Alfarama Journal of Basic & Applied Sciences

Faculty of Science Port Said University

https://ajbas.journals.ekb.eg
ajbas@sci.psu.edu.eg
http://sci.psu.edu.eg/en/

October 2023, Volume 4 , Issue IV

DOI:https://doi.org/10.21608/ajbas.2023.227755.1167

ISSN 2682-275X

Submitted: 16/08/2023
Accepted: 26/09/2023

Pages: 554 - 563

Influence of Maternal Western Dietary Pattern on Offspring's Health: A Systematic Review of Previous Studies

Zahraa A. Greash[1,*], Alaa A. Eldsokey[1], Alaa E. Atia[1]

[1] Zoology Department, Faculty of Science, Port Said Univ., Egypt.

***Corresponding author:** zahraa_greash@yahoo.com

ABSTRACT

The importance of maternal nutrition to the health of future generations beside the women health makes it a significant public health issue. So-called "Western diet" is a common unhealthy modern diet pattern that high in calories from refined sugar and fat, poor in fibers, loaded with processed foods and consumed in large quantities. According to the hypothesis of prenatal programming, environmental factors like the mother's "unhealthy diet" can start already in utero and affect the fetus' prenatal development. PubMed and Science direct database were searched from 2000 until February 2023 for eligible studies. Fifty-one relevant articles were included and classified into four categories according to maternal western diet and pregnancy complications; birth outcomes; long-term offspring outcomes as well as the supplementary consumed with it. The following data: study design, study objective, maternal diet period and main findings regarding the offspring health were extracted and presented as a narrative review results due to the heterogeneity of the article design. The studies clearly shows that the maternal western diet pattern before, during pregnancy as well as the lactation whether combined or separate periods increase risk of pregnancy complications beside the disease in later offspring life. Despite the increasing rates of Western-style nutrition, its share of prenatal research is insufficient. Therefore, we recommend paying more attention to this research point in order to raise awareness of the risks of eating this dietary pattern on pregnancy, embryo, newborn, infant, child and adolescent. Also, find solutions to minimize its complication hazards.

Key Words:

Fetus, maternal, offspring, supplementary, Western diet.

1. INTRODUCTION

Nutrition plays an essential role in the pregnant women health and their fetuses' growth [1]. Just as perinatal nutrition can program the response to a nutritional challenge later in life [2], maternal malnutrition may raise the chance of stillbirth, neonatal morbidity and permanent deficits in growth and neurocognitive development [3].

According to the World Health Organization (WHO), malnutrition is the result of imbalances, excesses or deficiencies in a person nutrient and/or energy intake. Over-nutrition likely plays a dominant

role in the origin of metabolic diseases. Thus, even more than maternal under-nutrition, mother overeating of "junk food" during pregnancy might affect the development of the fetus [4].

Junk food, fast food and cafeteria food, all mimics the same obesogenic diet known as a western diet style where processed meats, prepackaged foods, high-fat dairy products, refined grains, high-sugar drinks, fried foods, traditional animal products, eggs, red meat, candy, corn and sweets [5, 6]. One of the main global risk factors for premature death and chronic disease is unhealthy diet [7] which also evident in the high prevalence of metabolic diseases as well as obesity worldwide [8].

Cafeteria feeding causing a significant increase of energy intake in dams during gestation and lactation that was due to overconsumption of sugar and fat, whereas protein intake was reduced [9] that cause dams to obtain high content of a dipose tissue leading to body weight raising beside metabolic abnormalities, such as hyperinsulinemia, hypercholesterolemia and hyperleptinemia [10].

The aim of this work was to systematically overview and summarizes the currently existing research articles dealing with the relationship between a maternal western diet pattern and various outcomes of child health problems as well as the beneficial supplements used to improve these health complexes.

2. METHODS

We conducted an extensive literature review to assess whether maternal nutrition that depends on "western diet pattern" can influence their offspring health. Literature searches were performed in both Pubmed (https://pubmed.ncbi.nlm.nih.gov; accessed February 2023) and Science Direct databases (https://sciencedirect.com; accessed February 2023), utilizing the following keywords alone or in combination: Maternal western diet/ food, maternal cafeteria diet/ food, maternal junk food, offspring, fetus, pups, malformation, deformation, complication, pregnancy, lactation, fetal programming, child development, birth defect, prenatal/ perinatal and supplementary. The website of World Health Organization (WHO) was consulted to identify important recommendations and reports about malnutrition (https://www.who.int/news-room/fact-sheets/detail/malnutrition).

