Early childhood is a critical period of growth and development. This paper explores the importance of adequate nutrition and the federal nutrition programs in supporting this growth and development, especially for vulnerable children. More specifically, the paper is divided into sections starting with an overview of the stages of children's physical and cognitive development and the importance of nutrition to these stages. This will be followed by the current state of young children's dietary patterns and how these patterns might influence cognitive development. Finally, the paper will provide details on how the federal food programs such as the Child and Adult Care Food Program and the Special Supplemental Nutrition Program for Women, Infants, and Children can play a vital role in improving dietary patterns and cognitive outcomes for the nation's most vulnerable children.

Introduction to Child Development:

The first five years of a child's life is the most critical period for physiological, social, linguistic, and cognitive development[1-4]. The rate at which these developments occur is unmatched in any other phase of life. These rapid developments require a supportive environment in all aspects, from nurturing relationships to adequate nutrition[4-5].

The most rapid advances in physiological and cognitive development occur in infancy. Between birth and the first year of life, infants triple their birthweight[6]. Organ systems continue to grow and increase in complexity, and networks of neurons are being continually remodeled and becoming more organized[5]. During the first two years of life, the brain grows to 80% of its adult weight[2]. These advances in brain development facilitate progression in gross motor skills and voluntary muscle movements[5].

Toddlers continue to grow rapidly but the rate begins to taper, gaining 0.8 ounces and growing 0.4 inches each month[5]. This phase of growth is characterized by specific advances in motor and language skills. Toddlers learn to walk, climb, sit independently, and jump[5]. Their vocabularies exponentially increase from around 15 to 100 words[5]. During the preschool years, children gain 4.4 pounds and grow 2.75 inches each year and by age five, the brain has reached 90% of its adult weight[2, 5]. These developments coincide with children's first expressions of autonomy and uses of internal behavior control[5].

These unmatched physiological and cognitive developments mark the first five years as a critical, sensitive period[4]. While these changes are in part orchestrated by genetics, environmental factors such as adequate nutrition undoubtedly play an important role. As shown in Figure 1**,** many factors impact a child's development[4]. Because of its importance, the remainder of the paper will focus on adequate nutrition in developmental processes.

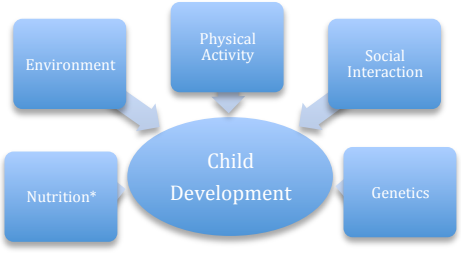

Figure 1: Factors influencing child development.

Key Dietary Factors for Physical Development:

The availability of high quality, nutrient-dense foods is essential to young children achieving their full growth and developmental potential. Several dietary factors play a particularly important role in development:

Energy: Energy (calorie) intake must match the high energy demand created by 1) linear growth, weight gain, and physiological development and 2) increases in physical activity that occur as children's motor skills advance. For young children, it is especially important to choose foods that not only meet their calorie needs but that are also concentrated with vitamins and minerals important to growth and development[5].

Protein: Protein serves as the building blocks for tissue deposition and growth, so protein needs remain high throughout the first 5 years of life[6]. Also, young children use amino acids from existing body proteins more readily to form glucose between meals. Therefore, maintaining high levels of circulating amino acids from foods consumed is important to prevent growing body tissues from breaking down to produce glucose[5].

Fats: In young children, dietary fat is a key source of energy for organs such as the liver, heart, and brain[5]. Research has shown that the type of fats that young children consume is of utmost importance to their physiological and cognitive development[7].

Vitamins and Minerals: Iron, zinc, calcium, vitamin D, and fluoride are particularly important to the overall development of young children[5-6]. Infants have sufficient iron stored in their tissues at birth for their first several months of life; however, after approximately 6 months, dietary iron is necessary to meet their needs. Iron deficiency in the early years of life is associated with long-term cognitive delays and behavioral problems[5]. Zinc is critical to the activity of hundreds of enzymes and the expression of many genes[7]. Zinc deficiency is associated with growth retardation and cognitive delays in young children[6]. Calcium and vitamin D are key contributors to proper bone growth[6]. Fluoride also assists in the formation of bone and is critical to tooth development and the prevention of dental caries[6]. The majority of these outcomes are related to young children's physical development; however, the rest of this paper will focus on the impact of dietary factors on cognitive development.

