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Obesity, Metabolic Syndrome, and Nutrition

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Introduction

Childhood obesity is a significant global health issue with serious implications for the well-being of children and society at large. It adversely affects both physical and mental health and often continues into adulthood, increasing the risk of morbidity and mortality. The multifaceted nature of childhood obesity arises from a complex interplay of genetic, environmental, socioeconomic, and behavioral factors.

Nutrition plays a significant role in both the prevention and management of childhood obesity. Despite substantial efforts, numerous challenges remain in addressing this issue and promoting healthy nutrition. These challenges include socioeconomic disparities in access to nutritious food, pervasive marketing of unhealthy foods to children, inadequate nutrition education, and cultural norms surrounding food and eating behaviors.

Early-life conditions significantly impact the physiology and metabolism of the unborn child, contributing to the early shaping of human health. Several studies reviewed in this chapter examine in utero exposures such as maternal weight, maternal gestational diabetes, maternal diet quality during pregnancy and postpartum, and maternal supplementation during pregnancy with folic acid, docosahexaenoic acid, and fish oil. These studies explore the associations between these factors and the subsequent development of childhood obesity and cardiometabolic risk in offspring.

Early-life nutrition also plays a significant role in lifelong health. Some studies evaluated breastfeeding as a preventive measure against obesity and examined the content of infant formula as a factor influencing childhood adiposity, insulin resistance, and cardiometabolic risk. Additionally, one study assessed the impact of the timing and quality of complementary food introduction in infancy on ectopic fat deposition in childhood.

Further studies investigated the impact of diet composition and mineral intake during childhood on adiposity. A healthy diet is essential for fostering healthy growth and preventing future diseases. The global increase in ultra-processed food consumption has contributed to rising obesity trends. Children with obesity are at higher risk of developing obesity-related comorbidities. A systematic review presented in this chapter reports on the impact of ultra-processed food intake on obesity and cardiometabolic comorbidities in children and adolescents.

In this year's edition of the yearbook chapter focused on the relationship between nutrition and obesity, we conducted a Medline search for articles dealing with the following topics: nutrition and obesity and nutrition and cardiometabolic comorbidities from infancy to childhood and young adulthood. We selected 14 notable articles from many meritorious manuscripts that offer some insight into these issues published in the past year between July 2023 and June 2024.

Key articles reviewed for this chapter

Maternal Diet during Pregnancy and Risk of Childhood Obesity

Relationships of pregnancy and postpartum diet quality with offspring birth weight and weight status through 12 months
Lipsky L, Cummings J, Siega-Riz AM, Nansel T
Obesity (Silver Spring) 2023;31:3008–3015

Maternal folic acid supplementation during pregnancy in association with childhood overweight or obesity
Hung CY, Lee HJ, Tsai ZT, Huang SJ, Huang HY, Tsai HJ, Yao TC
Obesity (Silver Spring) 2024;32:1179–1186

Effects of prenatal docosahexaenoic acid supplementation on offspring cardiometabolic health at 11 years differs by maternal single nucleotide polymorphism rs174602: follow-up of a randomized controlled trial in Mexico
Wimalasena ST, Ramírez-Silva CI, Gonzalez Casanova I, Stein AD, Sun YV, Rivera JA, Demmelmair H, Koletzko B, Ramakrishnan U
Am J Clin Nutr 2023;118:1123–1132

Fish oil supplementation during pregnancy, anthropometrics, and metabolic health at age ten: a randomized clinical trial
Vinding RK, Sevelsted A, Horner D, Vahman N, Lauritzen L, Hagen CP, Chawes B, Stokholm J, Bønnelykke K
Am J Clin Nutr 2024;119:960–968

Randomization to a provided higher-complex-carbohydrate versus conventional diet in gestational diabetes mellitus results in similar newborn adiposity
Hernandez TL, Farabi SS, Fosdick BK, Hirsch N, Dunn EZ, Rolloff K, Corbett JP, Haugen E, Marden T, Higgins J, Friedman JE, Barbour LA
Diabetes Care 2023;46:1931–1940

Associations among prenatal exposure to gestational diabetes mellitus, brain structure, and child adiposity markers
Luo S, Hsu E, Lawrence KE, Adise S, Pickering TA, Herting MM, Buchanan T, Page KA, Thompson PM
Obesity (Silver Spring) 2023;31:2699–2708

Nutrition during Infancy and Risk of Childhood Obesity

Maternal pre-pregnancy BMI, breastfeeding, and child BMI
Shipp GM, Wosu AC, Knapp EA, Sauder KA, Dabelea D, Perng W, Zhu Y, Ferrara A, Dunlop AL, Deoni S, Gern J, Porucznik C, Aris IM, Karagas MR, Sathyanarayana S, O'Connor TG, Carroll KN, Wright RJ, Hockett CW, Johnson CC, Meeker JD, Cordero J, Paneth N, Comstock SS, Kerver JM; program collaborators for Environmental influences on Child Health Outcomes
Pediatrics 2024;153:e2023061466

Low-protein infant formula enriched with alpha-lactalbumin during early infancy may reduce insulin resistance at 12 months: a follow-up of a randomized controlled trial
Tinghäll Nilsson U, Lönnerdal B, Hernell O, Kvistgaard AS, Jacobsen LN, Karlsland Åkeson P
Nutrients 2024;16:1026

Infant milk formula with large, milk phospholipid-coated lipid droplets enriched in dairy lipids affects body mass index trajectories and blood pressure at school age: follow-up of a randomized controlled trial
Abrahamse-Berkeveld M, Jespers SN, Khoo PC, Rigo V, Peeters SM, van Beek RH, Norbruis OF, Schoen S, Marintcheva-Petrova M, van der Beek EM, Stoelhorst GM, Vandenplas Y, Hokken-Koelega AC; Mercurius Study Group
Am J Clin Nutr 2024;119:87–99

Nutrition during Childhood and Risk of Childhood Obesity

Epigenome-wide meta-analysis reveals associations between dietary glycemic index and glycemic load and DNA methylation in children and adolescents of different body sizes
Ott R, Stein R, Hauta-Alus HH, Ronkainen J, Fernández-Barrés S, Spielau U, Kirsten H, Poulain T, Melton PE, Küpers LK, Azaryah H, Colombo M, Landgraf K, Tobi EW, O'Sullivan T, Huang RC, Campoy C, Winkler C, Vioque J, Vrijheid M, Kiess W, Körner A, Sebert S, Jarvelin MR, Ziegler AG, Hummel S
Diabetes Care 2023;46:2067–2075

Association between minerals intake and childhood obesity: a cross-sectional study of the NHANES database in 2007–2014
Wang L, Liu W, Bi S, Zhou L, Li L
PLoS ONE 2023;18:e0295765

Longitudinal associations between diet quality, sedentary behaviours and physical activity and risk of overweight and obesity in preschool children: the ToyBox-study
Miguel-Berges ML, Mouratidou T, Santaliestra-Pasias A, Androutsos O, Iotova V, Galcheva S, De Craemer M, Cardon G, Koletzko B, Kulaga Z, Manios Y, Moreno LA; on behalf of the ToyBox-study group
Pediatr Obes 2023;18:e13068

Nutrition and Risk of Obesity-Related Comorbidities

Associations of infant feeding practices with abdominal and hepatic fat measures in childhood in the longitudinal Healthy Start Study
Cohen CC, Harrall KK, Hu H, Glueck DH, Perng W, Shankar K, Dabelea D
Am J Clin Nutr 2024;119:560–568