In addition, we performed a manual search to find the articles referenced in the initial search. We only looked for reviews that were released between 2000 and 2023. However, we found some classic articles prior to 2000 relevant to our aim, so we combined them to our study. Each included articles references were further examined in order to determine any relevant citations, which were then manually retrieved. The articles excluded were that published prior to 2000; those written in languages other than English and those whose purpose were different than our aim study, as well as if they had a different design like narrative or systematic reviews.

There were 1203 articles in total found during the initial search. After eliminating duplicates, the articles were selected by title and abstract yielding 84 papers that undergo a discussion by all team members through their weekly meetings to determine which articles should be included in the study, resulting 33 papers were excluded leaving 51 studies for analysis (Fig. 1).

The articles were classified into four categories according to maternal western diet and pregnancy complications; birth outcomes; long-term offspring outcomes as well as the supplementary consumed with it. The following data: study design, study objective, maternal diet period and main findings regarding the offspring health were all taken from the included papers, and presented as a narrative review results due to the heterogeneity of the article design.

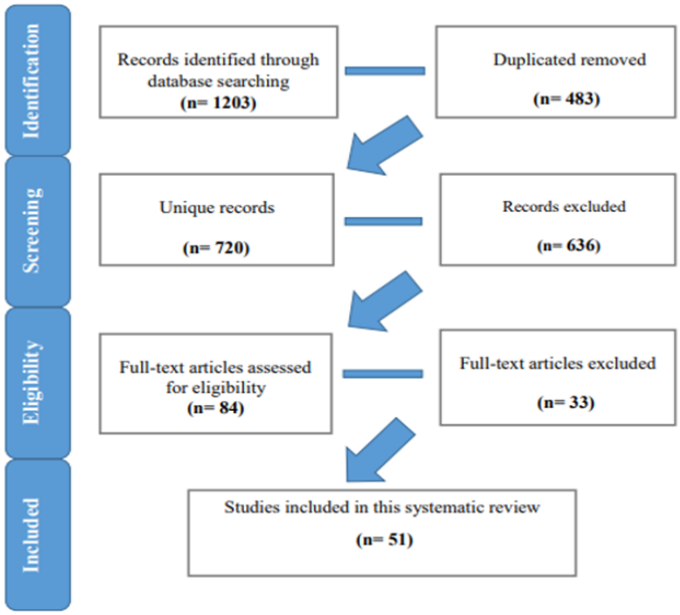

Fig. (1): Prisma flow chart shows the study selection process steps.

3. RESULTS

Fifty-one studies demonstrated as their relation to the maternal western diet style and its different effects, that varied between its relation to pregnancy complications, birth outcomes, and long-term offspring outcomes as well as the effect of supplementary added to the western dietary pattern of the mother (Fig. 2A). The majority of the investigations were carried out in the United Kingdom, albeit they were all undertaken in other nations (Fig. 2B). The rat model was the one that was most frequently utilized in the research, which also included woman as a case study (Fig. 2C). Studies on the mother's western diet have shown varying levels of interest over time, fluctuating between increases and decreases. The years 2014 and 2018 had the highest levels of interest (Fig. 2D).