Key Dietary Factors for Cognitive Development:

The consumption of a high quality, nutrient-dense diet is important not only to a young children's overall development, but to cognitive development in this critical window. The first five years of life are a time of unparalleled changes in the anatomy and physiology of the brain[3]. These rapid physiological changes require specific vitamins and minerals, which are used for processes like tissue formation and synthesis of specific compounds.

Inadequate intake of specific vitamins and minerals such as iron, zinc, folate, iodine, and B vitamins is associated with deficits in brain development and cognitive functions such as language and memory[8]. The mechanisms through which these nutrient deficiencies cause delays in cognitive development are well understood.

Iron: Iron is involved in myelination, neurotransmitter synthesis, and brain tissue formation[8]. Iron deficiency in the early years is associated with long-term cognitive delays and behavioral deficits.

Zinc: Zinc facilitates the migration and formation of neurons and the creation of nerve synapses[8]. Zinc deficiency is associated with altered brain development and poor performance on tests of memory and attention[8].

Iodine: Iodine is required for the synthesis of thyroid hormones, which play a direct role in brain development[8].

B Vitamins: B vitamin deficiencies, such as folate and B12 deficiency, cause alterations in brain development and worse scores on cognitive achievement tests. These two B vitamins facilitate neurotransmitter synthesis and the creation of vasculature in the brain[8].

Essential Fatty Acids: Essential fatty acids such as eicosapentanoic acid (EPA) and docosohexanoic acid (DHA) are key components of hormones, steroids, and neuroactive compounds[5]. They are also required for neuronal membrane fluidity and brain cell composition[8]. EPA and DHA alone make up 20% of the brain's dry weight[7]. The critical role of each of these nutrients to brain and nervous system development underscores the importance of high quality, nutrient-dense dietary patterns in early life.

The State of Young Children's Diet Quality:

The research is clear that adequate food and nutrient intake plays a critical role in the growth and development of young children. The Dietary Guidelines for Americans encourage consumption of a variety of fruits and vegetables, whole grains, lean protein, and low-fat or fat-free milk and discourage consumption of sweetened beverages and foods high in sodium or solid fats[9]. Over the last several decades, there has been a shift in young children's diets away from these recommended nutrient-dense, home-prepared foods toward processed, convenience foods[10]. In fact, among children in the United States, the top three most commonly consumed foods are grain-based desserts, pizza, and soda or energy drinks[11].

The Feeding Infants and Toddlers Study takes a closer look at food consumption patterns of children ages 0 to 3 years[12]. Data from this study demonstrate that young children's diets do not align with the dietary guidelines for nearly every food group:

- Among infants, too few consume iron-fortified cereals and too many consume ready-to-eat cereals[13].
- In children ages 2 and 3, more than 25% of all children do not consume a vegetable and 13% of children do not consume fruit or 100% fruit juice during the day[13].
- The most commonly consumed vegetable among two and three year olds is french fries[13].
- Eighty six percent of children consume a sweetened beverage, dessert, or salty snack daily[13].

Collectively, these findings are indicative of the national shift away from nutrient-dense, home-prepared foods toward processed and convenience foods dense in energy but deficient in important nutrients. This shift away from nutrient-dense dietary patterns has the potential to create subtle, subclinical deficiencies in important nutrients that could impact cognitive development through the same mechanisms detailed in the previous section.

Children living in low-income households are at an increased risk of consuming processed dietary patterns. In the United States, higher quality diets are often more expensive, according to some studies[14-15]. Low-income households often lack the resources necessary to purchase high-quality and nutrient dense foods. In the United States, 21.4 percent of children experience some form of food insecurity[16]. Lacking consistent access to sufficient high quality, nutritious food too often translates into worse developmental and cognitive outcomes for low-income children[1, 17-18]. Children in food insecure households have higher rates of hospitalization, behavioral problems, chronic health conditions, colds, and anxiety and depression[17]. Particularly relevant to this paper, food insecure children often have worse cognitive outcomes than their food secure peers ranging from lower math and reading scores to deficits in attentiveness and self-control[17, 19].

