Maternal obesity and the intergenerational risk of cancer : Epidemiologic evidence and mechanistic insights

Moeckli, Beat; Rocha, Margarida; Wassmer, Charles-Henri; El Hajji, Sofia; Collet, Tinh-Hai; Lacotte, Stéphanie; Toso, Christian

How to cite

MOECKLI, Beat et al. Maternal obesity and the intergenerational risk of cancer : Epidemiologic evidence and mechanistic insights. In: Cancer epidemiology, 2026, vol. 102, p. 103079. doi: 10.1016/j.canep.2026.103079

This publication URL: https://archive-ouverte.unige.ch/unige:193652

Publication DOI: 10.1016/j.canep.2026.103079

Cancer Epidemiology 102 (2026) 103079

Contents lists available at ScienceDirect

Cancer Epidemiology

journal homepage: www.elsevier.com/locate/canep

Maternal obesity and the intergenerational risk of cancer: Epidemiologic evidence and mechanistic insights

Beat Moeckli [a,b,c,*], Margarida Rocha [b], Charles-Henri Wassmer [a,b], Sofia El Hajji [a,b], Tinh-Hai Collet [d,e], Stephanie Lacotte [b], Christian Toso [a,b]

[a] Department of Surgery, Division of Visceral Surgery, Geneva University Hospitals, Geneva 1205, Switzerland
[b] Transplantation and Hepatology Laboratory, Department of Surgery, Faculty of Medicine, University of Geneva, Geneva 1206, Switzerland
[c] Transplant Center, Mayo Clinic, Rochester, MN, USA
[d] Division of Endocrinology, Diabetology and Metabolism, Department of Medicine, Geneva University Hospitals, Geneva 14, 1211, Switzerland
[e] Diabetes Center, Faculty of Medicine, University of Geneva, Geneva 1206, Switzerland

ARTICLE INFO

Keywords:
Maternal Obesity
Cancer
Intergenerational
Epigenetics
Gut Microbiome

ABSTRACT

Over recent decades, the prevalence of obesity has markedly surged. While excess maternal weight is a well-established risk factor for adverse pregnancy outcomes, growing evidence suggests that maternal obesity may also increase the long-term risk of cancer in offspring. This comprehensive review synthesizes epidemiological and experimental data linking maternal obesity to heightened cancer susceptibility in the next generation. Observational studies demonstrate increased risks of childhood leukemia and colorectal cancer in offspring of obese mothers, whereas preclinical models support associations with breast, liver, colon, and pancreatic cancers. Mechanistically, maternal obesity induces epigenetic reprogramming, immune dysregulation, and vertical transmission of a dysbiotic gut microbiota, which may lead to persistent alterations in metabolic and inflammatory signaling pathways in offspring, thereby promoting a pro-tumorigenic environment and potentially increasing cancer susceptibility. Given the global burden of obesity, this intergenerational risk has critical public health implications. Lifestyle modifications, weight-loss interventions, and targeted approaches such as probiotic supplementation may offer promising strategies to mitigate cancer risk in offspring, but require scientific confirmation in further studies. Future research should prioritize mechanistic dissection of exposure windows, identification of predictive biomarkers, and the development of effective, scalable preventive therapies.

1. Introduction

Obesity has become a public health challenge in Western societies, with the global prevalence having more than doubled since 1990. Projections indicate that by 2050, over half of the world's adult population will be living with overweight or obesity [1]. Particularly worrying is the situation for women of reproductive age, with over two thirds of adult women below 40 years old being overweight or obese in certain world regions [1,2]. In 1960, researchers identified only 10% of young women as obese [3]. Between 1980 and 2018, the obesity rate among women of reproductive age doubled, soaring from 17% to 40% [3,4].

Historically, overweight and obesity have been defined using body mass index (BMI), with a BMI $\geq$ 25 kg/m^2 indicating overweight and a BMI $\geq$ 30 kg/m^2 indicating obesity, due to its simplicity and broad correlation with health risks at the population level [5,6]. However, this approach has been criticized for not directly measuring adiposity and misclassifying muscular individuals or those with harmful fat distribution despite lower BMI. The 2025 Lancet Diabetes & Endocrinology Commission introduces a paradigm shift by redefining obesity diagnostic criteria. According to the Commission, obesity is clinically confirmed by demonstrating excess or abnormal adiposity through direct body fat measurement (e.g., DEXA), the presence of one anthropometric criterion (e.g., waist circumference) in addition to BMI, or at least two anthropometric criteria regardless of BMI [7]. Clinical obesity is further defined by the above, accompanied by impaired organ function or limitations in daily activities, thereby identifying an even larger affected population [7,8].

The influence of obesity on women's health extends to their children. Obese women are at increased risk of pregnancy complications, such as gestational diabetes mellitus and preeclampsia, and are more likely to

* Correspondence to: Department of Surgery, Division of Visceral Surgery, Rue Gabrielle-Perret-Gentil 4, Geneva 1205, Switzerland.
E-mail address: beat.moeckli@unige.ch (B. Moeckli).

https://doi.org/10.1016/j.canep.2026.103079
Received 12 January 2026; Received in revised form 9 April 2026; Accepted 13 April 2026

require a cesarean section or experience preterm delivery [9,10]. The risk of fetal complications, fetal death, and stillbirth is also increased, while Apgar scores are lower compared with those of neonates born to normal-weight women [11,12]. Long-term effects of maternal obesity on offspring include an increased risk of overweight and metabolic syndrome [13,14], impaired cognitive development [15], and even a higher rate of certain types of cancer [16,17]. However, most patients affected by malignancies are older than 50 years of age [18]. Hence, the whole effects of the current obesity upsurge on cancer incidence will not be observable for another 20–30 years. This epidemiological reality further adds to the complexity of the research hypothesis of how maternal obesity, as a multifactorial condition, influences cancer risk in children.

In this review, we summarize the literature on the link between offspring cancer risk and obesity of the mother and investigate potential mechanisms underlying this association. We aim to examine the implications of the obesity epidemic for offspring cancer risk in future generations as the outcome of interest, and thereby support the establishment of efficient preventive interventions.

2. Epidemiological evidence and clinical studies

A structured literature search was conducted in PubMed using predefined search terms to identify studies published up to December 2025, with selection based primarily on relevance and conceptual contribution (Supplementary Data 1). Studies were included in Table 1 and Table 2 if they explicitly reported associations between maternal obesity or overweight and offspring cancer outcomes, regardless of whether maternal obesity was the primary exposure. The methodological quality of included cohort and case-control studies was assessed independently by two reviewers using the Newcastle-Ottawa Scale (Supplementary Data).

To date, we have identified seven cohort studies addressing this question, including more than eight million live births in their analysis (Table 1). Four of these studies assessed cancers occurring during childhood [16,19–21], other studies the risk of colorectal cancer [17], breast cancer [22], and the overall risk of cancer [23]. Four studies found a significant connection between BMI and cancer incidence in the offspring [16,17,19,20,23], and two did not [21,22].

Stacy et al. investigated the connection between maternal BMI and childhood cancer risk in a cohort study including close to 2 million children born from 2003 to 2016 [16]. Extracting data directly from medical records, the authors examined the Pennsylvania birth and cancer registry. The prospective cohort design reduced the recall bias characteristic of retrospective case-control studies. The authors discovered that children born to mothers with a BMI $\geq$ 40 kg/m^2 had a higher risk for any cancer (HR 1.32, 95% CI 1.08–1.62) and leukemia (HR 1.57, 95% CI 1.12–2.20). Moreover, Stacy et al. found a linear dose-response association between maternal BMI $>$ 30 kg/m^2 and offspring cancer risk. Interestingly, pregnancy weight gain did not significantly increase the risk of cancer, suggesting that preconception maternal nutritional and environmental factors play a larger role in transmitting risk from mother to child.

Murphy et al. published the first study examining the relationship between maternal BMI and malignancy risk of their children in adulthood. The study included more than 18,000 births in the 1960s registered by a single healthcare provider in California, the California Cancer

Table 1
Cohort studies on cancer risk in offspring of obese mothers.

Author	Year	Cancer	Findings	Cohort	Study design	Birth Years	Number of live births	Number of mothers	Person-years at risk	Adjusted HR (95% CI)
Liu et al. [19]	2025	Acute lymphoblastic Leukemia	Maternal BMI $\geq$ 25 during pregnancy associated with ALL	Population-based cohort in Sweden	Prospective cohort study	1983–2018	2961,435	NA	NA	1.2 (1.1–1.3)
Murphy et al. [17]	2022	Colorectal cancer	Maternal preconception obesity associated with higher risk for CRC	Prospective cohort, Californian child health development study	Prospective cohort study	1959–1966	18,751	14,507	738,048	2.51 (1.05–6.02)
Kessous et al. [20]	2020	Childhood cancers	Maternal preconception obesity associated with higher risk for childhood malignancies $<$ 18 years of age	Birth cohort from one Israeli tertiary center	Prospective cohort study	1991–2014	241,273	NA	NA	1.81 (1.02–3.22)
Schmid et al. [22]	2020	Breast cancer	Maternal preconception BMI not associated with higher risk of breast cancer	Nurses' Health Study (NHS) II and Nurses' Mothers' Cohort Study	Prospective cohort study	NA	35,133	35,133	403,786	0.98 (0.74–1.30)
Stacy et al. [16]	2019	Childhood cancers	Maternal preconception BMI $>$ 40 on birth certificate associated with higher risk for childhood cancers	Pennsylvania birth registry linked to Cancer Registry	Prospective cohort study	2003–2016	1803,199	1826,403	13,785,309	1.57 (1.12–2.12)
Petridou et al. [21]	2015	Childhood cancers	Maternal preconception BMI not associated with higher childhood cancers	Population-based Swedish Medical Birth Registry	Prospective cohort study	1973–2007	3'444'136	NA	NA	1.09 (0.76–1.57)
Eriksson et al. [23]	2014	Overall cancer incidence	Increased cancer incidence in offspring of mothers with a BMI $>$ 28	Helsinki birth cohort study	Prospective cohort study	1934–1944	13,345	NA	NA	1.17 (1.03–1.31)

Abbreviations: Acute lymphoblastic leukemia (ALL); Body Mass Index (BMI); Colorectal cancer (CRC); Hazard ratio (HR);

Table 2
Case-control studies on cancer risk in offspring of obese mothers.