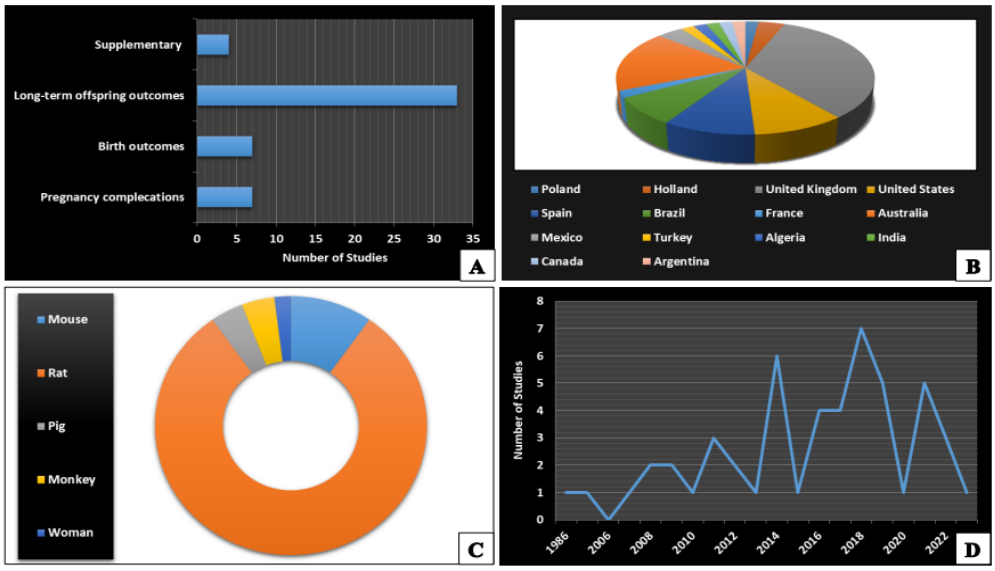

Fig. (2): A. Bar chart show the number of studies interested on the maternal western diet style and their different effects; **B.** Pie chart show the countries interested in maternal western diet style (%); **C.** Doughnut chart show the different models used through the studies that dialed with maternal western diet style (%); **D.** Line chart show the numbers variation of studies interested in maternal western diet style through years.

3.1. Maternal western diet style and pregnancy complications.

Seven studies focused on the maternal diet style and pregnancy complications. Two studies were done in Australia, while the others were done in different countries through different species that varied between rat, pig and monkey. All studies used cafeteria diet verse control, the models of studies exposed to both diet styles before as well as during conception, and the main findings summarized in table (1).

Table 1. Studies on maternal western diet style and pregnancy complications.

Source (Country)	Strain (Species)	Maternal diet period	Findings
Gastiazoro *et al.* (2022) **(Spain)** [11]	Wistar **(Rat)**	From weaning until parturition.	Cafeteria diet didn't affect reproductive performance or fetal weight and length. However, the placental weight and index were decreased in dams fed cafeteria diet and their pups exhibited a low birth weight.
Akyol *et al.* (2009) **(United Kingdom)** [12]	Wistar **(Rat)**	From weaning until parturition.	Cafeteria feeding was effective in inducing obesity, as demonstrated by increased fat depot weights and total body fat, without impacting upon reproductive success or circulating lipid concentrations. The maternal body fatness and diet have differential effects upon fetal and placental growth, with pre-gestational obesity leading to lower fetal weight at day 20 of gestation.
Vithayathil *et al.* (2018) **(Australia)** [13]	Albino Wistar **(Rat)**	4-6 weeks before conception until parturition.	There were no differences in gestation length, litter size or the percentage of male and female pups, however body weights of pups at birth were ~ 20% lower and there were also significantly more litters in which pups died either before or shortly after birth in the in the cafeteria diet group.
Nash *et al.* (2021) **(United States)** [14]	Japanese Macaques **(Monkey)**	For 2–9 years prior to conception and throughout pregnancy.	Hepatic stellate cell (HSC) and myofibroblasts are sensitive to maternal western diet-associated oxidative stress in the fetal liver, which is accompanied by increased periportal collagen deposition, indicative of early fibrogenesis beginning in utero.
Crew *et al.* (2016) **(Australia)** [15]	Albino Wistar **(Rat)**	8 weeks of pre-pregnancy until day 21 of gestation.	Maternal obesity induced by a cafeteria diet before and during pregnancy does not increase the inflammatory status of the mother, placenta or fetus in late gestation.
Kannan and Bhaskaran (2019) **(India)** [16]	Sprague Dawley **(Rat)**	From weaning until 32 weeks of age as well as through gestation until delivery.	Hypoprolactinemia, sub-fecundity, sub-fertility, delayed conception and macrosomic pups of reduced litter size in sustained obese rats. Beside, decrease in the number of ovarian follicles (primordial, primary, secondary and antral follicles) and corpus luteum indicates impairment in folliculogenesis and ovulation.
Sinclair *et al.* (2018) **(Canada)** [17]	Guinea **(Pig)**	From weaning and through pregnancy.	Maternal Western Diet consumption prior to and during pregnancy induces differences in maternal liver fat content, fetal liver volume and liver fat storage, as well as changes in fetal adipose tissue deposition that can be measured in utero using MRI.