These relationships between food insecurity, processed dietary patterns, and poor cognitive outcomes in low-income children and the general population may be emerging because diets high in processed foods lack important vitamins and minerals and provide excessive amounts of solid fats and sugar. When comparing a "processed" dietary pattern to a "health conscious" and a "traditional" dietary pattern in a large cohort of young children, researchers found significant differences in intake of specific nutrients based on a child's dietary pattern[20]. As would be expected, the "processed" dietary pattern high in chips, pizza, burgers, sweets, and ice cream was positively associated with high intakes of

calories, total fat, and sugar, and negatively associated with vitamin and mineral intake[20]. The "health conscious" and "traditional" diet patterns were associated with more favorable nutrient profiles, particularly for protein, fiber, potassium, magnesium, iron, zinc, and several B vitamins[20].

Clearly, research demonstrates that young children, particularly those in the lowest-income groups, are increasingly consuming diets deficient in nutrients of utmost importance to their health and cognitive development. The Dietary Guidelines for Americans (DGA's) establish recommendations for healthy eating patterns that ensure individuals receive the nutrients they need to promote health and prevent disease[9]. In order to ensure adequate intake of the nutrients detailed in previous sections such as iron and zinc, the DGA's recommend increasing consumption of fruits, vegetables, low-fat milk, lean meats, whole grains, and oils[9]. These foods are rich in the nutrients that support both physical and cognitive development. The DGA's encourage individuals to limit their consumption of sodium, saturated and trans fats, cholesterol, and refined grains[9]. These dietary factors are common ingredients in processed and convenience foods. The current shift away from dietary patterns centered on nutrient-dense, freshly prepared foods toward those high in convenience and processed foods clearly has serious implications for the nutrient intake and development of young children.

Although data indicate a poor state of nutrient intake for some children, how this affects development, specifically cognitive development, has not been well-described. No systematic review of the literature currently exists on this important topic; thus, such a review was undertaken.

Review of the Research on Dietary Patterns and Cognitive Development:

Search Terms and Databases: In order to understand the link between dietary patterns and cognitive development a systematic review of the literature was conducted. The databases used included: PubMed, Google Scholar, PsychInfo (psychology), and Eric (education). The search terms used in each database were: preschool, preschooler, toddler, child*, young child*, cognition, academ*, test score*, cognitive development, brain development, school*, IQ, intelligence quotient, diet* quality, diet* pattern, nutrient density, and food quality. Relevant articles were also identified using the references of articles found through these databases.

Inclusion and Exclusion Criteria: Titles and abstracts were reviewed to eliminate articles that did not include both a dietary assessment and a measure of cognitive function (e.g., a 24-hour recall and a WISC III test). Articles were also excluded if they did not use a quantitative assessment of the relationship between dietary patterns and cognitive function. Additionally, articles were only included if the study population was recruited from a developed nation with dietary patterns similar to those in the United States (e.g. the United Kingdom, Australia). Lastly, articles studying children older than 5 years of age were excluded.

Search Results: From this systematic review, 8 papers that met the search criteria were identified. These articles are cohort and cross-sectional studies with sample sizes ranging from 241 to 7052 children. All studies showed some association between dietary patterns and cognitive development, although some age groups or dietary patterns within individual studies did not show any association. Only one dietary pattern, snacking, reported in a single study, did not support the hypotheses that dietary patterns high in nutrient-dense foods are associated with improved cognitive outcomes and dietary patterns high in processed, convenience foods are associated with worse cognitive outcomes. Analyses used in all but one of these studies controlled for important variables such as family income, education, race/ethnicity, and/or home environment characteristics.

The findings from this systematic review are summarized in the Table**,** which defines each of the dietary patterns or food groups studied and their influence on cognitive development. Some of the studies

included in the Table (e.g., Smithers 2012, Northstone 2010) studied the effects of multiple dietary patterns, so they appear more than once in the table. Additionally, some of the dietary patterns—particularly the traditional pattern—show both positive and negative effects on cognitive development in different studies. These varying results suggest the research is inconclusive on some dietary patterns and more research is warranted to obtain a clear understanding of the association.

Table: Summary of Research Findings.

