well beyond that of producing a healthy newborn. During the prenatal period through the first two years of life, childhood and later adult health problems, including obesity, high blood pressure, and diabetes, may be determined by the quality of nutrition during this short time period. Significant implications for cognitive abilities, academic skills, socialization, and behaviour can result from inadequate nutrition in the first 1000 days following conception. These implications exceed that of trouble in school and difficulty making

friends, as they may impact decision making abilities, frustration tolerance, perseverance, and higher-level thinking. The effects of these early adverse experiences cannot be understated as they may contribute to a lifetime of medical problems and cognitive deficits, and this lost academic achievement, self-esteem, and productivity, can affect not only the child but future generations.

Widely and easily accessible information on cognitive development should be prioritized and discussed during prenatal medical appointments in the same way as would medical-related issues such as birth defects. Likewise, evidence is clear that pre- and postnatal as well as early childhood nutrition are contributing risk factors to later health problems such as obesity. Alarmingly, 20% of children in the US already meet the criteria for obesity, thus preventative measures are of critical importance. Healthcare professionals should be knowledgeable of and refer patients to existing services for nutrition support for pre- and postnatal women, infants, and young children. Healthcare professionals alone; however, cannot bear the full burden of educating patients on the importance of nutrition. As such, all childhood providers (daycare, preschool, schools, social services, community organizations, etc.) should also be knowledgeable on and/or refer clients for nutritional guidance. Finally, prioritizing policies that promote and ensure access to adequate information and nutrition during this critical time period would allow all children the opportunity for early optimal neurodevelopment and growth, both of which are key factors in achieving long-term health.

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