3.2. Maternal western diet style and birth outcomes.

Seven studies interested on the relation between maternal western diet style and birth outcomes, four of them done in the United Kingdom through rat models, while only one case study on woman was done in Holland, and the other two studies were done in different countries through different species that varied between rat and mouse. All studies used cafeteria diet verse control, the models of studies exposed to both diet styles during conception and lactation or before gestation as well. In the woman case study, to determine the maternal preconception intake, the nutritional intakes of mother were assessed after birth of the index child for 14 months. The age of offspring varied between neonate, 10, 21 and 23 day post-natal, and the main findings summarized in table (2).

Table 2. Studies on the associations between maternal western diet style and birth outcomes.

Source (Country)	Strain (Species)	Maternal diet period	Offspring age	Findings
Bayol *et al.* (2005) **(United Kingdom)** [4]	Wistar **(Rat)**	During gestation alone or during both gestation and lactation.	21 days post-partum	Rats exposed to a cafeteria diet during gestation and lactation exhibited impaired skeletal muscle development and increased adiposity.
George *et al.* (2019) **(United Kingdom)** [18]	Wistar **(Rat)**	8 weeks before mating, throughout pregnancy and lactation.	Neonates and 21 days post-partum.	Exposure to obesity during pregnancy was associated with lower offspring birth weight and body weight in early-postnatal life. In contrast, exposure during lactation alone reduced offspring weight but increased adiposity in male offspring of a cafeteria-fed dam before weaning.
Frihauf *et al.* (2016) **(United Kingdom)** [19]	DR and DIO **(Rat)**	54 days before mating, throughout pregnancy and lactation.	23 days post-partum	Maternal Western diet covertly programmed increased adiposity in childhood and adulthood, disrupted relations of energy regulatory hormones with body fat, and decreased energy expenditure in offspring of lean, genetically obesity-resistant mothers.
Vujkovic *et al.* (2007) **(Holland)** [20]	Case study **(Woman)**	Maternal nutritional intakes were assessed 14 months after the birth of the index child to estimate the preconception intake.	Neonates	Maternal Western diet increases the risk of offspring with a cleft lip or cleft palate approximately two fold.
Rothwell and Stock (1986) **(United Kingdom)** [21]	Sprague-Dawley **(Rat)**	During gestation and lactation.	21 days post-partum	Cafeteria-fed mothers gave birth to the same number and weight of pups as controls, and these grew normally, but were fatter at weaning than control pups. The Brown fat activity in their offspring at weaning did not differ between treatments, although tissue protein content was depressed in the pups of cafeteria-fed dams.
Rossetti *et al.* (2019) **(Argentina)** [22]	Wistar **(Rat)**	From weaning	Embryonic day 21 and day 10 postnatal.	Maternal junk-food feeding can affect reward system during development and early postnatal life.
Du *et al.* (2012) **(United States)** [23]	C57B6J **(Mouse)**	2 weeks before breeding, throughout pregnancy and lactation	Nursing pups	Maternal western diet feeding causes neonatal toxicity, manifested as lipid accumulation, inflammation, and alopecia.

3.3. Maternal western diet style and long-term offspring outcomes.

Thirty-three studies dealt with the relationship between maternal western diet style and long-term offspring outcomes, the studies were done in different countries through various models mouse, rat, pig and monkey. All studies used cafeteria diet verse control, the models of studies exposed to both diet styles pre-conception, during gestation and lactation as aggregated or separated periods. The offspring of all studies after weaning exposed to either standard or cafeteria diet style and the main findings summarized in table (3A-D).

Table 3A. Studies investigating maternal western diet style and long-term offspring outcomes.