The impact of ultra-processed foods on obesity and cardiometabolic comorbidities in children and adolescents: a systematic review
Petridi E, Karatzi K, Magriplis E, Charidemou E, Philippou E, Zampelas A
Nutr Rev 2024;82:913–928

Relationships of pregnancy and postpartum diet quality with offspring birth weight and weight status through 12 months

Lipsky L[1], Cummings J[1,2], Siega-Riz AM[3,4], Nansel T[1]

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Comments: Understanding influences on infant weight status is critical for preventing child obesity risk. Maternal pregnancy nutrition is an important factor on fetal growth. In fact, available data have documented lower odds for macrosomia and multiple indicators of lower neonatal adiposity and weight status (e.g., skinfolds, fat mass, and size-for-gestational-age) are associated with several condition including a lower maternal high-fat diet, higher protein diet, greater intake of fruit and pulses, healthier data-derived dietary patterns, and higher scores on a priori diet quality indices. However, still few data characterizing the relationship of pregnancy and postpartum diet quality with weight status throughout infancy are available. In this prospective, observational study, Lipsky et al. by evaluating data from the Pregnancy Eating Attributes Study (PEAS) (a prospective cohort study of women enrolled in early pregnancy and followed up through 12 months postpartum) were able to show that a higher maternal diet quality was associated with lower infant weight-for-length Z-scores and body mass index Z-scores throughout the first year of life. Associations were driven by the moderation components of the Healthy Eating Index (HEI), suggesting that maternal pregnant and postpartum intake of refined grains, added sugars, fatty acids, sodium, and saturated fat is more strongly associated with infant weight outcomes than intake of adequacy components (i.e., fruit, vegetables, whole grains, dairy, and protein foods). Higher pregnancy diet quality was associated with lower large for gestational age child at birth and lower infant age- and sex-specific body mass index Z-scores and weight-for-length Z-scores from birth through age 12 months. In infants who received any breast milk for at least 6 months, maternal postpartum diet quality was associated with lower age- and sex-specific BMI Z-scores and weight-for-length Z-scores from birth through age 12 months, whereas the estimated associations were closer to zero and not statistically significant in infants who were breastfed for fewer than 6 months. Therefore, taken together, these results stress the relevance of adopting strategies aimed to increase maternal adherence to the dietary guidelines for Americans during pregnancy and postpartum, which may lead to lower offspring weight status throughout infancy.

Maternal folic acid supplementation during pregnancy in association with childhood overweight or obesity

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Comments: Nutrition during pregnancy may influence susceptibility to obesity through epigenetic mechanisms, such as alterations in methylation levels that modify gene expression patterns. Folate intake during pregnancy, as well as the maternal methyltetrahydrofolate reductase (MTHFR) C677T genotype, affects the availability of methyl donors for methylation during gestation. This may, in turn, be associated with offspring body composition in childhood. At present, there is insufficient evidence on whether prenatal folic acid supplementation can have an effect on early childhood health.

A previous study [1] investigated the associations between maternal folic acid supplementation at 18 and 32 weeks of pregnancy, dietary folate intake at 32 weeks of pregnancy, and offspring body composition at age nine in a large cohort of UK children. This study did not find evidence supporting the hypothesis that intrauterine folate exposure influences childhood body composition. In contrast, a prospective birth cohort study from the United States [2] examined whether maternal folate concentrations significantly affect child metabolic health and whether sufficient maternal folate levels can mitigate the metabolic risks associated with pre-pregnancy obesity. This study found an L-shaped association between maternal plasma folate concentrations and child overweight or obesity in an urban low-income population, highlighting the benefits of sufficient folate concentrations, especially among obese mothers. However, maternal plasma folic acid concentrations in this study reflected both dietary intake and folic acid supplementation during pregnancy.

The current study provides further evidence that maternal folic acid supplementation during pregnancy is significantly associated with a decreased risk of childhood overweight, obesity, and body fat percentage, particularly after adjusting for relevant confounding factors. The findings suggest that the beneficial effects of maternal folic acid supplementation on reducing obesity risk may be more pronounced among children with obesity risk factors, such as lack of breastfeeding and low parental educational levels.

The study's strengths include a large population-based cohort and the use of body fat percentages as an objective marker of adiposity. However, limitations include the retrospective self-reporting of maternal folic acid supplementation, which may be subject to recall bias, and the lack of data on dietary folate intake and the dose and timing of folic acid supplementation during pregnancy.

Over the past few decades, folic acid supplementation during pregnancy has been recommended in many countries to prevent neonatal neural tube defects. This study illuminates additional beneficial effects of folic acid supplementation during pregnancy, suggesting potential benefits beyond neurodevelopment that may extend to obesity prevention.

Effects of prenatal docosahexaenoic acid supplementation on offspring cardiometabolic health at 11 years differs by maternal single nucleotide polymorphism rs174602: follow-up of a randomized controlled trial in Mexico

Wimalasena ST[1], Ramírez-Silva CI[2], Gonzalez Casanova I[3], Stein AD[1,4], Sun YV[5], Rivera JA[2], Demmelmair H[6], Koletzko B[6], Ramakrishnan U[1,4]

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Comments: Docosahexaenoic acid (DHA) is an omega-3 long-chain polyunsaturated fatty acid (LC-PUFA) that plays a crucial role during the latter half of pregnancy, supporting optimal fetal tissue development, immune function, and DHA deposition in fetal tissues. Animal models and epidemiological studies indicate that variations in prenatal DHA supply may affect long-term cardiometabolic risk in offspring by influencing cell and organ development, gene expression, and neuroendocrine signaling pathways.

Observational studies in humans [3] have linked higher maternal omega-3 LC-PUFA status during pregnancy with reduced adiposity, dyslipidemia, and leptin levels in offspring during early to mid-childhood. Moreover, prenatal DHA supplementation appears particularly advantageous for mother-offspring pairs, especially among overweight or obese women. This supplementation enhances maternal insulin sensitivity, improves lipid profiles, and reduces placental inflammation, thereby potentially mitigating fetal overnutrition and adiposity [4]. Tissue LC-PUFA concentrations are determined by dietary intake of omega-6 and omega-3 LC-PUFAs and the endogenous conversion from dietary PUFA precursors. This conversion involves a series of desaturation and elongation steps, with the rate-limiting desaturase steps mediated by Δ-6 and Δ-5 desaturase enzymes encoded by the fatty acid desaturase (*FADS*) gene cluster (*FADS1*, *FADS2*, *FADS3*). Notably, the maternal *FADS2* SNP rs174602 has been shown to influence the impact of prenatal DHA supplementation on offspring birth weight [5] and metabolome at 3 months of age [6].

In the present study, prenatal DHA supplementation exhibited no overall effect on offspring cardiometabolic health at 11 years of age. However, outcomes varied based on maternal *FADS2* SNP rs174602 variants. Offspring of mothers who were

homozygous for the minor allele (TT) and received prenatal DHA supplementation had lower metabolic syndrome (MetS) scores compared to those in the placebo group. Conversely, offspring of mothers homozygous for the major allele (CC) who received DHA supplementation had higher MetS scores compared to those whose mothers received a placebo. These findings suggest that the effects of prenatal DHA supplementation on long-term cardiometabolic risk in children may be influenced by the mother's genotype. Individuals with genotypes associated with lower endogenous conversion to DHA might be at a higher risk of DHA deficiency and could benefit more from supplementation with preformed DHA.