Author	Year	Cancer	Findings	Cohort	Birth Years	Number of cases	Number of controls	adjusted OR (95% CI)
Bailey et al. [26]	2017	Childhood brain tumors	Preconception obesity not associated with childhood brain tumors	Children diagnosed with childhood brain tumors < 15 in ESTELLE cohort (French national cohort)	1995–2011	301	1421	0.6 (0.3–1.3)
Peckham-Gregory et al. [27]	2017	Childhood lymphoma	Preconception overweight not associated with Non-Burkitt NHL lymphoma	Children and adolescents < 16 years diagnosed with Non-Burkitt NHL lymphoma in the Texas Cancer Registry	1995–2011	374	3740	1.44 (0.51–4.11)
Contreras et al. [28]	2016	Childhood cancers	Preconception BMI of 25–30 associated with leukemia in offspring	Children diagnosed with childhood malignancies < 6 years; California Cancer Registry matched with randomly sampled birth records	1988–2011	11,149	270,147	1.27 (1.01–1.59)
Heck et al. [29]	2015	Childhood retinoblastoma	Preconception obesity not significantly associated with Retinoblastoma < 14 years	Children diagnosed with sporadic retinoblastoma < 14 years in multiple institutions of the Children's Oncology Group	2006–2011	165	136	1.1 (0.5–2.5)
Greenop et al. [30]	2014	Childhood brain tumors	Preconception obesity not significantly associated with childhood brain tumors	Children < 14 years diagnosed with brain tumors in Australian pediatric oncology centers	2005–2010	319	1079	0.9 (0.6–1.5)
Musselman et al. [31]	2013	Childhood cancer	Preconception BMI not associated with hepatoblastoma in offspring	Children diagnosed with hepatoblastoma < 6 years in multiple institutions of the Children's Oncology Group	1994–2008	383	387	1.0 (0.98–1.04)
Wilson et al. [34]	2011	Breast cancer	Preconception BMI and weight gain during pregnancy not associated with breast cancer in daughters	Female nurses includes in Nurses's Health Studies I and II cohorts diagnosed with breast cancer	1921–1965	814	1807	0.72 (0.32–1.64)
Spector et al. [32]	2007	Childhood leukemia	Trend towards higher risk for leukemia in children of mothers with BMI > 25	Infants diagnosed with leukemia before the age of 1 in multiple institutions of the Children's Oncology Group	1996–2002	240	250	1.34 (0.92–1.94)
McLaughlin et al. [33]	2006	Childhood leukemia	Preconception overweight associated with higher risk of ALL diagnosed < 5 years	Patients born in New York state diagnosed with leukemia < 10 years	1978–2001	1060	9686	1.44 (1.03–2.01)
Sanderson et al. [35]	1998	Breast cancer	Preconception BMI of > 22.6 of the mother not associated with breast cancer in daughters	Women diagnosed with breast cancer < 45 years from Washington State matched with randomly selected controls	1944–1962	510	436	1.1 (0.8–1.6)

Abbreviations: Odds ratio (OR); Non Hodgkin Lymohoma (NHL); Body Mass Index (BMI); Acute lymphoblastic leukemia (ALL)

Registry dataset [17]. The researchers matched mothers and descendants, and found an association between maternal obesity and the incidence of colorectal adenocarcinoma in the offspring with a 2.5 times greater risk. Furthermore, Murphy et al. examined the significance of weight gain in early pregnancy, reflecting an increase in availability of nutrients to the fetus, compared to late weight gain which can be attributed to fluid expansion and size growth [24,25]. The authors found that offspring from mothers with an early weight gain rate disproportional to the total pregnancy weight gain were at greatest risk of colorectal adenocarcinoma. Future studies should include the trajectories of pregnancy weight gain.

Using a nationwide Swedish cohort of nearly 3 million children born from 1983 to 2018, Liu et al. examined the relationship between maternal weight during pregnancy and childhood acute lymphoblastic leukemia (ALL) [19]. Maternal overweight and obesity were associated with a 40% increased risk of ALL in female offspring only, while no association was observed in males. Gestational weight gain was not linked to ALL risk in either sex. These findings indicate a sex-specific relationship and suggest that intrauterine metabolic or hormonal factors related to maternal adiposity may influence ALL development.

Additionally, we identified ten case-control studies that studied the influence of maternal BMI on cancer incidence in the next generation (Table 2). All [26–33] but two studies focused on childhood malignancies [34,35]. While the two largest studies with more than 1000 cases found a significant connection linking maternal pre-pregnancy weight and the risk of malignancy in offspring [28,33], the studies with < 1000 cases did not. This could be an indication that some of the smaller studies are underpowered or too heterogeneous for this type of hypothesis. Studies with fewer than 1000 cases may lack sufficient statistical power to detect modest associations (e.g., odds ratios in the range of 1.2–1.5), thereby increasing the risk of false-negative findings. Despite the potential of case-control studies to examine the association between maternal obesity and cancer incidence in the next generation for rare malignancies, such as liver or pancreatic cancer, these study designs are limited by the risk of confounding and recall bias, as well as selection bias arising from the identification and recruitment of cases and controls. They also still require the inclusion of a large number of cancer cases to draw robust conclusions.

Epidemiological research on the influence of preconception BMI on the risk of cancer in offspring is incomplete, but intriguing and supports an association with certain types of childhood malignancies, leukemia, and colorectal cancer (Fig. 1, Table 1) [16,17,19,20,33]. Further investigations should focus on obesity-related cancers, such as liver, esophageal, pancreas, colorectal, and breast cancer, occurring during adulthood decades later [36,37]. Future studies should be adequately powered to differentiate between underlying etiologies and cancer sub-types, for instance by ensuring sufficient sample sizes to detect small-to-moderate associations and conducting formal power calculations. Cancer registries and national cohorts are instrumental to answer these critical questions.

3. Preclinical studies and mechanistic evidence

The intergenerational increase in cancer risk from mother to her

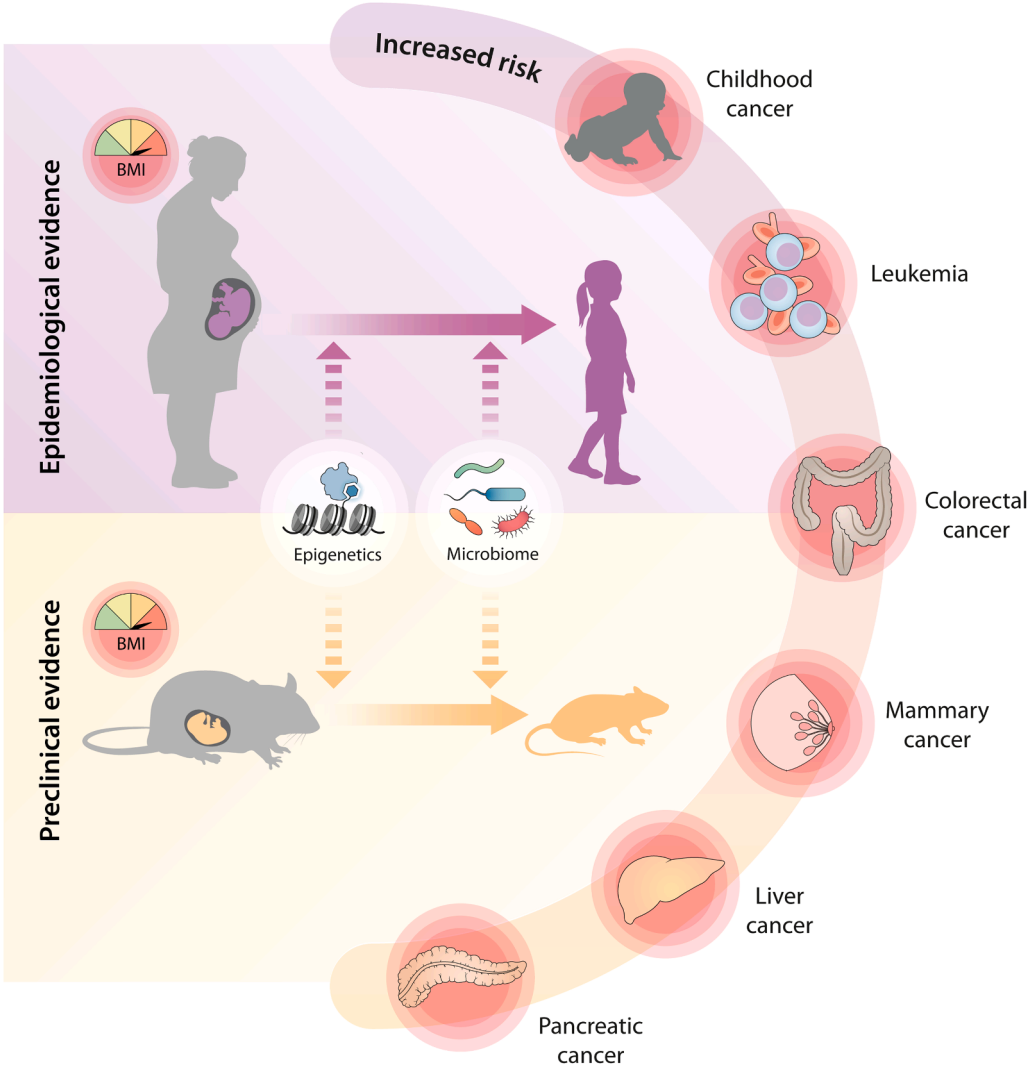

Fig. 1. Maternal obesity increases cancer risk in offspring. Epidemiological studies demonstrate an elevated risk for leukemia, childhood cancer, and colorectal cancer (top part of the figure in purple), while animal studies suggest an increased risk for mammary, pancreatic, colorectal, and liver cancer (bottom part of the figure in orange). The underlying mechanisms driving this increased risk may involve the transmission of a dysbiotic gut microbiota and epigenetic reprogramming.

children is a complex, long, and multifactorial process, making it challenging to identify the exact mechanisms involved through epidemiological studies. In the same way, animal studies in this field often rely on either genetically predisposed or chemically induced tumor models, which only partially reflect the pathophysiological processes of clinical reality. Nevertheless, animal studies provide valuable insights into the underlying biology that explains clinical observations. This section provides an overview of the available literature and discusses potential mechanisms.