Source (Country)	Strain (Species)	Maternal diet period	Offspring Exposures& Period	Findings
Speight *et al.* (2017) **(United Kingdom)** [9]	Wistar **(Rat)**	During lactation.	Offspring were fed standard diet after weaning until 23 postnatal days.	Cafeteria diet-fed dams had a higher energy intake, due to an overconsumption of sugars and fats. When offspring from these dams were exposed to the open field after weaning, their locomotor activity was increased.
Hiramatsu *et al.* (2017) **(United States)** [24]	Hsd:ICR **(Mouse)**	2 weeks prior to mating until 14 days after parturition.	Offspring fed standard diet from 15 days old until 6 weeks of age.	Maternal Western diet had long-lasting and general effects on offspring adult morphology, but effects on adult behavior were limited and contingent on sex and genetic background.
Wright *et al.* (2011) **(United Kingdom)** [6]	Wistar **(Rat)**	Pre-pregnancy, pregnancy and lactation periods.	Offspring were fed either standard or cafeteria diet from weaning until 10 weeks of age.	Pre-gestational, gestational and lactational maternal cafeteria diet programme behaviour in the offspring with lactational cafeteria diet reducing anxiety in the male offspring.
Jacobs *et al.* (2014) **(Brazil)** [25]	Wistar **(Rat)**	10 weeks pre-pregnancy, pregnancy and lactation periods.	Offspring were fed standard diet after weaning until 90 post-natal days age.	Maternal consumption of cafeteria diet affected reproductive hormone regulation in the offspring and such modifications were reflected on sexual performance.
Vithayathil *et al.* (2018) **(Australia)** [13]	Albino Wistar **(Rat)**	Before and during pregnancy as well as lactation period.	Pups were cross-fostered to another dam that gave birth within the 24 h period after birth from either the same or different dietary treatment group till weaning age (3 weeks of age). After weaning, the pups were fed with standard rat chow until 6 weeks of age.	Exposure to a cafeteria diet during the prenatal or early postnatal period has different effects on fat deposition and the expression of lipogenic/adipokine genes in adipose tissue in the offspring, and that a number of these effects are sex-specific. As well as, the suckling period plays a more important role in the regulation of both lean tissue growth and fat deposition at weaning than exposure before birth.
Ruegsegger *et al.* (2017) **(United States)** [26]	Wistar **(Rat)**	5 weeks before and throughout pregnancy.	All offspring consumed standard diet until 18 weeks of age.	The exposure to western diet reprograms voluntary and spontaneous physical activity levels. Beside, influences dopamine and leptin signaling in mesolimbic brain nuclei.
Pruis *et al.* (2014) **(Holland)** [27]	C57BL/6 **(Mouse)**	6 weeks before and during gestation and lactation.	Male offspring were assigned either the Western or the control diet after weaning until 29 weeks of age.	Male offspring exposed to prenatal and post-weaning western-style diet showed hepatomegaly combined with accumulation of hepatic cholesterol and triglycerides.
Akyol *et al.* (2012) **(United Kingdom)** [28]	Wistar **(Rat)**	7 weeks pre-pregnancy, pregnancy and lactation periods.	Offspring were fed either standard or cafeteria diet until 13 weeks of age.	Maternal overnutrition and obesity during pregnancy are risk factors for metabolic disturbance in the resulting offspring. Although the effects on glucose homeostasis were independent of offspring adiposity, the programming of a glucose-intolerant phenotype was only observed when offspring were weaned on a diet that induced greater fat deposition.
Ribeiro *et al.* (2018) **(Brazil)** [29]	Swiss **(Mouse)**	During the gestation period.	Offspring were fed standard chow diet from 0 till 32 day of weaning.	Maternal consumption of a cafeteria diet during the gestation period can program developmental and behavioral courses in the offspring.
Matuszewska *et al.* (2021) **(Poland)** [30]	Wistar **(Rat)**	4 weeks pre-pregnancy, pregnancy and lactation periods.	Offspring were fed either standard or cafeteria diet until 25 days postnatal.	Maternal cafeteria diet affects fat content, metabolic profiles, and inflammation parameters in offspring. Above effects are sex-specific, with female offspring being more susceptible to the diet.
Pomar *et al.* (2017) **(Spain)** [31]	Wistar **(Rat)**	During lactation	Offspring were weaned onto a control diet until the age of 6 months.	Offspring of rats fed a cafeteria diet during lactation showed lower body weight and lower lean mass, but greater fat accumulation, compared with controls. They also displayed hyperleptinaemia, altered lipid profile and impaired response to an oral glucose tolerance test.

Table 3B. Studies investigating maternal western diet style and long-term offspring outcomes.