The study's strengths include its double-blind randomized controlled trial (RCT) design, high compliance with the prenatal intervention, comprehensive characterization of mothers and children throughout the trial, long follow-up duration, and availability of genetic data. The study sample was representative of a population with low dietary intakes of preformed DHA, high dietary intakes of omega-6 fatty acids, and a high prevalence of alleles associated with lower conversion of precursor PUFAs into LC-PUFAs.

However, the study also has limitations. Dietary data were collected via a single 24-h recall, which may introduce recall bias. Additionally, the trial was not originally designed to assess offspring cardiometabolic health, leading to small sample sizes and potentially limited statistical power to detect differences by treatment group or genotype. While the study highlights the potential importance of maternal *FADS* genotype in guiding supplementation strategies, the role of offspring genotype remains uncertain. These findings highlight the importance of incorporating genetic analysis of *FADS* polymorphisms in DHA supplementation trials. Such analyses may ultimately help develop targeted supplementation recommendations early in life to improve cardiometabolic health in clinical settings.

Fish oil supplementation during pregnancy, anthropometrics, and metabolic health at age ten: a randomized clinical trial

Vinding RK[1], Sevelsted A[1], Horner D[1], Vahman N[1], Lauritzen L[2], Hagen CP[3,4], Chawes B[1], Stokholm J[1,5], Bønnelykke K[1]

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Comments: Maternal obesity during pregnancy can lead to systemic inflammation and an exaggerated form of insulin resistance, particularly in the latter half of pregnancy. This condition results in an increased delivery of lipids and glucose to the fetus, which can

lead to higher birth weight and greater body fat in the offspring. The underlying mechanism involves alterations in gene expression mediated by epigenetic changes, potentially increasing the risk of metabolic dysfunction and diseases later in life.

Interventional strategies during pregnancy, particularly anti-inflammatory and insulin-sensitizing treatments, are being explored to mitigate these adverse outcomes. Notably, higher fish consumption during pregnancy, or increased levels of *n*-3 long-chain polyunsaturated fatty acids (LC-PUFAs) from fatty fish, have been associated with lower BMI and healthier metabolic profiles in children, as evidenced by both animal and observational human studies. Fish oil supplementation during pregnancy, which enhances insulin sensitivity [7], is proposed as a potential preventive measure against the development of greater adiposity and metabolic dysfunction in the offspring of overweight or obese mothers.

A previous study [8] examined the effects of fish oil supplementation during the latter half of pregnancy and lactation in overweight or obese mothers on infant body composition and metabolism. The study found that fish oil supplementation reduced maternal and infant triglyceride levels but did not influence maternal or infant insulin resistance or infant body composition. Another randomized controlled trial [9] evaluated the impact of fish oil supplementation from the 24th week of pregnancy on offspring BMI and body composition up to 6 years of age. The trial reported a higher BMI in offspring from birth to 6 years of age without increasing the risk of obesity at age six. The body composition at 6 years was characterized by proportional increases in lean, bone, and fat mass, suggesting a general growth-stimulating effect of *n*-3 LC-PUFA.

The current study extends the follow-up period to age 10 years for participants of the previous study, assessing their metabolic health. The findings suggest that children of mothers who received *n*-3 LC-PUFA supplementation had an increased BMI at age 10, a higher risk of being overweight, tendencies toward a higher fat percentage, and elevated metabolic syndrome score. These results indicate a potential shift in body composition toward a higher proportion of fat mass and a less favorable metabolic profile due to prenatal *n*-3 LC-PUFA supplementation.

The study limitations include the treatment initiation from mid-pregnancy rather than preconception or throughout the entire pregnancy, which may impact results. The study's strengths include a relatively large sample size and a long follow-up period of 10 years.

The findings raise concerns about the potential adverse health effects of *n*-3 LC-PUFA supplementation during pregnancy. Replication of these results in larger, independent randomized controlled trials is essential before making any changes to current recommendations for fish oil supplementation during pregnancy.

Randomization to a provided higher-complex-carbohydrate versus conventional diet in gestational diabetes mellitus results in similar newborn adiposity

Hernandez TL[1,2,3], Farabi SS[4,5], Fosdick BK[6], Hirsch N[1,2], Dunn EZ[1,2], Rolloff K[1,2], Corbett JP[7], Haugen E[2], Marden T[8], Higgins J[2], Friedman JE[9], Barbour LA[2,10]

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Comments: Preventive strategies aimed to tackle the problem of childhood obesity must be focused on all the modifiable risk factors not only related to child life but also associated to those factors related to pregnancy. Particularly, gestational diabetes mellitus represents an important modifiable risk factor. Gestational diabetes mellitus is defined as hyperglycemia first recognized during pregnancy. Gestational diabetes mellitus is related not only to perinatal morbidity but also to an increased risk of diabetes and cardiovascular disease in the mother in later life, and to childhood obesity in the offspring [10]. As pre-pregnancy body mass index has rapidly increased, the global gestational diabetes mellitus prevalence is estimated at 14%, with some high-risk populations exceeding 20% [10]. The United States has reported a 20% increase in gestational diabetes mellitus cases between 2016 and 2020 alone, with Asian, Native American, and Hispanic/Latina women disproportionately affected [11]. Therefore, studies evaluating preventive strategies related to the metabolic alteration related to gestational maternal diabetes are needed. Interestingly, in this controlled, prospective RCT study, authors investigated whether randomization to a higher complex carbohydrate (60%) and lower fat (25%) diet versus a conventional lower carbohydrate (40%) and higher fat (45%) diet in gestational diabetes results in lower newborn adiposity and improves maternal insulin resistance and 24-h glycemia. Authors have shown no between-diet differences in newborn adiposity, maternal 24-h glycemia, and insulin resistance. Thus, despite a 100-g carbohydrate difference, both diets achieved similar glycemic and newborn outcomes. Therefore, these data suggest that flexibility in dietary CHO is possible while limiting simple sugars, saturated fats, and excess calories, paving the way for expanded and personalized options for nutrition therapy in gestational maternal diabetes. Pregnancy is a window period, and occurrence of gestational diabetes mellitus during pregnancy represents an opportunity to reduce short- and long-term risk of adverse health outcomes in the mothers and their children. Offspring born to mothers diagnosed with gestational diabetes mellitus, as defined by the World Health Organization 2013 gestational diabetes mellitus criteria, had higher rates of abnormal glucose tolerance, higher rates of overweight or obesity, greater body mass index, higher blood pressure, lower oral disposition index, and a trend toward reduced β-cell function compared with those born to mothers without gestational diabetes mellitus. Medical nutrition therapy for gestational diabetes mellitus is an individualized nutrition plan developed between the pregnant person and a registered dietitian nutritionist (RDN) familiar with the management of gestational diabetes mellitus [12]. The food plan should provide adequate calorie intake to promote fetal/neonatal and maternal health, achieve glycemic goals, and promote appropriate weight gain, according to the 2009 National Academy of Medicine recommendations [12]. However, so far

there is no definitive research that identifies a specific optimal calorie intake for women with gestational diabetes mellitus or suggests that their calorie needs are different from those of pregnant individuals without gestational diabetes mellitus [12]. Therefore, further studies exploring appropriate and novel diet approaches to gestational maternal diabetes are needed to guide public health prevention efforts in childhood obesity.