3.1. *Epigenetic changes*

The role of the early-life environment in shaping the risk for chronic diseases later in adulthood is well-established within the Developmental Origins of Health and Disease (DOHaD) framework [38]. Epidemiological studies since the 1990s reported that an adverse prenatal environment can influence circulating levels of coagulation factors in adulthood [39], illustrating the lasting effects of an early exposure. Animal studies have demonstrated that temporary exposure to stressful environments during gestation can induce lasting epigenetic reprogramming of the genome, including alterations in DNA methylation, histone modification, and noncoding RNA expression [40–42].

3.1.1. *DNA methylation*

Environmental stimuli can lead to specific methylation of the cytosine base of the DNA to become 5-methylcytosine. Through hyper- or hypomethylation of promoter regions, gene expression can be regulated to adapt to a certain environment. These methylation changes can influence gene expression and phenotype over many decades. An example for such long-lasting methylation changes is the Dutch famine, which occurred during World War II. Several studies showed that individuals who experienced the famine *in utero* faced increased rates of obesity, impaired glucose tolerance, and altered lipid levels compared to their siblings conceived before or after the famine [43–46]. An effect that persists over several generations [43]. Du et al. recently examined the umbilical cord hematopietic stem cells from 72 neonates and found that maternal prepregnancy obesity was associated with global hypermethylation in offspring affecting DNA repair pathways, which could contribute to increased cancer risk [47]. DNA methylation changes also play a role in cancer susceptibility, with tumor cells exhibiting hypermethylation of tumor suppressor regions alongside genome-wide hypomethylation [48].

While the preceding findings are based on human epidemiological data, additional mechanistic insights have been gained from animal models. Yuan and colleagues investigated how early-life methylation affects the expression of fibroblast growth factor 2, a liver-derived

peptide responsible for regulating metabolism and energy homeostasis [49]. This study underscores the enduring influence of the gestational environment on the expression of powerful regulators implicated in energy homeostasis and potentially even tumorigenesis [50,51]. Several other studies have also shown that maternal obesity leads to lasting methylation changes in adulthood [52–54]. No research has yet directly linked changes in methylation status induced by maternal obesity to increased cancer risk in the offspring.

3.1.2. Histone modification

Histones are highly basic proteins rich in arginine and lysine. They are essential components of the chromosomal architecture and act as spools around which the DNA is wound, thus forming chromatin. The modification of histones through acetylation, phosphorylation, or methylation can change the accessibility of DNA and, therefore, the level of expression of certain genes or genomic regions [55].

The maternal diet does influence the chromatin structure in the offspring. Aagaard-Tillery et al. demonstrated that a Western-style diet in the mother induces site-specific alterations of histone acetylation in the fetal liver of primates [56]. In a murine study, Panchenko et al. investigated the impact of a diet rich in fat on the epigenetic machinery and found that maternal obesity significantly alters the acetylation pathway [57]. In addition, naturally derived histone deacetylases inhibitors can activate histone alterations. An example of such an inhibitor is sulforaphane present in broccoli sprouts. A recent study found that broccoli sprout supplementation during gestation and lactation protects against breast cancer later in adult offspring, with longer tumor latency and lower tumor mass [58]. The authors were able to connect this specific diet to altered histone methylation in oncogene promoter regions.

3.1.3. MicroRNAs

MicroRNAs are defined as noncoding RNA molecules playing a role in the post-transcriptional regulation of gene expression. MicroRNAs can silence gene expression by binding to target mRNAs which leads to their degradation by the cellular machinery [59]. Besides methylation changes and histone modifications, microRNAs are another epigenetic mechanism in maternal obesity that affect offspring health.

In a study using a toxin-induced liver cancer model, Sun et al. studied the impact of maternal HFD feeding on liver cancer risk [60]. The study group found that offspring of mothers fed an HFD grew larger and more numerous liver tumors than those of non-obese mothers, with a more pronounced effect in subsequent generations. Gene expression analysis revealed that *Acsl1* and *Aldh2*, two metabolic genes downregulated in offspring of HFD mothers, appeared to be suppressed by the microRNA miR-27a-3p. The injection of miR-27a-3p into pregnant dams demonstrated a significant increase in tumor burden in the offspring, indicating the potential implication of microRNA regulation in the transgenerational transmission of liver cancer risk. However, our recent integrative genomic analysis of 11 previously published datasets showed no downregulation of *Acsl1* or *Aldh2* in any of the studies [61,62]. While microRNA may play a part in the maternal transmission of chronic liver disease to offspring, this evidence suggests it is not likely to be the sole cause of the observed effect. These findings emphasize the importance of elucidating the mechanisms by which maternal obesity increases hepatocellular carcinoma (HCC) risk in offspring.

Maternal obesity triggers epigenetic adaptations during *in utero* development. Emerging evidence suggests that epigenetic alterations induced by maternal obesity are associated with increased cancer risk in offspring, both directly and indirectly through their impact on metabolic disorders. Establishing causality between exposure in early life, specific epigenetic alterations, and heightened cancer rate will require preclinical functional studies and epidemiological designs that include epigenetic data [63].

3.2. Gut microbiome

The gut microbiome, lives symbiotically with the human host. Until the past two decades, researchers have largely overlooked the role of the gut microbiome in disease development [64]. Since then, tremendous progress has been made and several landmark studies have established the key role of gut microbiota in immunity, digestion, obesity, and cancer development [65–68]. This section will discuss its contribution to oncogenesis and the mechanisms of microbiome transmission between generations.

3.2.1. Cancer risk and the gut microbiome

The gut microbiota has numerous impacts on cancer risk. First, through host colonization by pathogens, it directly contributes to the establishment of a pro-inflammatory setting and impairment of the immune system. Secondly, the gut microbiome impacts cancer risk through alterations in the breakdown of nutritional constituents or endogenous substances like steroid hormones or bile acids [69]. Researchers have long established the association between bacterial pathogens and certain cancers. *Helicobacter pylori* infection is strongly associated with MALT lymphoma and gastric cancer, and *Salmonella typhi* colonization with gallbladder cancer [70,71]. Additionally, scientists have connected several bacterial genera colonizing the gut to a greater risk for colorectal cancer [72–74].

Furthermore, research groups have established the gut microbiome's impact on antitumor immunity through various mechanisms. For example, Greten et al. conducted a mouse study in which Gram-positive bacteria were eliminated from the gut microbiome through administration of Vancomycin. They discovered that this led to a decrease in hepatic tumor load, but did not affect the tumor burden outside the liver in multiple mouse models [75]. The authors attributed this to an increase in the hepatic natural killer T (NKT) cell population, which inhibited cancer growth. The elimination of Gram-positive species from the gut microbiota activated liver sinusoidal endothelial cells to express *CXCL16*, resulting in altered bile acid metabolism and promoting the attraction of NKT cells. This heterogenous T-cell subpopulation plays a vital role in antitumor immunity and immunoregulation, specifically in controlling hepatic tumor load [76].

Several clinical studies have shown that patients receiving immune checkpoint inhibitor therapy along with broad-spectrum antibiotics had a decreased progression-free survival compared to those who were not treated with antibiotics [77–79]. These findings support the notion that an undisturbed gut microbiota with high diversity is crucial for an effective immune surveillance to detect cancer cells, possibly through improved antigen presentation and enhanced T-cell function [80]. Additionally, fecal microbial transplantation from a healthy donor has been shown to improve a patient's response to immune checkpoint inhibitor treatment. Although the precise microbiome components responsible for this positive response remain unclear, these results suggest that the microbiota composition can enhance the antitumor immune response.

3.2.2. Gut microbiome transmission at birth and early life

Mother and child establish a microbial bond at birth when the microorganisms originating from the mother's microbiota colonize the newborn's skin and mucosal surface, including the gut. Ferretti et al. studied 25 mother-infant pairs to investigate the source and transmission paths of the infants' gut microbiomes [81]. Interestingly, newborns shared most gut microbiome species with their mothers, with colonization occurring within 24 h after vaginal birth, from different maternal body sites such as the skin, vagina, breast milk, and gut [82]. In a large observational cohort including 935 mother-infant pairs, Tun et al. investigated gut microbiota as a possible mediator in the connection between maternal obesity and childhood obesity [83]. Maternal obesity resulted in a 3- to 5-fold higher obesity risk in toddlers. Although the authors did not provide substantive proof for causality, they

associated this higher risk with a higher abundance of the *Lachnospiraceae* family and a higher diversity within the *Firmicutes* phylum [83]. Furthermore, specific bacterial species that decrease in abundance under a diet low in carbohydrates accessible for fermentation are not passed on to the following generation, leading to progressive loss of microbiome diversity [84].

A recent work from our group has provided compelling experimental evidence that maternal obesity can increase the risk of hepatocellular carcinoma in offspring via vertical transmission of a dysbiotic gut microbiome [85]. In a carcinogen-induced murine model of HCC, we demonstrated that maternal high-fat diet exposure led to profound and lasting alterations in the gut microbiome of female offspring, characterized by decreased diversity and increased abundance of pro-inflammatory taxa such as the *Erysipelotrichaceae* family. These microbial changes were associated with liver steatosis, fibrosis, and elevated hepatic expression of Toll-like receptors and innate immune markers. Most notably, the transmission of this altered microbiome significantly increased tumor incidence and growth in offspring, independent of postnatal diet. Strikingly, co-housing of high-fat exposed offspring with controls normalized the gut microbiome and restored tumor burden to baseline levels, establishing a causal role for the microbiome in mediating cancer risk [85]. These findings underscore the relevance of early-life microbial exposures in oncogenic programming and suggest that interventions targeting microbial composition may hold promise for cancer prevention in at-risk offspring of obese mothers.