Source (Country)	Strain (Species)	Maternal diet period	Offspring Exposures& Period	Findings
Val-Laillet *et al.* (2020) **(France)** [32]	Yucatan **(Pig)**	During gestation and lactation.	Offspring were fed standard diet after weaning until post-natal 90 days.	Maternal diet during pregnancy and lactation had significant effects on morphological changes of microglial cells in the offspring.
Trujillo-Villarreal *et al.* (2021) **(Mexico)** [33]	Wistar **(Rat)**	9 weeks (pre-pregnancy, pregnancy and lactation)	Offspring were fed with control diet and CAF-CAF offspring were fed with CAF diet after weaning at postnatal day 21 until 2 months of age.	Reduction in motivation for natural rewards, which relates with lower brain volume in the lateral hypothalamus and in the right nucleus accumbenst core showing defects in synaptophysin expression.
Bayol *et al.* (2008) **(United Kingdom)** [34]	Wistar **(Rat)**	During pregnancy and lactation periods.	Offspring were fed either standard or cafeteria diet until 10 weeks postnatal.	Maternal junk food diet promotes adiposity in offspring and the earlier onset of hyperglycemia, hyperinsulinemia and/or hyperlipidemia. Male and female offspring also display a different metabolic, cellular and molecular response to junk-food-diet-induced adiposity, the increased adiposity was more enhanced in female than male offspring.
Moreton *et al.* (2019) **(United Kingdom)** [35]	Wistar **(Rat)**	During lactation.	Offspring were fed standard diet until 26 days postnatal.	Obesogenic lactational diet can have a detrimental impact on cognition in adolescent offspring associated with aberrant prefrontal cortex serotonin and dopamine metabolism.
Pomar *et al.* (2022) **(Spain)** [36]	Wistar **(Rat)**	During lactation.	The offspring were weaned onto a standard diet, and at 16 weeks of age they were switched to a Western diet until week 24.	Offspring of cafeteria diet-fed dams during lactation displayed, at weaning, early adaptations in the expression profile of genes related to lipid metabolism and thermogenesis in the brown adipose tissue that would be aimed at counteracting the higher caloric intake from maternal milk. However, in adulthood, and after a Western diet challenge, these animals showed a lack of response to this new obesogenic stimulus, suggesting that the thermogenic capacity in the brown adipose tissue was impaired.
Tajaddini *et al.* (2022) **(Australia)** [37]	Sprague-Dawley **(Rat)**	6 weeks pre-pregnancy, gestation, and lactation.	Offspring were weaned onto chow or cafeteria diet for 11 weeks.	Maternal and post weaning exposure to a palatable 'cafeteria' diet each impacted offspring metabolic health and their effects were largely independent, with greater impact in male than female offspring. As well as, offspring appeared to exhibit reduced anxiety-like behavior on the elevated plus maze.
Perez *et al.* (2018) **(Spain)** [38]	C57BL/6Tac **(Mouse)**	10 weeks pre-gestation, gestation and lactation.	Offspring fed standard diet for 10 weeks post-weaning.	Maternal diet composition greatly influences survival of neonate, and that surviving offspring from dams chronically fed a Western diet do not display marked changes in body mass, eating patterns, or expression and function of the endocannabinoid system in several peripheral organs important for feeding behavior and energy homeostasis.
Nash *et al.* (2023) **(united states)** [39]	Japanese macaques **(Monkey)**	Before and throughout pregnancy for 1–8 years.	Offspring were kept with dams on their respective diets during lactation until weaning, at which point they were assigned to either a post-weaning chow diet or post-weaning western diet and maintained on that diet until 3years old.	Body weight was not increased in offspring from neither maternal western diet nor post-weaning western diet groups, but post-weaning western diet offspring had greater retroperitoneal adipose tissue and liver weights compared with post-weaning chow diet groups. 3-year-old offspring exposed to maternal western diet but weaned to a chow diet have periportal collagen deposition, with transcriptional and metabolic pathways underlying hepatic oxidative stress, compromised mitochondrial lipid sensing, and decreased antioxidant response. Exposure to post-weaning western diet worsens these phenotypes, triggers endoplasmic reticulum stress, and increases fibrosis.

Table 3C. Studies investigating maternal western diet style and long-term offspring outcomes.