First Author and Year of Publication	Age Group Enrolled	Dietary Pattern or Food Group	Description of Dietary Pattern	Influence on Cognitive Development
Nyaradi 2013	1-3 years (n=2868)	Healthy	Closely aligns with dietary guidelines.	Positive
Smithers 2012	6 months (n=7052)	Traditional	Home-prepared meats, vegetables, desserts.	Positive
Smithers 2013	6-24 months (n=4478)	Healthy	Breastfeeding or formula, raw fruits and vegetables, legumes, nuts, fish.	Positive
Smithers 2012	15 months (n=5610)	Contemporary	Legumes, eggs, raw fruits and vegetables.	Positive
Gale 2009	6 and 12 months (n=241)	Infant Guidelines	Fruits, vegetables, home prepared foods and breast milk.	Positive
Northstone 2011	3 years (n=7044)	Snack	Fruit, biscuits, bread, and cakes.	Positive
Von Stumm 2012	3 and 5 years (n=4194 and 3833)	Slow Meals	Home prepared meals with fresh ingredients and food from sit-down restaurants.	Positive
Nyaradi 2013	2 and 3 years (n= 2868)	Dairy	Milk, yogurt, cheese etc.	Positive
Theodore 2009	3.5 years (n=591)	Breads or cereals	Eating breads or cereals 4 or more times a day.	Positive
Nyaradi 2013	1 year (n= 2868)	Fruit	Fruits.	Positive
Feinstein 2007	3 years (n=5741)	Junk Food	Sausages, chips, chocolate, soda, take-out, etc.	Negative
Nyaradi 2013	1-3 years (n= 2868)	Unhealthy	Does not align closely with dietary guidelines.	Negative

Smithers 2013	6-24 months (n=4478)	Traditional	Potatoes, meat, vegetables.	Negative
Northstone 2011	3 years (n=7044)	Processed	High fat and high sugar foods and convenience foods.	Negative
Smithers 2013	6 -24 months (n=4478)	Discretionary	Chips, cookies, soda, chocolate, etc.	Negative
Von Stumm 2012	3 and 5 years (n=4193 and 3833)	Fast Meals	Take-away, frozen, fast food.	Negative
Smithers 2012	6, 15, and 24 months (n=7052, 5610, and 6366)	Discretionary	Cookies, sweets, chips, etc.	Negative
Smithers 2012	6, 15, and 24 months (n=7052, 5610, and 6366)	Ready To Eat	Commercially manufactured foods.	Negative
Nyaradi 2013	1 year (n= 2868)	Sweetened Beverages	Juice that is not 100% fruit juice, sodas, sweet tea, sports drinks, etc.	Negative
Theodore 2009	3.5 years (n=591)	Margarine	Eating margarine 1 or more times a day.	Negative

Nutrient-Dense Dietary Patterns and Cognitive Outcomes: Nutrient-dense dietary patterns are those that generally include fresh fruits and vegetables, lean protein, whole grains, and low-fat dairy. Five of the studies included demonstrated positive associations between nutrient-dense dietary patterns and cognitive outcomes among children less than 5 years old[21-25]. Two studies found no association[26-27]. Each the studies of children less than 3 years old and one study in children ages 3 and 5 demonstrated positive associations between nutrient-dense dietary patterns and cognitive development at later time points[21-25]:

- In a study of diet in the first 3 years of life, Nyaradi et al. found that at age 1 the more closely children's dietary patterns aligned with dietary guidelines, the higher verbal and non-verbal IQ scores were at age 10. This positive association was also found for 2 and 3 year old children; however, the relationship was not as strong[21]. This evidence may suggest a critical window for development at 1 year of age.
- Smithers et al. studied dietary patterns of children between ages 6, 15, and 24 months and found that 'healthy' dietary patterns at all three ages (defined by breastfeeding or formula, raw fruits and vegetables, legumes, nuts, fish, etc.) were positively and significantly associated with

full scale IQ (FSIQ) and verbal IQ (VIQ) at 8 years of age[23]. However, there was no association found between 'healthy' dietary patterns at all three ages and FSIQ at 16 years of age[23].