Associations among prenatal exposure to gestational diabetes mellitus, brain structure, and child adiposity markers

Luo S[1,2,3,4], Hsu E[1], Lawrence KE[5], Adise S[4,6], Pickering TA[7], Herting MM[7,8,9], Buchanan T[1,2], Page KA[1,2,9], Thompson PM[5,9]

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Comments: Offspring born to mothers diagnosed with gestational diabetes mellitus have an increased risk of higher adiposity measures (body mass index, waist-to-hip circumference, waist-to-height ratio) and increased risk of developing obesity later in life. Furthermore, the body mass index of offspring exposed to gestational diabetes mellitus is greater than that of their siblings who were not exposed to gestational diabetes mellitus [13], suggesting that the effect of prenatal gestational diabetes mellitus exposure on offspring body mass index is independent of shared genetics and environment. Therefore, different and still not completely elucidated mechanisms for increased obesity risk in gestational diabetes mellitus–exposed offspring need to be characterized. By evaluating anthropometric data in children aged 9–10 years old from the Adolescent Brain Cognitive Development (ABCD) study (a 10-year, large-scale, longitudinal study of pediatric brain and cognitive development in the United States), Shan Luo et al. were able to offer novel and interesting results examining the relationships between prenatal exposure to gestational diabetes mellitus and brain structural measures (i.e., cortical and subcortical volumes, cortical thickness, and surface area). Of note, authors were able to show that prenatal exposure to gestational diabetes mellitus was associated with lower global cortical and regional cortical gray matter volume in the entire study sample. Interestingly, similar results were confirmed also in a subset of the sample including siblings

discordant for gestational diabetes mellitus exposure. Finally, results also showed that the global cortical gray matter volume, in part, mediated relationships between prenatal gestational diabetes mellitus exposure and adiposity markers in children. Therefore, taken together, these results suggest that a low cortical gray matter volume may be a potential neural mechanism by which prenatal gestational diabetes mellitus exposure mediates obesity risk in offspring. Thus, it is important for clinicians to be aware of detrimental effects of diabetes during pregnancy on the developing brain in offspring. In gestational diabetes mellitus–exposed offspring, the mechanisms for the increase of significantly higher rates of abnormal glucose tolerance, higher rates of overweight or obesity, greater body mass index, higher blood pressure, lower oral disposition index, and a trend toward reduced β-cell function still need to be completely characterized. Therefore, additional studies are needed in order to completely understand the underlying mechanisms and suggest novel preventive and therapeutic approach in childhood obesity. In addition, future studies are needed to examine potential interventions that may mitigate adverse effects of prenatal gestational diabetes mellitus exposure on offspring brain development, thereby reducing obesity risk.

Nutrition during Infancy and Risk of Childhood Obesity

Maternal pre-pregnancy BMI, breastfeeding, and child BMI

Shipp GM[1], Wosu AC[2], Knapp EA[2], Sauder KA[3], Dabelea D[4], Perng W[3], Zhu Y[5], Ferrara A[5], Dunlop AL[6], Deoni S[7], Gern J[8], Porucznik C[9], Aris IM[10], Karagas MR[11], Sathyanarayana S[12], O'Connor TG[13], Carroll KN[14], Wright RJ[14], Hockett CW[15,16], Johnson CC[17], Meeker JD[18], Cordero J[19], Paneth N[20,21], Comstock SS[22], Kerver JM[20,21]; on behalf of program collaborators for Environmental influences on Child Health Outcomes

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Comments: Childhood obesity has become a public health problem worldwide, thus imposing to take effective preventive and therapeutic measures in children to address the major risk factors related to fat accumulation. Relatively recent data have shown that the characterization of the major risk factors and the most appropriate time of intervention represent two of the major components of all preventive strategies. Particularly, some preventable risk factors need be characterized in peculiar times of the life due to their pivotal role in the risk of childhood obesity. In addition, infancy seems to be one of the most important periods influencing health later in life and may thus represent the best time to prevent obesity and its adverse consequences. A growing amount of evidence suggests that the first 1,000 days of life, encompassing the time from conception to the age of 24 months, is a key period for the development of later overweight and obesity. Several important risk factors have been identified during this period: excessive maternal weight before pregnancy, excessive maternal weight gain during pregnancy, maternal smoking during pregnancy, gestational diabetes, absence or short duration of breastfeeding, high protein intake, caesarean section, vitamin D_3 deficiency, high birth weight or excessive weight gain in the first year of life, low socioeconomic status, shortened daily sleep of the infant, and early (<4 months of age) introduction of solid foods. All these factors can co-occur and, through a cumulative effect, further increase the risk of obesity [14]. Among the modifiable risk factors related to childhood obesity in the first 1,000 days of life, breastfeeding has been shown by a large body of evidence to be a protective factor although still few data evaluating this relationship among women with obesity before and during pregnancy are still poor. Interestingly, in this study by Shipp et al., authors explored the associations between breastfeeding practices and child body mass index for age Z-score (BMIz), stratified by maternal body mass index. Particularly, authors were able to show a protective association between breastfeeding and childhood obesity regardless of maternal pre-pregnancy body mass index category. More importantly, across most breastfeeding exposures, the associations were stronger among children with mothers who had obesity at pre-pregnancy compared with those whose mothers were categorized as overweight at pre-pregnancy. Similar results were observed when comparing children of mothers with pre-pregnancy obesity to mothers with a healthy weight across all breastfeeding practices. Although, the WHO recommends exclusive breastfeeding until 6 months, with continued breastfeeding and appropriate complementary foods up to 2 years of age or beyond, some reports have shown that women with obesity are less likely to initiate breastfeeding and are more prone to early cessation compared with women of a healthy weight. Therefore, these aspects make it difficult to assess the associations between breastfeeding behavior and childhood obesity in this group. These results support the encouragement of all women, including women who are overweight or obese before conception, to breastfeed as a preventive measure against the

development of childhood obesity. Therefore, in order to progress in tackling the problem of childhood obesity, future studies and public health prevention efforts should continue focusing on addressing two highly prevalent problems that disproportionately affect marginalized populations resulting in adverse health outcomes: shortened duration of breastfeeding and maternal overweight and obesity.

Low-protein infant formula enriched with alpha-lactalbumin during early infancy may reduce insulin resistance at 12 months: a follow-up of a randomized controlled trial

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Comments: Despite efforts to promote breastfeeding, various social factors and maternal illnesses often lead mothers to cease breastfeeding prematurely. Consequently, there is a demand for infant formulas that offer optimal nutritional composition essential for adequate infant growth and development. Ongoing research has facilitated the development of infant formulas that closely mimic human milk by incorporating diverse food ingredients to meet infants' nutritional needs and contribute to their development.

Certain studies have indicated that high protein intake during early life may be linked to obesity and an increased risk of metabolic diseases in later stages [15]. To address this, the protein composition of infant formulas has been adjusted in both quality and quantity, reducing protein intake and altering the whey/casein ratio. The development of infant formula containing bovine α-lactalbumin (a whey protein component) has enabled a reduction in the overall protein content of the formula.

Protein overload can result in elevated serum concentrations of branched-chain amino acids (BCAAs), leading to increased secretion of insulin and insulin-like growth factor 1 (IGF-1). Consequently, high protein intake during infancy may be associated with accelerated early weight gain, increased fat deposition, and the development of overweight and obesity [16]. Previous studies have reported higher serum insulin and IGF-1 levels in formula-fed (FF) infants compared to breastfed (BF) infants during the first half of infancy [17]. Thus, the higher protein content in infant formula compared to breast milk could contribute to the higher weight gain observed in FF infants.