Source (Country)	Strain (Species)	Maternal diet period	Offspring Exposures& Period	Findings
Grassi *et al.* (2018) **(Brazil)** [40]	Sprague-Dawley **(Rat)**	From gestational day 12 until post-natal day 21.	At PND 21, female offspring received a single dose of N-Methyl-N-Nitrosourea (MNU, 50 mg/kg body weight) and were fed a control diet for 13 weeks.	Maternal western-style diet during pregnancy and lactation resulted in mammary tumors with differential expression of several genes involved in the promotion of tumor growth, invasion, and metastasis in female offspring initiated with MNU.
Wait *et al.* (2021) **(United Kingdom)** [41]	Wistar **(Rat)**	During lactation.	Offspring were fed standard diet until 26 days postnatal.	Exposure to a palatable, but unbalanced, hyper-energetic cafeteria diet during lactation impairs recency memory and object location memory in early adolescence, whereas the impact on spatial habituation learning warrants further investigation.
Bayol *et al.* (2010) **(United Kingdom)** [42]	Wistar **(Rat)**	During gestation and lactation	Offspring were fed either standard or cafeteria diet after weaning up to the end of adolescence.	Maternal junk food diet in pregnancy and lactation contributes to the development of nonalcoholic fatty liver disease in offspring.
Bayol *et al.* (2008) **(United Kingdom)** [43]	Wistar **(Rat)**	During pregnancy and lactation periods.	Offspring were fed either standard or cafeteria diet until 10 weeks postnatal.	Maternal junk food diet during pregnancy and lactation may be an important contributing factor in the development of obesity.
Ong and Muhlhausler (2014) **(Australia)** [44]	Albino Wistar **(Rat)**	4 weeks before pregnancy and throughout pregnancy and lactation.	Offspring were weaned onto a standard rodent chow until 6 weeks (juvenile) or 3 months (adult). They were then given free access to both chow and junk food for 3 weeks.	The effects of perinatal junk food exposure on food preferences and fat mass can be reversed by consuming a low-fat diet from weaning to adulthood in males. Females, however, retain a higher propensity for diet-induced obesity even after consuming a low-fat diet for an extended period after weaning.
Vithayathil *et al.* (2016) **(Australia)** [45]	Albino Wistar **(Rat)**	4–6 weeks before pregnancy and throughout pregnancy and lactation.	Pups were cross-fostered to another dam that gave birth within the 24 h period after birth from either the same or different dietary treatment group till weaning age (3 weeks of age). After weaning, the pups were fed with standard rat chow until 6 weeks of age.	Offspring suckled by cafeteria fed dams had a lower omega-3 LCPUFA and omega-6 PUFA status at weaning and higher trans fatty acid levels at both weaning and 6 weeks of age.
Mucellini *et al.* (2014) **(Brazil)** [46]	Wistar **(Rat)**	From their own weaning to the weaning of their offspring.	Offspring were fed either standard or cafeteria diet from day 16 of lactation to the day 120 of age.	Maternal obesity does not modulate the metabolism of male offspring independently, modifying body weight only when associated with the intake of a cafeteria diet by the offspring.
Bayol *et al.* (2009) **(United Kingdom)** [47]	Wistar **(Rat)**	During pregnancy, lactation	Offspring were fed either standard or cafeteria diet from post-weaning up to 10 weeks of age.	Adult offspring from mothers fed the junk food diet in pregnancy and lactation display reduced muscle force (both specific twitch and tetanic tensions) regardless of the post-weaning diet compared with offspring from mothers fed a balanced diet.
Daniel *et al.* (2014) **(United Kingdom)** [48]	Wistar **(Rat)**	During lactation	Offspring were fed either standard or cafeteria diet from post-weaning up to 13 weeks of age.	Responses to cafeteria diet during both phases of the experiment varied between males and females. Global DNA methylation was altered in the liver following cafeteria feeding in the post-weaning period, in males but not females.
Wright *et al.* (2011) **(United Kingdom)** [49]	Wistar **(Rat)**	During lactation	Offspring were chow fed after weaning up to 20 weeks of age.	Lactational cafeteria diet has a programming effect on feeding behaviour and brain monoaminergic neurons.

Table 3D. Studies investigating maternal western diet style and long-term offspring outcomes.