- In a similar study of children 6, 15, and 24 months old, Smithers et al. found that at 15 months, a 'contemporary' dietary pattern (legumes, eggs, raw fruits and vegetables) was positively associated with FSIQ, VIQ and PIQ at 8 years[22]. Lastly, a 'contemporary' dietary pattern at 24 months was positively associated with FSIQ and VIQ at age 8[22].
- Gale et al. found that dietary patterns aligned with infant dietary guidance (high in fruits, vegetables, home prepared foods and breast milk, low in formula and canned baby food) at 6 and 12 months were positively and significantly associated with FSIQ at 4 years of age[24]. There was no association found between healthier dietary patterns and additional cognitive outcomes measured such as verbal fluency and visual attention[24].
- When one group of researchers assessed the relationship between dietary patterns at 3 and 4 years old and cognitive outcomes at 8.5 years, they did not find a significant relationship between a 'health conscious' (salads, fruits, vegetables, fish) dietary pattern and IQ scores[26]. Interestingly, a 'snack' dietary pattern (fruit, biscuits, bread, and cakes) at age 3 was associated with improved IQ at age 8.5[26].
- Similarly, Feinstein et al did not find a significant association between a 'healthy' dietary pattern (nuts, salad, fish, fruit, cheese) at ages 3 and 4 and English, math and science scores at ages 6-7 or ages 10-11[27]. However, significant negative associations were found between 'junk food' dietary patterns (sausages, chips, chocolate, soda, take-out) at 3 years and test scores at later time points[27].
- Lastly, in a study of the effects of 'slow meals' (home prepared with fresh ingredients and sit-down restaurants) and 'fast meals' (take-away, frozen, fast food), researchers found that slow meals at age 3 and 5 were positively associated with scores on a vocabulary test at ages 3 and 5 and scores on a picture similarity test at age 3[25].

Traditional Dietary Patterns and Cognitive Outcomes: Traditional dietary patterns are high in cooked meats, potatoes, and cooked vegetables. Four of the eight studies measured the relationship between 'traditional' dietary patterns and cognitive outcomes[22-23, 26-27]. Two studies found no association, one study found a positive association, and one study found a negative association with cognitive development:

- In a study of dietary patterns at age 3 and 4 and English, math and science scores at ages 4-5, 6-6, and 10-11, researchers did not find a significant association between 'traditional' dietary patterns (meats and cooked vegetables) and test scores[27].
- Northstone et al. surveyed the relationship between dietary patterns at ages 3 and 4 on IQ at 8.5 years[26]. They did not find a relationship between a 'traditional' (meats, potatoes, vegetables) dietary pattern at ages 3 and 4 and IQ at age 8.5[26].
- In a study of children's dietary patterns at 6, 15, and 24 months, researchers found that the 'home-made traditional' dietary pattern (home-prepared meats, vegetables, desserts) at 6 months was positively associated with FSIQ, VIQ, and performance IQ at age 8[22].
- Similarly, in a study of dietary patterns from 6 to 24 months, researchers found that consistently consuming a 'traditional' dietary pattern (potatoes, meat, vegetables) between 6 and 24 months was negatively associated with IQ at 8 and 15 years of age[23]. This relationship was only statistically significant at 15 years of age[23].

***Processed and Convenience Dietary Patterns and Cognitive Outcomes*:** Processed and convenience dietary patterns generally consist of ready-made foods that contain higher than the recommended

amounts of sodium, added sugars, and solid fats. Six of the eight studies found significant negative associations between dietary patterns high in processed or convenience foods in early childhood and cognitive development[21-25, 27]. One study found no association and interestingly one study found that a 'snack' dietary pattern was positively associated with cognition[26].