Over the past decades, the protein concentration in infant formulas has been reduced, and protein quality has improved. Despite this, current infant formulas with reduced protein concentrations still contain higher protein levels than breast milk. Some infant formulas with protein content slightly below the EU regulatory lower limit, enriched with alpha-lactalbumin-enriched whey (α-lac-EW) or casein glycomacropeptide-reduced whey (CGMP-RW), have been developed.

The current double-blind, controlled, prospective intervention trial with follow-up evaluated the effects on growth, and metabolic and hormonal markers at 12 and

6 months postintervention, of feeding low-protein infant formulas with either α-lac-EW or CGMP-RW compared to standard infant formula or breast milk in early infancy. The study results indicated that growth, as well as serum insulin and C-peptide levels at follow-up at 12 months of age, was more similar to BF infants among those fed low-protein infant formula with either α-lac-EW or CGMP-RW during early infancy. This suggests that low protein intake, closer to that of BF infants, influences growth 6 months postintervention, potentially through reduced insulin resistance. It has been shown previously that although serum BCAAs (S-BCAAs) were higher in all formula groups compared to the BF group during the intervention, S-BCAAs were lower in the low-protein formula groups than in the standard formula group at 6 months [15]. Furthermore, at this age, weight gain and BMI were more similar in the low-protein formula groups and the BF group. Therefore, it is possible that BCAA concentrations influenced insulin concentration postintervention, resulting in lower weight gain between 6 and 12 months and lower BMI at 12 months in the low-protein formula groups compared to the standard formula group, aligning growth rates more closely with BF infants. In this study, serum insulin at 12 months, but not at 6 months, was associated with weight gain between 6 and 12 months, suggesting potential imprinting of insulin secretion by protein intake during the intervention period.

The study's strengths include the analysis of metabolic and hormonal markers (IGF-1, insulin, C-peptide, leptin) 6 months postintervention, which allows for a better evaluation of whether low-protein formula given during the first half of infancy influences growth and the metabolic profile 6 months postintervention. However, the study's limitations include the lack of data regarding body composition, which precludes evaluating the proportions between fat mass and fat-free mass.

The results demonstrated that feeding a modified low-protein infant formula early in life resulted in growth patterns 6 months postintervention that were more similar to those of BF infants compared to feeding a standard formula with higher protein concentration. Hence, further reducing formula protein concentration by modifying protein quality may be a viable strategy for the early prevention of childhood overweight and obesity. Longer follow-up of the study population will be necessary to evaluate whether these findings persist later in childhood.

Infant milk formula with large, milk phospholipid-coated lipid droplets enriched in dairy lipids affects body mass index trajectories and blood pressure at school age: follow-up of a randomized controlled trial

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Comments: Lipids are essential for healthy infant growth and development. Compared to formula feeding, human milk feeding is associated with different growth and adiposity patterns during infancy and may offer protection against childhood overweight and adverse metabolic health outcomes. One contributing factor could be the distinct differences in the supramolecular structure of lipid droplets. Human milk features large fat globules enveloped by a trilayered phospholipid membrane, while infant milk formula (IMF) contains small lipid droplets primarily coated by proteins.

Recently, a concept IMF was developed to more closely mimic the structure and composition of human milk fat globules. A previous study [18] evaluated whether a concept IMF with large, milk phospholipid-coated lipid droplets is equivalent to standard IMF regarding growth adequacy and safety in healthy, term infants. The findings indicated that the concept IMF supports adequate growth and was well tolerated and safe for use in healthy infants.

Additionally, a multicenter, randomized controlled trial [19] was conducted to assess the nutritional adequacy and safety of a concept IMF with large, milk phospholipid-coated lipid droplets containing dairy lipids. This trial demonstrated that the concept IMF, provided during the first months of age, was safe and well tolerated, with equivalent daily weight gain, daily length gain, and daily head circumference gain from baseline to 4 months of age compared to a control IMF with conventional, small lipid droplets containing vegetable oils.

The present research reports the results of the follow-up period of the previous study [19], focusing on later BMI outcomes until 5 years of age and blood pressure at school age as potential biomarkers for a healthier metabolic trajectory. The findings revealed that compared to the control IMF group, the concept IMF group had consistently lower mean BMI values during follow-up, particularly if the mother had overweight or obesity, with the most pronounced difference observed at 1 year of age, with mean values approaching those of the breastfed group. The control group had higher mean BMI values compared to the breastfed group during the follow-up from 1 to 5 years of age. At 5 years of age, the concept group exhibited lower diastolic and arterial blood pressure compared to the control group.

The study's strengths include its randomized design, multicountry setting, and prospective long-term follow-up with a breastfed infant group included as a reference. However, limitations include the relatively small number of patients in each group during the follow-up period and the lack of data on other foods consumed during the postintervention period, which may have influenced the children's anthropometric status during follow-up.

Future longitudinal, larger clinical studies are necessary to confirm the potential impact of this concept IMF on body composition and metabolic health outcomes.

Epigenome-wide meta-analysis reveals associations between dietary glycemic index and glycemic load and DNA methylation in children and adolescents of different body sizes

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Comments: The glycemic index (GI) and glycemic load (GL) are measures for assessing the rate at which the body converts carbohydrates into glucose, thereby indicating the glycemic impact of carbohydrate-containing foods. Previous research, including a meta-

analysis and cohort studies [20], suggests a significant association between high GI or high GL and an increased risk of cardiovascular disease (CVD) events. These events encompass diabetes, metabolic syndrome (MS), coronary heart disease (CHD), stroke, and stroke mortality in the general population. The risk of CVD outcomes appears to be stratified by sex, obesity status, and preexisting CVD conditions. High GI is associated with a higher propensity for CVD risk factors and mortality in healthy individuals, whereas high GL is linked to an elevated risk of severe heart diseases, including CVD or all-cause mortality, particularly in at-risk populations. Consequently, dietary interventions aimed at lowering both GI and GL are recommended for preventing CVD outcomes across all populations.

DNA methylation (DNAm) is a pivotal epigenetic mechanism regulating gene activity. Increasing evidence suggests that dietary factors can influence DNAm, thereby contributing to the long-term health effects of diet. The current study conducted meta-analyses of epigenome-wide association studies (EWAS) to investigate the relationship between dietary GI and GL and blood DNAm in children and adolescents. Researchers identified 537 associations between dietary GI and GL and blood DNAm, predominantly in children and adolescents with overweight or obesity.

The study's strengths include the derivation of GI and GL values across six cohorts and the use of data from similar age groups to evaluate the functional properties of DNAm sites in blood and adipose tissue. However, the study's limitations include a low sample size, particularly in the BMI-stratified analysis. Additionally, heterogeneity arising from various dietary sources across the cohorts may have influenced the GI and GL scores, and misreporting of food consumption could have affected the associations.

Although further investigation is needed to ascertain the functional importance of the identified CpGs, multiple CpGs appear to play regulatory roles in the expression of genes involved in metabolic impairment and obesity development. High-GI and/or high-GL diets may influence epigenetic gene regulation, promoting metabolic derangements in young individuals with increased BMI. Further analyses with larger sample sizes are required to support these observations and explore the causality and functionality of the identified CpG-gene relationships.