Source (Country)	Strain (Species)	Maternal diet period	Offspring Exposures& Period	Findings
Wright *et al.* (2014) **(United Kingdom)** [50]	Wistar **(Rat)**	During lactation	Offspring were chow fed after weaning up to 13 weeks of age.	Maternal exposure to the cafeteria diet programmes a novel object discrimination (NOD) in the adult. In better-performing females, dietary programming interferes with NOD, whereas NOD was improved in males after lactational cafeteria diet feeding.
Ong and Muhlhausler (2011) **(Australia)** [51]	Albino Wistar **(Rat)**	4 weeks before pregnancy and throughout pregnancy and lactation.	Offspring were fed either standard or cafeteria diet from post-weaning up to 3 months of age.	Perinatal exposure to high-fat, high-sugar diets results in altered development of the central reward system, resulting in increased fat intake and altered response of the reward system to excessive junk-food intake in postnatal life.
Gugusheff *et al.* (2016) **(Australia)** [52]	Albino Wistar **(Rat)**	2 weeks prior to mating and throughout pregnancy and lactation.	Offspring were fed either standard or cafeteria diet until 28 post-natal day.	No effects of perinatal junk food exposure on mu-opioid receptor mRNA expression or binding were detected at these time points in male offspring.
Gugusheff *et al.* (2013) **(Australia)** [53]	Albino Wistar **(Rat)**	4–6 weeks before pregnancy and throughout pregnancy and lactation.	Pups were cross-fostered to another dam that gave birth within the 24 h period after birth from either the same or different dietary treatment group till weaning age (3 weeks of age). After weaning, the pups were fed with standard rat chow until 10 weeks of age.	Prenatal exposure to a junk food diet effect on food preferences in females and susceptibility to diet-induced obesity in males can be prevented by improved nutrition during the suckling period.

3.4. Supplementary with maternal western diet style.

Four studies dealt with adding supplements to the maternal western diet style. The studies were done in different countries through rat models. All studies used cafeteria diet verse control, the models of studies exposed to both diet styles beside the supplementary before and during conception as well as lactation periods. The type and dose of supplementary added, and the main findings summarized in table (4).

Table 4. Studies dealing the supplementary with maternal western diet style.

Source (Country)	Supplementary used	Strain (Species)	Maternal Exposures& Period	Findings
de la Garza *et al.* (2019) **(Mexico)** [36]	Flavonoids	Wistar **(Rat)**	It was used a cafeteria diet supplemented with flavonoids, kaempferol-3-O-glucoside (15 mg/kg bw) and narirutin (30 mg/kg bw) three weeks before mating until offspring birth and lactation.	Dietary supplementation with flavonoids revert the depression-like behaviour in the female offspring.
Kabasakal Çetin *et al.* (2021) **(Turkey)** [53]	Taurine	Wistar **(Rat)**	Female Wistar rats were fed a control diet (CON), CON supplemented with 1.5% taurine in drinking water (CONT), cafeteria diet (CAF) or CAF supplemented with taurine (CAFT) from weaning (Pre-pregnancy, pregnancy, and lactation).	Maternal taurine supplementation exerted modest protective effects on cafeteria diet induced maternal obesity. The increased neonatal mortality in CONT neonates indicates possible detrimental effects of taurine supplementation in the setting of normal pregnancy.
Benaissa *et al.* (2015) **(Algeria)** [55]	Linseed Oil	Wistar **(Rat)**	Female Wistar rats were fed control or cafeteria food, which were either supplemented or not supplemented with linseed oil (5%) for 1 month before and during gestation.	Linseed oil improved metabolic status and it displayed health benefits by modulating tissue enzyme activities in both obese mothers and their newborns.
Sánchez-Blanco *et al.* (2018) **(Spain)** [56]	Fish oil	Sprague Dawley **(Rat)**	Rats were fed control or cafeteria diet (CD) supplemented (or not) with fish oil (8.78g/100g) during just the first 12 days of pregnancy, or during the whole of pregnancy and lactation.	Fish oil supplement during just the first half of gestation or during pregnancy and lactation in rats on cafeteria diet decreases the liver steatosis in male adult offspring.

4. CONCLUSION

Evidence from clinical and experimental studies clearly show that the maternal western diet pattern before, during pregnancy as well as the lactation whether combined or separated periods increase risk of pregnancy complications beside the disease in later offspring life.

It was also noted that the risk of disease increased with the continuation of feeding on the western diet pattern post-weaning period. Despite the increasing rates of Western-style nutrition, its share of prenatal research is insufficient. Therefore, we recommend paying more attention to this research point in order to raise awareness of the risks of eating this dietary pattern on pregnancy, embryo, newborn, infant, child and adolescent. Also, find solutions to minimize its complication hazards.

Finally, we hope that a healthy eating pattern becomes trendy nowadays for its obvious beneficial implications in enhancing mother and their children health, as well as securing the health, fecundity and life expectancy, which is a promise of good health for the future generation.

5. REFERENCES

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