- Similar to the results from Nyaradi et al. described above, these researchers also found at age 1 that the more dietary patterns differed from the dietary guidelines, the lower verbal and non-verbal IQ scores were in children at age 10[21]. They observed a similar association in children ages 2 and 3, but the relationship was not statistically significant[21].
- In a study assessing the effect of dietary patterns at ages 3,4, 7 and 8.5 years and IQ at 8.5, researchers found a 'processed' diet pattern (high fat and high sugar foods and convenience foods) at age 3 was associated with significant decreases in IQ at 8.5[26]. Interestingly, a 'snack' pattern (fruit, breads, cakes) at age 3 is also associated with increases in IQ at age 8.5[26]. These findings may suggest a critical window for the influence of dietary patterns around age 3[26].
- Smithers et al found that a 'discretionary' (chips, cookies, soda, chocolate) dietary pattern at all 3 time points of 6, 15, and 24 months of age was negatively associated with IQ at 8 and 15 years[23]. However, this association was only statistically significant at 15 years of age[23]. They did not find a relationship between the 'ready-to-eat' dietary pattern (ready-made convenience foods) at these three ages and IQ[23].
- In a study of dietary patterns effects on English, math and science test scores, Feinstein et al found that the 'junk food' dietary pattern (sausages, chips, chocolate, soda, take-out) at age 3 was associated with worse test scores at ages 4-5, 6-7, and 10-11 [27]. Again, these data may suggest a critical window for the negative influence of processed dietary patterns around 3 years of age.
- Von Stumm et al found that dietary patterns higher in 'fast meals' (take-away, frozen, fast food) at ages 3 and 5 were associated with worse scores on vocabulary tests at ages 3 and 5 and picture similarity tests at age 3[25].
- In a study of dietary patterns of children 6 and 12 months old, researchers found no association between an 'adult' dietary pattern (chips, cookies, breakfast cereals) and cognitive outcomes at 4 years of age[24].
- Lastly, one study demonstrated that 'discretionary' (cookies, sweets, chips) and 'ready-prepared baby foods' (commercially manufactured foods) patterns at 6 months and 15 months were negatively associated with FSIQ and VIQ at 8 years[22]. Similarly, at 24 months, 'discretionary' and 'ready-to-eat foods' patterns were associated with decreases in FSIQ at 8 years[22].

Food Groups and Cognitive Outcomes:

Two of the studies did not assess dietary patterns alone, but also looked at the relationship between food groups consumed in early childhood (e.g., fruits, breads, sodas) and cognitive development[21, 28].

- Nyaradi et al. found that higher consumption of fruits at age 1 was positively associated with verbal IQ, but higher consumption of sweetened beverages was negatively associated with verbal and non-verbal IQ at age 10[21]. At ages 2 and 3, higher consumption of dairy was positively associated with verbal and nonverbal IQ at age 10[21].
- Another study found that at age 3.5, eating breads or cereals more than four times each day was associated increases in IQ at 3.5 years[28]. Additionally, daily consumption of margarine at age 3.5 was associated with decreases in IQ at 3.5 years[28].

Interpretation of Research Findings: Overall, these studies suggest there is likely an important link between dietary patterns early in childhood and cognitive development. Among this small number of

studies, there appears to be a distinction between the effects of dietary patterns before and after age 3. In the earlier years, these studies suggest the presence of nutrient-dense foods exerts a stronger effect than the presence of processed or convenience foods. However, after age 3 diet patterns excessive in calories, added sugars, and fat seem to have a strong negative impact on cognitive development. Both of these findings emphasize the importance of diets high in nutrient-dense, fresh foods and low in processed, convenience foods during this time of rapid brain development. While the exact mechanisms of these relationships cannot be determined, research has shown that these two diet patterns, healthy and processed, differ greatly in content of vitamins and minerals important to cognitive development[20]. It is also important to acknowledge that in many of the studies described above, the relationships observed were less robust after confounding variables such as socioeconomic status, parental education, and family income were taken into account. These findings suggest that dietary patterns are one of many factors that influence cognitive development in the early years[7].

The Role of Federal Food Programs in Fostering Cognitive Development:

The available evidence shows that early childhood dietary patterns are associated with cognitive development. Low-income children are particularly at risk of the worse cognitive outcomes associated with poor dietary patterns due to lack of sufficient household resources to purchase high-quality, nutrient dense foods[29]. In the United States, processed foods higher in fat and sugar and lower in important micronutrients are generally less expensive[14-15]. Given what is known about food cost and food quality, federal food programs such as the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) and the Child and Adult Care Food Program (CACFP) provide a critical safety net for young children and play an important role in buffering the relationship between income, diet quality, and cognitive outcomes (Figure 2).

Figure 2: Theoretical relationship between food insecurity and cognitive development.

WIC: The WIC program provides supplemental nutritious foods, nutrition education, and health screenings for pregnant and postpartum women and infants and children up to 5 years of age who are at nutritional risk[30]. Over 8.6 million Americans receive nutritious foods each month as a result of the WIC program[30]. There is a wealth of evidence that supports the WIC program as vitally important to ensuring that low-income infants and children maintain the high-quality dietary patterns associated with improved cognition. In 2007, the WIC food package was revised to align more closely with current science and dietary guidelines[31]. The new food package emphasizes fruits, vegetables, whole grains, limits saturated fat, and allows for substitutions and more diverse food choices[31]. The studies detailed below focus on the benefits of the old WIC food package prior to the improvements:

- In one study, researchers found that participation in the WIC program was positively associated with the intake of 10 nutrients (protein, vitamin E, several B vitamins, magnesium, iron, and folate). These results are particularly important given the well-understood relationship between B vitamins, iron, zinc, and cognitive development[32].
- In another study comparing WIC participants to income-eligible non-participants, researchers found that WIC participation was positively associated with intakes of iron, folate, vitamin B6, vitamin C, and vitamin A. These researchers were also able to conclude that the differences observed were due to increased nutrient density of the foods provided through the WIC

program, not as a result of increased consumption of food energy (calories) by WIC participants[33].

- In a study of the food intake and snacking behavior patterns of WIC participants, researchers found that WIC participation was associated with lower total intakes of fat and added sugars and higher intakes of carbohydrates, fruits and vegetables, and iron. Additionally, WIC participation was associated with a lower prevalence of snacking[29].
- In a study of the nutrient intakes and dietary patterns of WIC participant children and income-eligible non-participant children, researchers showed that WIC participation was associated with significantly less consumption of solid fats and added sugars, both of which are commonly associated with dietary patterns high in processed and convenience foods. Additionally, WIC participants had significantly higher scores on a "Nutrient-Rich Score" (a measure of the ratio of nutrients to calories) of their overall diets than income-eligible non-participants[34].

These studies demonstrate the long-standing positive influence of the WIC program on the nutrient intake of low-income children in America. Emerging research on the benefits of the recent changes to the WIC food package suggests that the changes have significantly increased young children's intakes of nutrient-dense foods such as fruits, vegetables, low-fat milk, and whole grains[35-37]. These foods are rich in the nutrients that support optimal cognitive development. Therefore, it is highly likely that emerging research on the nutritional and developmental benefits of the WIC program will show similar or improved results compared to the data presented above. Clearly, the WIC program plays a critical role in fostering the cognitive development of the children that participate.

CACFP: The CACFP program provides reimbursements for meals served in child care centers, family day care homes, at-risk afterschool care centers, adult day care centers, and emergency shelters[38]. More than 120,000 adults and 3.3 million children receive nutritious foods every day as a result of the CACFP program[38]. Research supports the important role that CACFP plays in improving the dietary patterns and, in turn, the cognitive development of the children that it serves:

- In one study comparing child care centers participating in CACFP and those not participating, CACFP centers were more likely to serve fruits, vegetables, milk, and less likely to serve sweetened beverages and other sweets[39].
- Another study assessing CACFP's role in the nutrition of preschoolers found that children participating in CACFP were more likely to consume the recommended amounts of milk and vegetables than non-participating children[40].
- Bruening et al. compared nutrient intakes and health outcomes for children in 2 child care centers, one participating in CACFP and one not participating. Children at the participating center had higher intakes of milk, vegetables, vitamin A, B vitamins, iron, zinc, magnesium, and calcium and lower intakes of fats and sweets. Also, children participating in CACFP were less likely to experience absences due to illness[41].
- Lastly, a study by the Economic Research Service showed that children participating in CACFP were more milk and fruit and less fat, soda, and added sugars. CACFP participants were also more likely to consume a greater variety of foods[42].

The research clearly demonstrates that federal nutrition programs such as WIC and CACFP are vital to improving the dietary quality of the low-income children that participate. Given what is known about the role of dietary patterns and cognitive development, federal nutrition programs are one of several integral components to fostering optimal cognitive development in our nation's youngest and most vulnerable children.

Conclusions:

The positive influence of high-quality nutrition on cognition in the first year of life is well understood. This brief highlights the importance of maintaining high quality, nutrient-dense dietary patterns as young children transition to their first foods and establish lifelong dietary patterns. The finding that dietary patterns high in processed or convenience foods, particularly around the age of 3, have negative effects on cognitive outcomes later in childhood has serious implications. Low-income children are at increased risk of poor dietary patterns due to lack of sufficient household resources. Federal nutrition programs such as WIC and CACFP play a critical role in improving dietary patterns and ensuring adequate nutrient intake for the nation's most at-risk children. We should continue our support and investment in these programs to safeguard not only young children's dietary adequacy, but also to improve cognitive outcomes, close gaps in school achievement, and provide opportunities for all children to achieve their optimal growth and developmental potential.

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