Association between minerals intake and childhood obesity: a cross-sectional study of the NHANES database in 2007–2014

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Comments: The number of children with obesity has increased ten-fold during the last decades worldwide. Epidemiological data have documented a significant shift in its prevalence for boys and girls, moving from 5 and 6 million in 1975 to 50 and 74 million in 2016, respectively. In addition, prediction models have also shown alarming data suggesting that, by the end of 2050, the 25% of all children under 16 years will be

affected by obesity [21]. Obesity in children affects multiple organs in the body and is associated with both significant morbidity and ultimately with an increased risk of chronic diseases and premature mortality. Treatment guidelines currently focus on intervention with lifestyle and behavioral modifications, with pharmacotherapy and surgery reserved for patients who are refractory to such treatment. However, these approaches still need to be perfected. Particularly, most dietary measures on weight control focused on reducing the intake of macronutrients such as carbohydrates and fats. However, recent reports have also focused on a potentially relevant role of other diet components, such as minerals on obesity according to their oxidant or antioxidant functions and effects on insulin and glucose metabolism [22]. Interestingly in the study by Wang et al., authors have explored the association between minerals and obesity and body mass index in a very large group of children with different ages. In this cross-sectional study by using data of 10,450 children aged 2–17 years old extracted from the NHANES database in 2007–2014, authors were able to present robust results on the role of minerals dietary content. In fact, they reported a relevant association between dietary intakes of nine common minerals and childhood obesity and body mass index. Particularly, authors have shown that higher levels of dietary Fe and Zn intakes were associated with lower odds of childhood obesity. Oppositely, higher levels of dietary Cu and Na intakes seemed to be associated with higher odds of obesity. Dietary intakes of Ca, Na, and K were positively linked to the children's body mass index, whereas dietary Fe and Zn consumptions shared negative associations with body mass index. These relationships were also found in children with different age. Although the study has some relevant limitation regarding the retrospective design of the protocol as well as the information used for evaluating the dietary intake, this study clearly suggests that it is necessary to develop individualization recommendations of minerals intake for children with high risk of obesity in different age in the future. In addition, this study may provide some references for further studies exploring the causal associations and may further help the prevention and management of childhood obesity. Therefore, further prospective cohort studies focusing on the long-term effects of dietary minerals intake on childhood obesity are still needed in order to provide relevant information on the effects of not only macronutrients but also common minerals on childhood obesity and body mass index.

Longitudinal associations between diet quality, sedentary behaviours and physical activity and risk of overweight and obesity in preschool children: the ToyBox-study

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Comments: To manage the growing public health crisis caused by the increasing rates of childhood obesity across the globe, effective and well-researched treatment options are essential. Particularly, all approaches must be started as early as possible. In fact, it is widely recommended that obesity prevention strategies focus on early childhood, as children with excess weight in adolescence are more likely to have obesity as adults. In addition, interventions focused on late childhood and adolescence are less effective given that lifestyle behaviors, such as eating and activity, are formed and established during the early years of life [23]. Moreover, it is important that childhood obesity is tackled early so that it can be managed before the onset of complications. At present, the management of childhood obesity focuses on lifestyle interventions and the importance of appropriate caloric intake. Lifestyle interventions have been shown to work in some patients, but the general increasing trend of this problem shows that it is not sufficient. The causes of these unsuccessful approaches are complex and multifactorial. In addition, they are mainly related to the fact that obesity in childhood is a multifactorial disease, resulting by the tight interaction between individual, sociocultural, community, and other factors, and follows a social gradient. Regarding lifestyle factors, evidence points to the synergetic effect of multiple lifestyle behaviors related to diet, physical activity, and sedentary behaviors, collectively referred to as energy balance–related behaviors (EBRBs), associated with increased risk of overweight and obesity. In the study by Miguel-Berges et al., authors examined the cross-sectional and longitudinal associations between diet, screen time (ST), and step recommendations and risk of overweight and obesity in European preschoolers participating in the ToyBox-study, a cluster-randomized controlled trial aiming to prevent obesity in preschool children conducted in six European countries. Particularly, authors found that adherence to EBRB recommendations was associated with decreased odds of having overweight/obesity. In fact, authors have reported that in European preschool children, the proportion of participants having a low Diet Quality Index score, not adhering to both step and ST recommendations, was very high, and it was associated with a high probability of developing overweight and obesity. The findings of this study strongly indicate that public health obesity prevention efforts should apply an integrated approach to physical activity and dietary intake from early childhood. Therefore, more effective and well-researched treatment options are essential and still need to be completely characterized. The development of effective obesity prevention interventions is even more relevant in the post–COVID-19 era as scientific evidence from young population groups indicates changes in dietary-lifestyle behaviors accompanied by a reduction in physical activity levels and lower energy expenditure that negatively affect body composition and

early metabolic alteration [24, 25]. Therefore, preschool children and their parents should try to increase family time spent at activities promoting physical activity and to minimize the time spent on ST or being sedentary, in order to maximize the effects of all types of preventive strategies in childhood obesity. Particularly, available literature in early years of life is scarce and further studies conducted in children are needed to perfect the available approaches.

Nutrition and Risk of Obesity-Related Comorbidities

Associations of infant feeding practices with abdominal and hepatic fat measures in childhood in the longitudinal Healthy Start Study

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Comments: Nutritional exposures during the perinatal period, such as infant feeding practices, have been shown to exert long-lasting effects on offspring health, including an increased susceptibility to obesity and related metabolic disorders. Research indicates that greater abdominal fat deposition, particularly visceral fat, and hepatic fat accumulation are significant risk factors for insulin resistance and other cardiometabolic conditions in youth, independent of total adiposity [26].

Previous studies have suggested associations between dietary factors in infancy and the accrual of abdominal subcutaneous and visceral fat early in life [27]. However, whether these associations persist into later childhood remains unclear. A recent study found that a combination of early complementary feeding and a shorter duration of breastfeeding (≤4 months) was linked to elevated adiposity and cardiometabolic markers in children [28].

This study investigated the associations between infant feeding practices and abdominal fat and hepatic fat trajectories in childhood within the Healthy Start Study, a prospective prebirth cohort in Colorado. Abdominal subcutaneous (SAT) and visceral adipose tissue (VAT) areas, along with hepatic fat percentage, were assessed via magnetic resonance imaging (MRI) in early and middle childhood (median ages 5 and 9 years, respectively). The results demonstrated that the timing and quality of complementary foods introduced during infancy and toddlerhood were associated with distinct trajectories for abdominal SAT, VAT, and hepatic fat deposition in childhood. Specifically, early introduction of complementary foods by 4 months was associated with accelerated rates of change in abdominal SAT and VAT from early to middle childhood. A similar pattern was observed for the early introduction of soda,

where children introduced to soda by 18 months exhibited faster rates of change in SAT, VAT, and hepatic fat, leading to higher levels of these outcomes by middle childhood.

Recent meta-analyses have reported a protective effect of human milk consumption in infancy on later obesity risk [29]. A systematic review, including six cohorts with sibling-pair analyses and one randomized controlled trial of a breastfeeding promotion intervention [30], suggested moderate evidence that consuming human milk, as compared to never consuming it, was associated with a lower risk of overweight and obesity at age 2 years and older, particularly if the duration of human milk consumption exceeded 6 months. However, evidence was insufficient to determine the relationship between the duration of any human milk consumption and overweight or obesity at age of 2 years and older. Notably, the current study found no associations between the duration of any human milk consumption and childhood abdominal or hepatic fat trajectories.