3.3. *Immune system*

It is well established that obesity is associated with a state of chronic low-grade inflammation [86–88]. Recent evidence also links maternal infection during pregnancy, reflecting an inflammatory state, to an increased risk of childhood leukemia [89]. Offspring of obese mothers, in both primates and mice, show transcriptomic changes in innate immunity pathways [62,90]. In addition, maternal high-fat diet exposure leads to an increased inflammatory response in the colon of the offspring, with higher levels of IL-1B, IL-6, and IL-17A [91]. Offspring born to HFD dams also developed a high blood leukocyte count and a decreased response to the bacterial antigen lipopolysaccharides (LPS) with downregulation of TLR-4 and LPS binding protein mRNA,

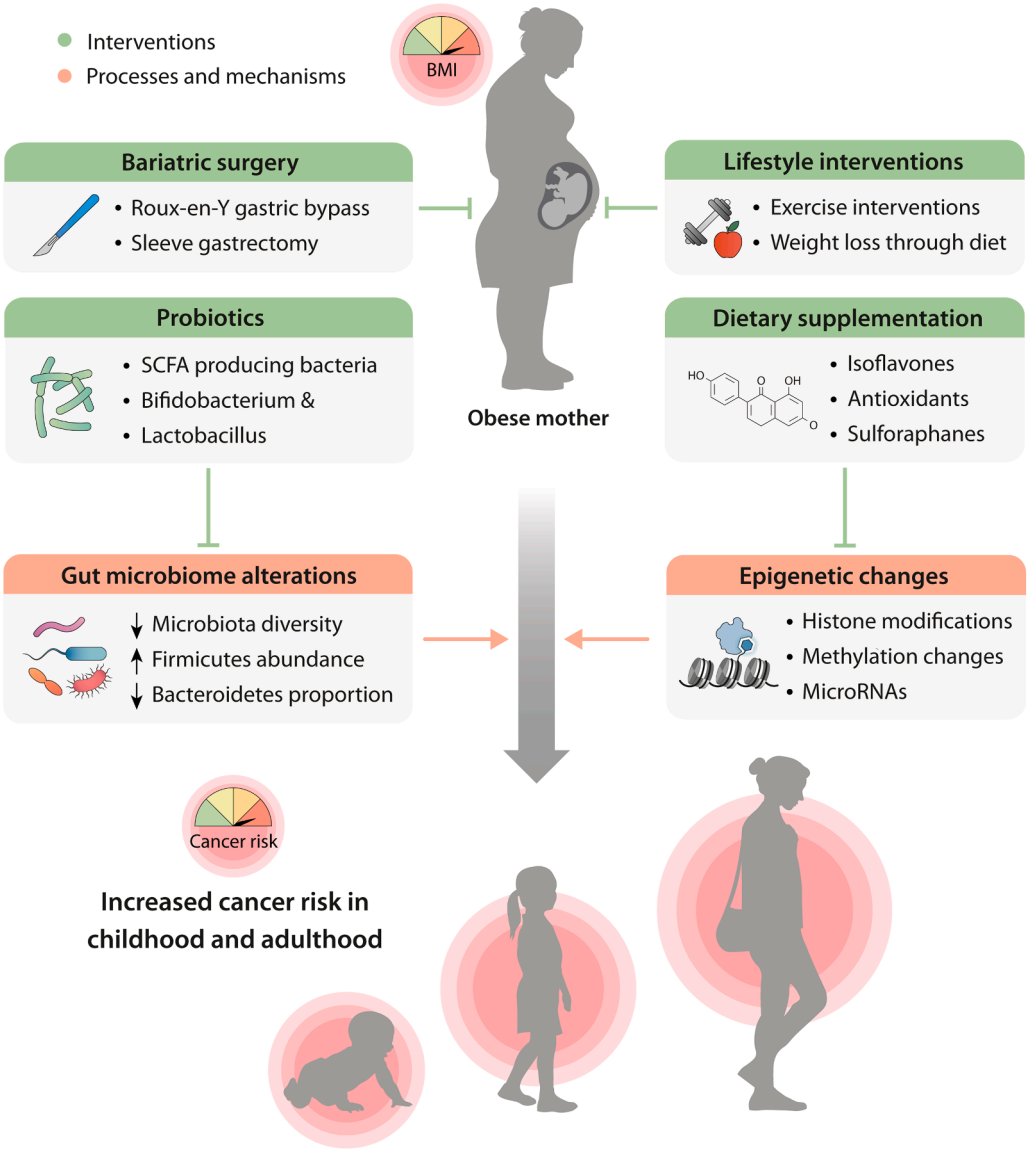

Fig. 2. Potential interventions to prevent cancer development in offspring of obese mothers. The higher cancer risk in offspring of obese mothers appears to be mediated mainly through epigenetic changes and the transmission of dysbiotic gut microbiota. Therefore, potential interventions include lifestyle modification, probiotic supplementation, dietary adaptation, and bariatric surgery.

suggesting systemic chronic inflammation and increased disease susceptibility. Another mouse model study showed that continuous LPS infusion in the mother led to increased adult weight gain comparable to a high-fat diet regimen, highlighting the lasting impact of early-life immune dysregulation [92].

Maternal obesity-induced alterations in the immune system of offspring can also impact anti-tumor immune surveillance. Zhang et al. observed a significant increase in cancer relapse in the offspring of HFD dams in a carcinogen-induced breast cancer model. This was attributed to overexpression of immunosuppressive genes and reduced recruitment of CD8 + effector T cells in recurrent cancerous lesions [93]. Together, these findings suggest that maternal obesity-induced immune alterations may impair anti-tumor surveillance and increase cancer susceptibility in offspring.

4. Preventive strategies

Understanding the impact of maternal obesity on malignancy risk in offspring is crucial for developing preventive strategies. Effective approaches to reduce intergenerational cancer risk focus on maternal weight optimization and modulation of the intrauterine and microbial environment (Fig. 2).

4.1. Lifestyle interventions

Observational and interventional evidence suggests that intentional weight loss is associated with a reduced risk of obesity-related cancers. In postmenopausal women, intentional weight loss was linked to a significantly lower cancer risk, while an intensive lifestyle intervention in overweight or obese adults with type 2 diabetes reduced obesity-related cancer incidence by 16% over long-term follow-up [94,95]. In a French cohort study, intentional weight loss in the year prior to conception resulted in a higher risk of pregnancy weight gain [96]. Furthermore, a meta-analysis of human studies demonstrated that exercise interventions initiated before and during early gestation reduced the incidence of gestational diabetes, indicating that pre-pregnancy physical activity favorably modulates the metabolic milieu during fetal development [97].

The limited availability of human research in this area contrasts with growing evidence from preclinical models showing that maternal exercise interventions can positively influence offspring health outcomes. For instance, in a murine study, exercise of pregnant dams on a treadwheel protected offspring from overweight and fatty liver disease later in life, even when fed an HFD. The authors observed an upregulation of AMP-activated protein kinase (AMPK) and PPARα during early life, which are both potent metabolic regulators that activate fatty acid oxidation [98]. Another mouse study found that switching pregnant dams from an HFD to a normal diet during late gestation led to the normalization of glucose tolerance and metabolism in their offspring [99]. Regarding the intergenerational transmission of obesity predisposition, maternal exercise has been shown to enhance brown adipose tissue development in dams and promote its transmission to the offspring, thereby conferring a long-term protective effect against obesity and subsequently against malignancies [100]. These metabolic improvements observed in murine models are possibly linked to reduced susceptibility to obesity-associated cancer development. These findings should be interpreted in light of the chronic and multifactorial nature of obesity, which is influenced by biopsychosocial factors and requires long-term, person-centered management [7,101,102].

4.2. Bariatric surgery

Metabolic surgery, such as Roux-en-Y gastric bypass surgery or sleeve gastrectomy, are effective weight-loss therapies in morbid obesity. Compared to other interventions, bariatric surgery results in enduring weight maintenance with persistent loss of excess weight > 50% at five years [103,104]. Furthermore, a recent study reported a reduced cancer incidence in patients who underwent bariatric surgery, with a 50% reduction in mortality due to cancer at the ten-year mark [105].

In a Swedish national register study, Johansson et al. found that women who underwent bariatric surgery were at a higher risk of complications during pregnancy, including neonatal death and small-for-gestational-age infants [106]. In contrast, a nationwide study, in which pre-surgery-weight-matched cohorts were compared, found that newborns of mothers who underwent malabsorptive surgery had fewer major congenital disabilities than those born to obese mothers [107]. Consensus recommendations and practice guidelines advise delaying pregnancy until individuals attain a stable weight and implementing systematic dietary monitoring and supplementation [108,109]. Bariatric surgery improves maternal health and reduces cancer risk in mothers, its role in preventing cancer in offspring remains uncertain.

4.3. Probiotic supplementation

Probiotics may modulate the maternal gut microbiome and influence offspring immune and metabolic development. Numerous preclinical studies have examined the effects of probiotics on colorectal cancer [110]. In a mouse model of familial adenomatous polyposis, Chen et al. demonstrated that administration of *Clostridium butyricum*, a short-chain fatty acid (SCFA) producing bacterial taxa, can attenuate the increased risk of colorectal cancer associated with a Western-style feeding [111]. In a different animal study, a group from Hong Kong examined the effects of a probiotic combination on hepatocellular carcinoma cells implanted under the skin [112]. Preemptive probiotic feeding led to a 40% reduction of tumor growth. Although the study authors did not offer a conclusive functional explanation, they observed reduced T helper 17 cell levels in the tumor microenvironment and an increased proportion of Bacteroidota taxa in the gut microbiota.

A recent meta-analysis demonstrated that maternal probiotic supplementation results in higher abundance of beneficial bacteria species in the offspring gut, a decrease in childhood obesity and decrease in childhood colic risk [113]. Thus, modulation of the maternal microbiome represents a promising but unproven strategy for cancer prevention.

5. Discussion

In recent decades, the increasing prevalence of obesity among women of reproductive age has raised concerns about its impact on the health of future generations. Maternal obesity may increase offspring risk for chronic diseases and certain cancers, highlighting the need for further research and effective preventive interventions.

The current scientific literature on maternal obesity and cancer is convincing but incomplete. Although preclinical studies established a robust link with breast cancer, research is limited for other obesity-related malignancies in offspring, including liver, pancreatic, esophageal, uterine, thyroid, and renal cancers. To achieve meaningful and translatable results, mouse models should replicate oncogenesis as closely as possible and incorporate long latency periods and sufficient sample sizes. Moreover, it is crucial to identify the specific developmental windows contributing to the heightened cancer risk in offspring, enabling the implementation of effective preventive interventions. Nevertheless, mechanistic evidence, particularly from animal models, should be interpreted with caution, as these studies provide biological plausibility but cannot establish causal relationships in humans for outcomes that may develop over several decades.