The strengths of this study include its relatively large, prospective design involving mother-child dyads who have undergone extensive assessments since pregnancy, with adjustments made for key confounding variables. Additionally, the use of MRI to evaluate abdominal adiposity (SAT and VAT) enhances the robustness of the findings. However, limitations include the fact that only a subgroup of children from the larger cohort underwent abdominal MRI assessments in childhood. Furthermore, the assessment of infant feeding practices relied on self-reported data, which may be subject to recall bias or social desirability bias, particularly among parents of infants with overweight or obesity. Additionally, there was a lack of detailed information on the frequency or dosage of soda and other complementary foods introduced during infancy, which could further influence the strength of the associations observed.

The clinical implications of these findings underscore the importance of educating parents about the timing and quality of complementary foods and beverages introduced during infancy and toddlerhood. Recommendations should also emphasize delaying the introduction of soda during this critical developmental period.

The impact of ultra-processed foods on obesity and cardiometabolic comorbidities in children and adolescents: a systematic review

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Comments: Diet represents one of the keystones of all the preventive and therapeutic approaches in childhood obesity. Particularly, the quality of the dietary pattern is defined not only according to its content in specific nutrients or food items but also by other important factors such as its content in processed foods. Over the last few years, a complex and alarming change in daily diet worldwide has been documented [31, 32]. In fact, in several

countries, traditional foods and freshly prepared dishes and meals have been displaced by ultra-processed foods. Therefore, these changes have determined an alarming shift from healthier diet such as mediterranean diet toward modern diet with ultra-processed foods, characterized by high energy density, sugar, sodium, saturated fats, and trans fats and low fiber and micronutrient content. Therefore, a complete characterization on the adiposity and cardiometabolic risk related to ultra-processed foods consumption in children is important to properly face the alarming data on childhood obesity. In particular, in this scoping systematic review of observational studies, authors attempted to gather all existing knowledge regarding the association between the consumption of ultra-processed foods with obesity and cardiometabolic risk factors among children and adolescents. Particularly, by reporting data obtained from 17 observational studies available, authors have documented that the majority of the studies showed a positive association either in the risk of obesity or in cardiometabolic comorbidities, although the type and quantity of processed foods consumed have not been evaluated. Therefore, this systematic review confirms similar data report in adult subjects [33, 34] and raises concerns for future health regarding modern diet regimes and ultra-processed foods consumption. These modern diets are characterized by a high consumption of many foods that have undergone some degree of processing. Particularly, ultra-processed foods are manufactured using several ingredients, contain little or no whole food, follow a series of processes, and are combined with a sophisticated use of additives to increase their shelf-life and their palatability. These characteristics let the ultra-processed foods that are ready-to-consume or ready-to-heat and thus require little or no culinary preparation, which makes them easily accessible and convenient. However, although more convenient, these foods have been clearly associated to health problems both in adults and children including cardiometabolic risk factors, such as excess body weight, hypertension, increased total cholesterol and low-density lipoprotein cholesterol, and metabolic syndrome, thus with increased morbidity and mortality in the general population. Therefore, as consumption of ultra-processed foods may directly increase weight and cardiometabolic risk factors during childhood, and since childhood dietary habits may also track to adulthood, more longitudinal studies are essential to further investigate these findings, identify facilitating factors and potential barriers for this dietary behavior in children and adolescents, and thus use this information to promote effective policies for reducing intake. The continuous increasing consumption of the ultra-processed foods reported worldwide and particularly changes in dietary habit of different countries need to be further investigated in order to explore the role of specific types of ultra-processed foods on cardiometabolic conditions and identify the daily intake levels that increase risk in order to shape appropriate public health policies.

Conflict of Interest Statement

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References

1 Lewis SJ, Leary S, Davey Smith G, Ness A. Body composition at age 9 years, maternal folate intake during pregnancy and methyltetrahydrofolate reductase (MTHFR) C677T genotype. Br J Nutr. 2009;102(04):493–6. https://doi.org/10.1017/s0007114509231746

2 Wang G, Hu FB, Mistry KB, Zhang C, Ren F, Huo Y, et al. Association between maternal pre pregnancy body mass index and plasma folate concentrations with child metabolic health. JAMA Pediatr. 2016;170(8):e160845. https://doi.org/10.1001/jamapediatrics.2016.0845

3 Voortman T, Tielemans MJ, Stroobant W, Schoufour JD, Kiefte-de Jong JC, Steenweg-de Graaff J, et al. Plasma fatty acid patterns during pregnancy and child's growth, body composition, and cardiometabolic health: the generation R study. Clin Nutr. 2018;37(3):984–92. https://doi.org/10.1016/j.clnu.2017.04.006

4 Satokar VV, Cutfield WS, Cameron-Smith D, Albert BB. Omega-3 fats in pregnancy: could a targeted approach lead to better metabolic health for children? Nutr Rev. 2021;79(5):574–84. https://doi.org/10.1093/nutrit/nuaa071

5 Gonzalez-Casanova I, Rzehak P, Stein AD, Garcia Feregrino R, Dommarco JAR, Barraza-Villarreal A, et al. Maternal single nucleotide polymorphisms in the fatty acid desaturase 1 and 2 coding regions modify the impact of prenatal supplementation with DHA on birth weight. Am J Clin Nutr. 2016;103(4):1171–8. https://doi.org/10.3945/ajcn.115.121244

6 Tandon S, Gonzalez-Casanova I, Barraza-Villarreal A, Romieu I, Demmelmair H, Jones DP, et al. Infant metabolome in relation to prenatal DHA supplementation and maternal single nucleotide polymorphism rs174602: secondary analysis of a randomized controlled trial in Mexico. J Nutr. 2021;151(11):3339–49. https://doi.org/10.1093/jn/nxab276

7 Derosa G, Cicero AF, D'Angelo A, Borghi C, Maffioli P. Effects of n-3 PUFAs on fasting plasma glucose and insulin resistance in patients with impaired fasting glucose or impaired glucose tolerance. Biofactors. 2016;42(3):316–22. https://doi.org/10.1002/biof.1277

8 Satokar VV, Derraik JGB, Harwood M, Okesene-Gafa K, Beck K, Cameron-Smith D, et al. Fish oil supplementation during pregnancy and postpartum in mothers with overweight and obesity to improve body composition and metabolic health during infancy: a double-blind randomized controlled trial. Am J Clin Nutr. 2023;117(5):883–95. https://doi.org/10.1016/j.ajcnut.2023.02.007

9 Vinding RK, Stokholm J, Sevelsted A, Sejersen T, Chawes BL, Bønnelykke K, et al. Effect of fish oil supplementation in pregnancy on bone, lean, and fat mass at six years: randomised clinical trial. BMJ. 2018;362:k3312. https://doi.org/10.1136/bmj.k3312

10 Wang H, Li N, Chivese T, Werfalli M, Sun H, Yuen L, et al. IDF diabetes atlas: estimation of global and regional gestational diabetes mellitus prevalence for 2021 by international association of diabetes in pregnancy study group's criteria. Diabetes Res Clin Pract. 2022;183:109050. https://doi.org/10.1016/j.diabres.2021.109050

11 Marshall NE, Abrams B, Barbour LA, Catalano P, Christian P, Friedman JE, et al. The importance of nutrition in pregnancy and lactation: lifelong consequences. Am J Obstet Gynecol. 2022;226(5):607–32. https://doi.org/10.1016/j.ajog.2021.12.035