The current epidemiological literature on maternal obesity and cancer is limited and designing high-quality clinical studies presents a challenge. To overcome this, it is crucial to use maternal BMI as a direct measure of maternal obesity and avoid surrogate markers like high birth weight. The low incidence of certain cancers, long latency periods, and

modest expected effect sizes, with expected hazard ratios between 1.5 and 3, further complicate study design. Linking the medical records of mothers and children presents an additional challenge, especially for births prior to the advent of electronic medical records. To extract meaningful results, establishing large databases comprising substantial numbers of mother-infant pairs is essential. Addressing this global health challenge will require multinational collaborative research and the inclusion of national registries [114].

An improved mechanistic understanding is essential to establish a direct link between maternal obesity and malignancy risk in offspring, which is the first step toward developing effective therapeutic interventions. This risk transmission is likely multifactorial, with varying contributions to the altered risk profile for each cancer type, with early-life epigenetic modifications implicated in breast cancer [115], and the transfer of the mother's altered gut microbiome playing a greater role in colon and liver cancer given their biological functions [116]. Therefore, well-designed preclinical studies are needed to establish strong causation for the underlying mechanisms [117].

An increasing body of literature identifies maternal obesity as a new risk factor for certain cancers. Epigenetic modifications during early life and the transmission of an altered microbiota are likely involved in this process. As the prevalence of obesity continues to rise, many more children are being exposed during their development, which may lead to increased cancer incidence. This development poses a major threat to future generations. To break this cycle of maternal obesity and cancer, a deeper understanding of the mechanisms behind this increased risk is essential. Developing targeted interventions can help prevent cancer in the children of obese mothers and pave the way toward a healthier future for generations to come.

CRediT authorship contribution statement

Christian Toso: Writing – review & editing, Supervision, Project administration, Funding acquisition, Conceptualization. **Margarida Rocha:** Writing – review & editing, Writing – original draft. **Charles-Henri Wassmer:** Writing – review & editing, Writing – original draft. **Beat Moeckli:** Writing – review & editing, Writing – original draft, Supervision, Project administration, Funding acquisition, Conceptualization. **Sofia El Hajji:** Writing – review & editing, Writing – original draft. **Tinh-Hai Collet:** Writing – review & editing. **Stephanie Lacotte:** Writing – review & editing, Writing – original draft, Supervision, Project administration, Funding acquisition, Conceptualization.

Consent for publication

Not applicable

Ethics approval and consent to participate

Not applicable

Funding

The Swiss National Science Foundation (grant number 182471), the "Fondation Francis & Marie-France Minkoff ", the Professor Dr. Max Cloëtta Foundation, and the Leenaards Foundation (grant number 5489) funded this research.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Beat Moeckli reports financial support was provided by Professor Dr. Max Cloëtta Foundation. Christian Toso reports financial support was provided by Swiss National Science Foundation. Christian Toso reports financial support was provided by Leenaards Foundation. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

The authors would like to thank Beata Kusmider (Geneva University Hospitals) for the artful creation of Fig. 1 and the proofreading of the manuscript. Thanks also goes to Antonio Garcia for the design of Fig. 2.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.canep.2026.103079.

Data availability

Not applicable

References

[1] GBD 2021 Adult BMI Collaborators, Global, regional, and national prevalence of adult overweight and obesity, 1990-2021, with forecasts to 2050: a forecasting study for the Global Burden of Disease Study 2021, Lancet 405 (2025) 813–838, https://doi.org/10.1016/S0140-6736(25)00355-1.
[2] K.M. Flegal, M.D. Carroll, C.L. Ogden, L.R. Curtin, Prevalence and trends in obesity among US adults, 1999-2008, JAMA 303 (2010) 235–241, https://doi.org/10.1001/jama.2009.2014.
[3] K.M. Flegal, M.D. Carroll, R.J. Kuczmarski, C.L. Johnson, Overweight and obesity in the United States: prevalence and trends, 1960–1994, Int J. Obes. 22 (1998) 39–47, https://doi.org/10.1038/sj.ijo.0800541.
[4] C.M. Hales, Preval. Obes. Sev. Obes. Adults U. S. 8 (2020) 2017–2018.
[5] Obesity: preventing and managing the global epidemic. Report of a WHO consultation, World Health Organ Tech. Rep. Ser. 894 (i–xii) (2000) 1–253.
[6] Obesity and overweight, (n.d.). ⟨https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight⟩ (accessed December 27, 2025).
[7] F. Rubino, D.E. Cummings, R.H. Eckel, R.V. Cohen, J.P.H. Wilding, W.A. Brown, F.C. Stanford, R.L. Batterham, I.S. Farooqi, N.J. Farpour-Lambert, C.W. le Roux, N. Sattar, L.A. Baur, K.M. Morrison, A. Misra, T. Kadowaki, K.W. Tham, P. Sumithran, W.T. Garvey, J.P. Kirwan, J.-M. Fernández-Real, B.E. Corkey, H. Toplak, A. Kokkinos, R.F. Kushner, F. Branca, J. Valabhji, M. Blüher, S. R. Bornstein, H.J. Grill, E. Ravussin, E. Gregg, N.B. Al Busaidi, N.F. Alfaris, E. Al Ozairi, L.M.S. Carlsson, K. Clément, J.-P. Després, J.B. Dixon, G. Galea, L. M. Kaplan, B. Laferrère, M. Laville, S. Lim, J.R. Luna Fuentes, V.M. Mooney, J. Nadglowski, A. Urudinachi, M. Olszanecka-Glinianowicz, A. Pan, F. Pattou, P. R. Schauer, M.H. Tschöp, M.T. van der Merwe, R. Vettor, G. Mingrone, Definition and diagnostic criteria of clinical obesity, Lancet Diabetes Endocrinol. 13 (2025) 221–262, https://doi.org/10.1016/S2213-8587(24)00316-4.
[8] L.T. Fourman, A. Awwad, A. Gutiérrez-Sacristán, C.A. Dash, J.E. Johnson, A. K. Thistle, N. Chahal, S.L. Stockman, M. Toribio, C. Anekwe, A.K. Gattu, S. K. Grinspoon, Implications of a new obesity definition among the all of Us cohort, JAMA Netw. Open 8 (2025) e2537619, https://doi.org/10.1001/jamanetworkopen.2025.37619.
[9] M. Shirvanifar, V.H. Ahlqvist, M. Lundberg, K. Kosidou, Á. Herraiz-Adillo, D. Berglind, C. Magnusson, P. Henriksson, Adverse pregnancy outcomes attributable to overweight and obesity across maternal birth regions: a Swedish population-based cohort study, Lancet Public Health 9 (2024) e776–e786, https://doi.org/10.1016/S2468-2667(24)00188-9.
[10] F. Abdi, S. Alizadeh, N. Roozbeh, F. Montazeri, M. Banaei, V. Mehrnoush, F. Darsareh, Prepregnancy overweight and obesity and the risk of adverse pregnancy outcomes, Sci. Rep. 15 (2025) 16846, https://doi.org/10.1038/s41598-025-02113-9.
[11] D. Aune, O.D. Saugstad, T. Henriksen, S. Tonstad, Maternal body mass index and the risk of fetal death, stillbirth, and infant death: a systematic review and meta-analysis, JAMA 311 (2014) 1536–1546, https://doi.org/10.1001/jama.2014.2269.
[12] T. Zhu, J. Tang, F. Zhao, Y. Qu, D. Mu, Association between maternal obesity and offspring Apgar score or cord pH: a systematic review and meta-analysis, Sci. Rep. 5 (2015) 18386, https://doi.org/10.1038/srep18386.
[13] J.M. Ohlendorf, K. Robinson, M. Garnier-Villarreal, The impact of maternal BMI, gestational weight gain, and breastfeeding on early childhood weight: analysis of a statewide WIC dataset, Prev. Med. 118 (2019) 210–215, https://doi.org/10.1016/j.ypmed.2018.11.001.
[14] V. Hirschler, M.I. Roque, M.L. Calcagno, C. Gonzalez, C. Aranda, Maternal waist circumference and the prediction of children's metabolic syndrome, Arch. Pedia Adolesc. Med 161 (2007) 1205–1210, https://doi.org/10.1001/archpedi.161.12.1205.
[15] A.A. Adane, G.D. Mishra, L.R. Tooth, Maternal pre-pregnancy obesity and childhood physical and cognitive development of children: a systematic review,