12 ElSayed NA, Aleppo G, Aroda VR, Bannuru RR, Brown FM, Bruemmer D, et al. 15. Management of diabetes in pregnancy: standards of care in diabetes—2023. Diabetes Care. 2023;46(suppl_1):S254–66. https://doi.org/10.2337/dc23-s015

13 Lawlor DA, Lichtenstein P, Långström N. Association of maternal diabetes mellitus in pregnancy with offspring adiposity into early adult hood: sibling study in a prospective cohort of 280,866 men from 248,293 families. Circulation. 2011;123(3):258–65. https://doi.org/10.1161/circulationaha.110.980169

14 Pérez-Muñoz C, Carretero-Bravo J, Ortega-Martín E, Ramos-Fiol B, Ferriz-Mas B, Díaz-Rodríguez M. Interventions in the first 1000 days to prevent childhood obesity: a systematic review and quantitative content analysis. BMC Publ Health. 2022;22(1):2367. https://doi.org/10.1186/s12889-022-14701-9

15 Brands B, Demmelmair H, Koletzko B, for the EarlyNutrition Project. How growth due to infant nutrition influences obesity and later disease risk. Acta Paediatr. 2014;103(6):578–85. https://doi.org/10.1111/apa.12593

16 Tinghäll Nilsson U, Hernell O, Lönnerdal B, Hartvigsen ML, Jacobsen LN, Kvistgaard AS, et al. Low-protein formulas with alpha-lactalbumin-enriched or glycomacropeptide-reduced whey: effects on growth, nutrient intake and protein metabolism during early infancy: a randomized, double-blinded controlled trial. Nutrients. 2023;15(4):1010. https://doi.org/10.3390/nu15041010

17 Grote V, Gruszfeld D, Janas R, Demmelmair H, Closa-Monasterolo R, Subías JE, et al. Milk protein intake, the metabolic-endocrine response, and growth in infancy: data from a randomized clinical trial. Am J Clin Nutr. 2011;94(6 suppl l):1776s–84s. https://doi.org/10.3945/ajcn.110.000596

18 Teoh OH, Lin TP, Abrahamse-Berkeveld M, Winokan A, Chong YS, Yap F, et al. An infant formula with large, milk phospholipid-coated lipid droplets supports adequate growth and is well-tolerated in healthy, term asian infants: a randomized, controlled double-blind clinical trial. Nutrients. 2022;14(3):634. https://doi.org/10.3390/nu14030634

19 Breij LM, Abrahamse-Berkeveld M, Vandenplas Y, Jespers SNJ, de Mol AC, Khoo PC, et al. An infant formula with large, milk phospholipid-coated lipid

droplets containing a mixture of dairy and vegetable lipids supports adequate growth and is well tolerated in healthy, term infants. Am J Clin Nutr. 2019;109(3):586–96. https://doi.org/10.1093/ajcn/nqy322
20 Dwivedi AK, Dubey P, Reddy SY, Clegg DJ. Associations of glycemic index and glycemic load with cardiovascular disease: updated evidence from meta-analysis and cohort studies. Curr Cardiol Rep. 2022;24(3):141–61. https://doi.org/10.1007/s11886-022-01635-2
21 Verduci E, Di Profio E, Fiore G, Zuccotti G. Integrated approaches to combatting childhood obesity. Ann Nutr Metab. 2022;78(suppl 2):8–19. https://doi.org/10.1159/000524962
22 Sagor MAT, Smita RM, Shuvo APR, Raihan S, Jahan R, Simin FA, et al. The role of mineral deficiencies in insulin resistance and obesity. Curr Diabetes Rev. 2022;18(7):e171121197987. https://doi.org/10.2174/1573399818666211117104626
23 Dalal M, Cazorla-Lancaster Y, Chu CG, Agarwal N. Healthy from the start-lifestyle interventions in early childhood. Am J Lifestyle Med. 2022;16(5):562–9. https://doi.org/10.1177/15598276221087672
24 Jenssen BP, Kelly MK, Powell M, Bouchelle Z, Mayne SL, Fiks AG. COVID- 19 and changes in child obesity. Pediatrics. 2021;147(5):e2021050123. https://doi.org/10.1542/peds.2021-050123
25 Giannini C, Mastromauro C, Chiarelli F, Mohn A. Effects of COVID-19 time on the development of pre-impaired glucose tolerance state in children and adolescents with overweight and obesity. Int J Obes (Lond). 2023;47(11):1050–6. https://doi.org/10.1038/s41366-023-01353-x
26 Caprio S, Perry R, Kursawe R. Adolescent obesity and insulin resistance: roles of ectopic fat accumulation and adipose inflammation. Gastroenterology. 2017;152(7):1638–46. https://doi.org/10.1053/j.gastro2016.12.051
27 Breij LM, Abrahamse-Berkeveld M, Acton D, De Lucia Rolfe E, Ong KK, Hokken-Koelega ACS. Impact of early infant growth, duration of breastfeeding and maternal factors on total body fat mass and visceral fat at 3 and 6 months of age. Ann Nutr Metab. 2017;71(3–4):203–10. https://doi.org/10.1159/000481539
28 Ong YY, Pang WW, Michael N, Aris IM, Sadananthan SA, Tint MT, et al. Timing of introduction of complementary foods, breastfeeding, and child cardiometabolic risk: a prospective multiethnic Asian cohort study. Am J Clin Nutr. 2023;117(1):83–92. https://doi.org/10.1016/j.ajcnut.2022.10.021
29 Horta BL, Rollins N, Dias MS, Garcez V, Pérez-Escamilla R. Systematic review and meta-analysis of breastfeeding and later overweight or obesity expands on previous study for World Health Organization. Acta Paediatr. 2023;112(1):34–41. https://doi.org/10.1111/apa.16460
30 Dewey KG, Güngör D, Donovan SM, Madan EM, Venkatramanan S, Davis TA, et al. Breastfeeding and risk of overweight in childhood and beyond: a systematic review with emphasis on sibling-pair and intervention studies. Am J Clin Nutr. 2021;114(5):1774–90. https://doi.org/10.1093/ajcn/nqab206
31 Moubarac JC, Batal M, Louzada ML, Martinez Steele E, Monteiro CA. Consumption of ultra-processed foods predicts diet quality in Canada. Appetite. 2017;108:512–20. https://doi.org/10.1016/j.appet.2016.11.006
32 Cediel G, Reyes M, Corvalán C, Levy RB, Uauy R, Monteiro CA. Ultra-processed foods drive to unhealthy diets: evidence from Chile. Public Health Nutr. 2021;24(7):1698–707. https://doi.org/10.1017/s1368980019004737
33 Silva Meneguelli T, Viana Hinkelmann J, Hermsdorff HHM, Zulet MÁ, Martínez JA, Bressan J. Food consumption by degree of processing and cardiometabolic risk: a systematic review. Int J Food Sci Nutr. 2020;71(6):678–92. https://doi.org/10.1080/09637486.2020.1725961
34 Blanco-Rojo R, Sandoval-Insausti H, López-Garcia E, Graciani A, Ordovás JM, Banegas JR, et al. Consumption of ultra processed foods and mortality: a national prospective cohort in Spain. Mayo Clin Proc. 2019;94(11):2178–88. https://doi.org/10.1016/j.mayocp.2019.03.035