Int J. Obes. (Lond.) 40 (2016) 1608–1618, https://doi.org/10.1038/ijo.2016.140.
[16] S.L. Stacy, J.M. Buchanich, Z.Q. Ma, C. Mair, L. Robertson, R.K. Sharma, E. O. Talbott, J.M. Yuan, Maternal obesity, birth size, and risk of childhood cancer development, Am. J. Epidemiol. 188 (2019) 1503–1511, https://doi.org/10.1093/aje/kwz118.
[17] C.C. Murphy, P.M. Cirillo, N.Y. Krigbaum, A.G. Singal, M. Lee, T. Zaki, E. Burstein, B.A. Cohn, Maternal obesity, pregnancy weight gain, and birth weight and risk of colorectal cancer, Gut (2021), https://doi.org/10.1136/gutjnl-2021-325001.
[18] M.C. White, D.M. Holman, J.E. Boehm, L.A. Peipins, M. Grossman, S.J. Henley, Age and Cancer Risk, Am. J. Prev. Med 46 (2014) S7–15, https://doi.org/10.1016/j.amepre.2013.10.029.
[19] J. Liu, E. Kharazmi, Q. Liang, Y. Chen, J. Sundquist, K. Sundquist, M. Fallah, Maternal weight during pregnancy and risk of childhood acute lymphoblastic leukemia in offspring, Leukemia 39 (2025) 590–598, https://doi.org/10.1038/s41375-025-02517-6.
[20] R. Kessous, T. Wainstock, E. Sheiner, Pre-pregnancy obesity and childhood malignancies: a population-based cohort study, Pedia Blood Cancer 67 (2020) e28269, https://doi.org/10.1002/pbc.28269.
[21] E.T. Petridou, T.N. Sergentanis, A. Skalkidou, C.N. Antonopoulos, N. Dessypris, T. Svensson, O. Stephansson, H. Kieler, K.E. Smedby, Maternal and birth anthropometric characteristics in relation to the risk of childhood lymphomas: a Swedish nationwide cohort study, Eur. J. Cancer Prev. 24 (2015) 535–541, https://doi.org/10.1097/CEJ.0000000000000122.
[22] D. Schmid, W.C. Willett, M. Ding, K.B. Michels, Maternal and infant anthropometric characteristics and breast cancer incidence in the daughter, Sci. Rep. 10 (2020) 2550, https://doi.org/10.1038/s41598-020-59527-w.
[23] J.G. Eriksson, S. Sandboge, M.K. Salonen, E. Kajantie, C. Osmond, Long-term consequences of maternal overweight in pregnancy on offspring later health: findings from the Helsinki Birth Cohort Study, Ann. Med 46 (2014) 434–438, https://doi.org/10.3109/07853890.2014.919728.
[24] R. Retnakaran, S.W. Wen, H. Tan, S. Zhou, C. Ye, M. Shen, G.N. Smith, M. C. Walker, Association of timing of weight gain in pregnancy with infant birth weight, JAMA Pediatr. 172 (2018) 136–142, https://doi.org/10.1001/jamapediatrics.2017.4016.
[25] S.L. Rifas-Shiman, A. Fleisch, M.-F. Hivert, C. Mantzoros, M.W. Gillman, E. Oken, First and second trimester gestational weight gains are most strongly associated with cord blood levels of hormones at delivery important for glycemic control and somatic growth, Metabolism 69 (2017) 112–119, https://doi.org/10.1016/j.metabol.2017.01.019.
[26] H.D. Bailey, P. Rios, B. Lacour, L. Guerrini-Rousseau, A.-I. Bertozzi, P. Leblond, C. Faure-Conter, I. Pellier, C. Freycon, J. Michon, S. Puget, S. Ducassou, L. Orsi, J. Clavel, Factors related to pregnancy and birth and the risk of childhood brain tumours: the ESTELLE and ESCALE studies (SFCE, France), Int. J. Cancer 140 (2017) 1757–1769, https://doi.org/10.1002/ijc.30597.
[27] E.C. Peckham-Gregory, H.E. Danysh, A.L. Brown, O. Eckstein, A. Grimes, R. Chakraborty, J. Lubega, K.L. McClain, C.E. Allen, M.E. Scheurer, P.J. Lupo, Evaluation of maternal and perinatal characteristics on childhood lymphoma risk: a population-based case-control study, Pediatr. Blood & Cancer 64 (2017) e26321, https://doi.org/10.1002/pbc.26321.
[28] Z.A. Contreras, B. Ritz, J. Virk, M. Cockburn, J.E. Heck, Maternal pre-pregnancy and gestational diabetes, obesity, gestational weight gain, and risk of cancer in young children: a population-based study in California, Cancer Causes Control 27 (2016) 1273–1285, https://doi.org/10.1007/s10552-016-0807-5.
[29] J.E. Heck, N. Omidakhsh, S. Azary, B. Ritz, O.S. von Ehrenstein, G.R. Bunin, A. Ganguly, A case–control study of sporadic retinoblastoma in relation to maternal health conditions and reproductive factors: a report from the Children's Oncology group, BMC Cancer 15 (2015) 735, https://doi.org/10.1186/s12885-015-1773-0.
[30] K.R. Greenop, E.M. Blair, C. Bower, B.K. Armstrong, E. Milne, Factors relating to pregnancy and birth and the risk of childhood brain tumors: results from an Australian case–control study, Pediatr. Blood & Cancer 61 (2014) 493–498, https://doi.org/10.1002/pbc.24751.
[31] J.R.B. Musselman, M.K. Georgieff, J.A. Ross, G.E. Tomlinson, J. Feusner, M. Krailo, L.G. Spector, Maternal pregnancy events and exposures and risk of hepatoblastoma: a children's Oncology Group (COG) study, Cancer Epidemiol. 37 (2013) 318–320, https://doi.org/10.1016/j.canep.2012.12.005.
[32] L.G. Spector, S.M. Davies, L.L. Robison, J.M. Hilden, M. Roesler, J.A. Ross, Birth Characteristics, Maternal Reproductive History, and the Risk of Infant Leukemia: A Report from the Children's Oncology Group, Cancer Epidemiol. Biomark. & Prev. 16 (2007) 128–134, https://doi.org/10.1158/1055-9965.EPI-06-0322.
[33] C.C. McLaughlin, M.S. Baptiste, M.J. Schymura, P.C. Nasca, M.S. Zdeb, Birth weight, maternal weight and childhood leukaemia, Br. J. Cancer 94 (2006) 1738–1744, https://doi.org/10.1038/sj.bjc.6603173.
[34] K.M. Wilson, W.C. Willett, K.B. Michels, Mothers' pre-pregnancy BMI and weight gain during pregnancy and risk of breast cancer in daughters, Breast Cancer Res Treat. 130 (2011) 273–279, https://doi.org/10.1007/s10549-011-1582-3.
[35] M. Sanderson, M.A. Williams, J.R. Daling, V.L. Holt, K.E. Malone, S.G. Self, D. E. Moore, Maternal factors and breast cancer risk among young women, Paediatr. Perinat. Epidemiol. 12 (1998) 397–407, https://doi.org/10.1046/j.1365-3016.1998.00133.x.
[36] K.I. Avgerinos, N. Spyrou, C.S. Mantzoros, M. Dalamaga, Obesity and cancer risk: Emerging biological mechanisms and perspectives, Metabolism 92 (2019) 121–135, https://doi.org/10.1016/j.metabol.2018.11.001.
[37] E.E. Calle, R. Kaaks, Overweight, obesity and cancer: epidemiological evidence and proposed mechanisms, Nat. Rev. Cancer 4 (2004) 579–591, https://doi.org/10.1038/nrc1408.
[38] P.D. Gluckman, M.A. Hanson, T. Buklijas, A conceptual framework for the developmental origins of health and disease, J. Dev. Orig. Health Dis. 1 (2010) 6–18, https://doi.org/10.1017/S2040174409990171.
[39] D.J. Barker, T.W. Meade, C.H. Fall, A. Lee, C. Osmond, K. Phipps, Y. Stirling, Relation of fetal and infant growth to plasma fibrinogen and factor VII concentrations in adult life, BMJ 304 (1992) 148–152, https://doi.org/10.1136/bmj.304.6820.148.
[40] P. Rinaudo, E. Wang, Fetal Programming and Metabolic Syndrome, Annu Rev. Physiol. 74 (2012) 107–130, https://doi.org/10.1146/annurev-physiol-020911-153245.
[41] C.D. Allis, T. Jenuwein, The molecular hallmarks of epigenetic control, Nat. Rev. Genet 17 (2016) 487–500, https://doi.org/10.1038/nrg.2016.59.
[42] S.B. Baylin, P.A. Jones, A decade of exploring the cancer epigenome — biological and translational implications, Nat. Rev. Cancer 11 (2011) 726–734, https://doi.org/10.1038/nrc3130.
[43] M.V.E. Veenendaal, R.C. Painter, S.R. de Rooij, P.M.M. Bossuyt, J. a M. van der Post, P.D. Gluckman, M.A. Hanson, T.J. Roseboom, Transgenerational effects of prenatal exposure to the 1944-45 Dutch famine, BJOG 120 (2013) 548–553, https://doi.org/10.1111/1471-0528.12136.
[44] A.C. Ravelli, J.H. van der Meulen, C. Osmond, D.J. Barker, O.P. Bleker, Obesity at the age of 50 y in men and women exposed to famine prenatally, Am. J. Clin. Nutr. 70 (1999) 811–816, https://doi.org/10.1093/ajcn/70.5.811.
[45] A. Ravelli, J. van der Meulen, R. Michels, C. Osmond, D. Barker, C. Hales, O. Bleker, Glucose tolerance in adults after prenatal exposure to famine, Lancet 351 (1998) 173–177, https://doi.org/10.1016/S0140-6736(97)07244-9.
[46] L. Lumey, A.D. Stein, H.S. Kahn, J. Romijn, Lipid profiles in middle-aged men and women after famine exposure during gestation: the Dutch Hunger Winter Families Study, Am. J. Clin. Nutr. 89 (2009) 1737–1743, https://doi.org/10.3945/ajcn.2008.27038.
[47] Y. Du, P.A. Benny, Y. Shao, R.J. Schlueter, A. Gurary, A. Lum-Jones, C.B. Lassiter, F.M. AlAkwaa, M. Tiirikainen, D. Towner, W.S. Ward, L.X. Garmire, Multiomics analysis of umbilical cord hematopoietic stem cells from a multiethnic cohort of Hawaii reveals the intergenerational effect of maternal prepregnancy obesity and risks for cancers, Gigascience 14 (2025) giaf039, https://doi.org/10.1093/gigascience/giaf039.
[48] A. Nishiyama, M. Nakanishi, Navigating the DNA methylation landscape of cancer, Trends Genet. 37 (2021) 1012–1027, https://doi.org/10.1016/j.tig.2021.05.002.
[49] X. Yuan, K. Tsujimoto, K. Hashimoto, K. Kawahori, N. Hanzawa, M. Hamaguchi, T. Seki, M. Nawa, T. Ehara, Y. Kitamura, I. Hatada, M. Konishi, N. Itoh, Y. Nakagawa, H. Shimano, T. Takai-Igarashi, Y. Kamei, Y. Ogawa, Epigenetic modulation of Fgf21 in the perinatal mouse liver ameliorates diet-induced obesity in adulthood, Nat. Commun. 9 (2018) 636, https://doi.org/10.1038/s41467-018-03038-w.
[50] K.H. Flippo, M.J. Potthoff, Metabolic Messengers: FGF21, Nat. Metab. 3 (2021) 309–317, https://doi.org/10.1038/s42255-021-00354-2.
[51] W. Lu, X. Li, Y. Luo, FGF21 in obesity and cancer: New insights, Cancer Lett. 499 (2021) 5–13, https://doi.org/10.1016/j.canlet.2020.11.026.
[52] C. Reichetzeder, Overweight and obesity in pregnancy: their impact on epigenetics, Eur. J. Clin. Nutr. 75 (2021) 1710–1722, https://doi.org/10.1038/s41430-021-00905-6.
[53] M.R. Keleher, R. Zaidi, S. Shah, M.E. Oakley, C. Pavlatos, S. El Idrissi, X. Xing, D. Li, T. Wang, J.M. Cheverud, Maternal high-fat diet associated with altered gene expression, DNA methylation, and obesity risk in mouse offspring, PLoS One 13 (2018) e0192606, https://doi.org/10.1371/journal.pone.0192606.
[54] Y. Li, C.A. Pollock, S. Saad, Aberrant DNA Methylation Mediates the Transgenerational Risk of Metabolic and Chronic Disease Due to Maternal Obesity and Overnutrition, Genes (Basel) 12 (2021) 1653, https://doi.org/10.3390/genes12111653.
[55] A.J. Bannister, T. Kouzarides, Regulation of chromatin by histone modifications, Cell Res 21 (2011) 381–395, https://doi.org/10.1038/cr.2011.22.
[56] K.M. Aagaard-Tillery, K. Grove, J. Bishop, X. Ke, Q. Fu, R. McKnight, R.H. Lane, Developmental origins of disease and determinants of chromatin structure: maternal diet modifies the primate fetal epigenome, J. Mol. Endocrinol. 41 (2008) 91–102, https://doi.org/10.1677/JME-08-0025.
[57] P.E. Panchenko, S. Voisin, M. Jouin, L. Jouneau, A. Prézelin, S. Lecoutre, C. Breton, H. Jammes, C. Junien, A. Gabory, Expression of epigenetic machinery genes is sensitive to maternal obesity and weight loss in relation to fetal growth in mice, Clin. Epigenetics 8 (2016) 22, https://doi.org/10.1186/s13148-016-0188-3.
[58] S. Li, M. Chen, H. Wu, Y. Li, T.O. Tollefsbol, Maternal Epigenetic Regulation Contributes to Prevention of Estrogen Receptor–negative Mammary Cancer with Broccoli Sprout Consumption, Cancer Prev. Res. 13 (2020) 449–462, https://doi.org/10.1158/1940-6207.CAPR-19-0491.
[59] J. O'Brien, H. Hayder, Y. Zayed, C. Peng, Overview of MicroRNA Biogenesis, Mechanisms of Actions, and Circulation, Front. Endocrinol. 9 (2018). ⟨https://www.frontiersin.org/articles/10.3389/fendo.2018.00402⟩ (accessed September 20, 2023).
[60] Y. Sun, Q. Wang, Y. Zhang, M. Geng, Y. Wei, Y. Liu, S. Liu, R.B. Petersen, J. Yue, K. Huang, L. Zheng, Multigenerational maternal obesity increases the incidence of HCC in offspring via miR-27a-3p, J. Hepatol. 73 (2020) 603–615, https://doi.org/10.1016/j.jhep.2020.03.050.

[61] B. Moeckli, S. Lacotte, C. Toso, The Role of Acsl1 and Aldh2 in the Increased Risk for Liver Cancer in Offspring of Obese Mothers, Front. Med. 9 (2022). ⟨https://www.frontiersin.org/article/10.3389/fmed.2022.907028⟩ (accessed June 27, 2022).

[62] B. Moeckli, V. Delaune, J. Prados, M. Tihy, A. Peloso, G. Oldani, T. Delmi, F. Slits, Q. Gex, L. Rubbia-Brandt, N. Goossens, S. Lacotte, C. Toso, Impact of Maternal Obesity on Liver Disease in the Offspring: A Comprehensive Transcriptomic Analysis and Confirmation of Results in a Murine Model, Biomedicines 10 (2022) 294, https://doi.org/10.3390/biomedicines10020294.

[63] Z. Herceg, A. Ghantous, C.P. Wild, A. Sklias, L. Casati, S.J. Duthie, R. Fry, J.-P. Issa, R. Kellermayer, I. Koturbash, Y. Kondo, J. Lepeule, S.C.S. Lima, C. J. Marsit, V. Rakyan, R. Saffery, J.A. Taylor, A.E. Teschendorff, T. Ushijima, P. Vineis, C.L. Walker, R.A. Waterland, J. Wiemels, S. Ambatipudi, D. Degli Esposti, H. Hernandez-Vargas, Roadmap for investigating epigenome deregulation and environmental origins of cancer, Int. J. Cancer 142 (2018) 874–882, https://doi.org/10.1002/ijc.31014.

[64] Y. Fan, O. Pedersen, Gut microbiota in human metabolic health and disease, Nat. Rev. Microbiol 19 (2021) 55–71, https://doi.org/10.1038/s41579-020-0433-9.

[65] S. Prakash, C. Tomaro-Duchesneau, S. Saha, A. Cantor, The Gut Microbiota and Human Health with an Emphasis on the Use of Microencapsulated Bacterial Cells, J. Biomed. Biotechnol. 2011 (2011) e981214, https://doi.org/10.1155/2011/981214.

[66] M. Régnier, M. Van Hul, C. Knauf, P.D. Cani, Gut microbiome, endocrine control of gut barrier function and metabolic diseases, J. Endocrinol. 248 (2021) R67–R82, https://doi.org/10.1530/JOE-20-0473.

[67] D. Zheng, T. Liwinski, E. Elinav, Interaction between microbiota and immunity in health and disease, Cell Res 30 (2020) 492–506, https://doi.org/10.1038/s41422-020-0332-7.

[68] P. Marzullo, S. Bettini, D. Menafra, S. Aprano, G. Muscogiuri, L. Barrea, S. Savastano, A. Colao, Spot-light on microbiota in obesity and cancer, Int J. Obes. 45 (2021) 2291–2299, https://doi.org/10.1038/s41366-021-00866-7.

[69] M.A.J. Hullar, A.N. Burnett-Hartman, J.W. Lampe, Gut Microbes, Diet, and Cancer, Cancer Treat. Res 159 (2014) 377–399, https://doi.org/10.1007/978-3-642-38007-5_22.

[70] J.Q. Huang, S. Sridhar, Y. Chen, R.H. Hunt, Meta-analysis of the relationship between Helicobacter pylori seropositivity and gastric cancer, Gastroenterology 114 (1998) 1169–1179, https://doi.org/10.1016/s0016-5085(98)70422-6.

[71] J. Koshiol, A. Wozniak, P. Cook, C. Adaniel, J. Acevedo, L. Azócar, A.W. Hsing, J. C. Roa, M.F. Pasetti, J.F. Miquel, M.M. Levine, C. Ferreccio, C.G. Aguayo, S. Baez, A. Díaz, H. Molina, C. Miranda, C. Castillo, A. Tello, G. Durán, C.P. Delgado, R. Quevedo, S. Pineda, T. la Barra, C. Reyes, C. Alegría, C. Aguayo, H. Losada, J. C. Arraya, E. Bellolio, O. Tapia, J. López, K. Medina, P. Barraza, S. Catalán, P. Riquelme, L. Órdenes, R. Garcés, C. Duarte, A. Hildesheim, Salmonella enterica serovar Typhi and gallbladder cancer: a case–control study and meta-analysis, –3235, Cancer Med 5 (2016) 3310, https://doi.org/10.1002/cam4.915.

[72] M.R. Rubinstein, X. Wang, W. Liu, Y. Hao, G. Cai, Y.W. Han, Fusobacterium nucleatum promotes colorectal carcinogenesis by modulating E-cadherin/β-catenin signaling via its FadA adhesin, Cell Host Microbe 14 (2013) 195–206, https://doi.org/10.1016/j.chom.2013.07.012.

[73] C. Gur, Y. Ibrahim, B. Isaacson, R. Yamin, J. Abed, M. Gamliel, J. Enk, Y. Bar-On, N. Stanietsky-Kaynan, S. Coppenhagen-Glazer, N. Shussman, G. Almogy, A. Cuapio, E. Hofer, D. Mevorach, A. Tabib, R. Ortenberg, G. Markel, K. Miklić, S. Jonjic, C.A. Brennan, W.S. Garrett, G. Bachrach, O. Mandelboim, Binding of the Fap2 protein of Fusobacterium nucleatum to human inhibitory receptor TIGIT protects tumors from immune cell attack, Immunity 42 (2015) 344–355, https://doi.org/10.1016/j.immuni.2015.01.010.

[74] A.C. Goodwin, C.E.Destefano Shields, S. Wu, D.L. Huso, X. Wu, T.R. Murray-Stewart, A. Hacker-Prietz, S. Rabizadeh, P.M. Woster, C.L. Sears, R.A. Casero, Polyamine catabolism contributes to enterotoxigenic Bacteroides fragilis-induced colon tumorigenesis, Proc. Natl. Acad. Sci. USA 108 (2011) 15354–15359, https://doi.org/10.1073/pnas.1010203108.

[75] C. Ma, M. Han, B. Heinrich, Q. Fu, Q. Zhang, M. Sandhu, D. Agdashian, M. Terabe, J.A. Berzofsky, V. Fako, T. Ritz, T. Longerich, C.M. Theriot, J. A. McCulloch, S. Roy, W. Yuan, V. Thovarai, S.K. Sen, M. Ruchirawat, F. Korangy, X.W. Wang, G. Trinchieri, T.F. Greten, Gut microbiome–mediated bile acid metabolism regulates liver cancer via NKT cells, Science 360 (2018) eaan5931, https://doi.org/10.1126/science.aan5931.

[76] M. Terabe, J.A. Berzofsky, Tissue-Specific Roles of NKT Cells in Tumor Immunity, Front Immunol. 9 (2018) 1838, https://doi.org/10.3389/fimmu.2018.01838.

[77] V. Gopalakrishnan, C.N. Spencer, L. Nezi, A. Reuben, M.C. Andrews, T. V. Karpinets, P.A. Prieto, D. Vicente, K. Hoffman, S.C. Wei, A.P. Cogdill, L. Zhao, C.W. Hudgens, D.S. Hutchinson, T. Manzo, M. Petaccia de Macedo, T. Cotechini, T. Kumar, W.S. Chen, S.M. Reddy, R. Szczepaniak Sloane, J. Galloway-Pena, H. Jiang, P.L. Chen, E.J. Shpall, K. Rezvani, A.M. Alousi, R.F. Chemaly, S. Shelburne, L.M. Vence, P.C. Okhuysen, V.B. Jensen, A.G. Swennes, F. McAllister, E. Marcelo Riquelme Sanchez, Y. Zhang, E. Le Chatelier, L. Zitvogel, N. Pons, J.L. Austin-Breneman, L.E. Haydu, E.M. Burton, J.M. Gardner, E. Sirmans, J. Hu, A.J. Lazar, T. Tsujikawa, A. Diab, H. Tawbi, I.C. Glitza, W. J. Hwu, S.P. Patel, S.E. Woodman, R.N. Amaria, M.A. Davies, J.E. Gershenwald, P. Hwu, J.E. Lee, J. Zhang, L.M. Coussens, Z.A. Cooper, P.A. Futreal, C.R. Daniel, N.J. Ajami, J.F. Petrosino, M.T. Tetzlaff, P. Sharma, J.P. Allison, R.R. Jenq, J. A. Wargo, Gut microbiome modulates response to anti-PD-1 immunotherapy in melanoma patients, Science 359 (2018) 97–103, https://doi.org/10.1126/science.aan4236.

[78] V. Serpas, J.E. Rogers, L. Xiao, K. Mola-Rudd, A. Dasari, B.K. Kee, M.J. Overman, B. Johnson, Impact of antibiotic exposure on the efficacy of immune checkpoint blockade in MSI-H metastatic CRC, –161, JCO 38 (2020) 161, https://doi.org/10.1200/JCO.2020.38.4_suppl.161.

[79] U. Khan, K. Ho, E.K. Hwang, C. Peña, J. Brouwer, K. Hoffman, D. Betel, G. F. Sonnenberg, B. Faltas, A. Saxena, K.E. Weisiger, S. Oh, E. Hissong, A. RoyChoudhury, M.A. Shah, Impact of Use of Antibiotics on Response to Immune Checkpoint Inhibitors and Tumor Microenvironment, Am. J. Clin. Oncol. 44 (2021) 247–253, https://doi.org/10.1097/COC.0000000000000813.

[80] E. Hayase, R.R. Jenq, Role of the intestinal microbiome and microbial-derived metabolites in immune checkpoint blockade immunotherapy of cancer, Genome Med. 13 (2021) 107, https://doi.org/10.1186/s13073-021-00923-w.

[81] P. Ferretti, E. Pasolli, A. Tett, F. Asnicar, V. Gorfer, S. Fedi, F. Armanini, D. T. Truong, S. Manara, M. Zolfo, F. Beghini, R. Bertorelli, V. De Sanctis, I. Bariletti, R. Canto, R. Clementi, M. Cologna, T. Crifò, G. Cusumano, S. Gottardi, C. Innamorati, C. Masè, D. Postai, D. Savoi, S. Duranti, G.A. Lugli, L. Mancabelli, F. Turroni, C. Ferrario, C. Milani, M. Mangifesta, R. Anzalone, A. Viappiani, M. Yassour, H. Vlamakis, R. Xavier, C.M. Collado, O. Koren, S. Tateo, M. Soffiati, A. Pedrotti, M. Ventura, C. Huttenhower, P. Bork, N. Segata, Mother-to-Infant Microbial Transmission from Different Body Sites Shapes the Developing Infant Gut Microbiome, Cell Host & Microbe 24 (2018) 133–145.e5, https://doi.org/10.1016/j.chom.2018.06.005.

[82] Y. Shao, S.C. Forster, E. Tsaliki, K. Vervier, A. Strang, N. Simpson, N. Kumar, M. D. Stares, A. Rodger, P. Brocklehurst, N. Field, T.D. Lawley, Stunted microbiota and opportunistic pathogen colonization in caesarean-section birth, Nature 574 (2019) 117–121, https://doi.org/10.1038/s41586-019-1560-1.

[83] H.M. Tun, S.L. Bridgman, R. Chari, C.J. Field, D.S. Guttman, A.B. Becker, P. J. Mandhane, S.E. Turvey, P. Subbarao, M.R. Sears, J.A. Scott, A.L. Kozyrskyj, Canadian Healthy Infant Longitudinal Development (CHILD) Study Investigators, Roles of Birth Mode and Infant Gut Microbiota in Intergenerational Transmission of Overweight and Obesity From Mother to Offspring, JAMA Pedia 172 (2018) 368–377, https://doi.org/10.1001/jamapediatrics.2017.5535.

[84] E.D. Sonnenburg, S.A. Smits, M. Tikhonov, S.K. Higginbottom, N.S. Wingreen, J. L. Sonnenburg, Diet-induced extinctions in the gut microbiota compound over generations, Nature 529 (2016) 212–215, https://doi.org/10.1038/nature16504.

[85] B. Moeckli, V. Delaune, B. Gilbert, A. Peloso, G. Oldani, S. El Hajji, F. Slits, J. R. Ribeiro, R. Mercier, A. Gleyzolle, L. Rubbia-Brandt, Q. Gex, S. Lacotte, C. Toso, Maternal obesity increases the risk of hepatocellular carcinoma through the transmission of an altered gut microbiome, JHEP Rep. 6 (2024) 101056, https://doi.org/10.1016/j.jhepr.2024.101056.

[86] G.S. Hotamisligil, P. Arner, J.F. Caro, R.L. Atkinson, B.M. Spiegelman, Increased adipose tissue expression of tumor necrosis factor-alpha in human obesity and insulin resistance, J. Clin. Invest 95 (1995) 2409–2415, https://doi.org/10.1172/JCI117936.

[87] M. Monserrat-Mesquida, M. Quetglas-Llabrés, C. Bouzas, X. Capó, D. Mateos, L. Ugarriza, J.A. Tur, A. Sureda, Peripheral Blood Mononuclear Cells Oxidative Stress and Plasma Inflammatory Biomarkers in Adults with Normal Weight, Overweight and Obesity, Antioxidants 10 (2021), https://doi.org/10.3390/antiox10050813.

[88] Y.S. Lee, J. Wollam, J.M. Olefsky, An Integrated View of Immunometabolism, Cell 172 (2018) 22–40, https://doi.org/10.1016/j.cell.2017.12.025.

[89] J.-R. He, Y. Yu, F. Fang, M. Gissler, P. Magnus, K.D. László, M.H. Ward, O. Paltiel, G. Tikellis, M.M. Maule, X. Qiu, J. Du, U.A. Valdimarsdóttir, K. Rahimi, J. L. Wiemels, M.S. Linet, J.E. Hirst, J. Li, T. Dwyer, Evaluation of Maternal Infection During Pregnancy and Childhood Leukemia Among Offspring in Denmark, JAMA Netw. Open 6 (2023) e230133, https://doi.org/10.1001/jamanetworkopen.2023.0133.

[90] D. Farley, M.E. Tejero, A.G. Comuzzie, P.B. Higgins, L. Cox, S.L. Werner, S. L. Jenkins, C. Li, J. Choi, E.J. Dick, G.B. Hubbard, P. Frost, D.J. Dudley, B. Ballesteros, G. Wu, P.W. Nathanielsz, N.E. Schlabritz-Loutsevitch, Feto-placental adaptations to maternal obesity in the baboon, Placenta 30 (2009) 752–760, https://doi.org/10.1016/j.placenta.2009.06.007.

[91] I.A. Myles, N.M. Fontecilla, B.M. Janelsins, P.J. Vithayathil, J.A. Segre, S.K. Datta, Parental Dietary Fat Intake Alters Offspring Microbiome and Immunity, J. I. 191 (2013) 3200–3209, https://doi.org/10.4049/jimmunol.1301057.

[92] A. Dudele, K.S. Hougaard, M. Kjølby, M. Hokland, G. Winther, B. Elfving, G. Wegener, A.L. Nielsen, A. Larsen, M.K. Nøhr, S.B. Pedersen, T. Wang, S. Lund, Chronic maternal inflammation or high-fat-feeding programs offspring obesity in a sex-dependent manner, Int J. Obes. 41 (2017) 1420–1426, https://doi.org/10.1038/ijo.2017.136.

[93] X. Zhang, F. de Oliveira Andrade, H. Zhang, I. Cruz, R. Clarke, P. Gaur, V. Verma, L. Hilakivi-Clarke, Maternal obesity increases offspring's mammary cancer recurrence and impairs tumor immune response, Endocr. Relat. Cancer 27 (2020) 469–482, https://doi.org/10.1530/ERC-20-0065.

[94] J. Luo, M. Hendryx, J.E. Manson, J.C. Figueiredo, E.S. LeBlanc, W. Barrington, T. E. Rohan, B.V. Howard, K. Reding, G.Y. Ho, D.O. Garcia, R.T. Chlebowski, Intentional Weight Loss and Obesity-Related Cancer Risk, JNCI Cancer Spectr. 3 (2019) pkz054, https://doi.org/10.1093/jncics/pkz054.

[95] L.A.R. Group, H.-C. Yeh, J.P. Bantle, M. Cassidy-Begay, G. Blackburn, G.A. Bray, T. Byers, J.M. Clark, M. Coday, C. Egan, M.A. Espeland, J.P. Foreyt, K. Garcia, V. Goldman, E.W. Gregg, H.P. Hazuda, L. Hesson, J.O. Hill, E.S. Horton, J. M. Jakicic, R.W. Jeffery, K.C. Johnson, S.E. Kahn, W.C. Knowler, M. Korytkowski, A. Kure, C.E. Lewis, C. Mantzoros, M. Meacham, M.G. Montez, D.M. Nathan, N. Pajewski, J. Patricio, A. Peters, F. Xavier Pi-Sunyer, H. Pownall, D.H. Ryan, M. Safford, R.L. Sedjo, H. Steinburg, M. Vitolins, T.A. Wadden, L.E. Wagenknecht, R.R. Wing, A.C. Wolff, H. Wyatt, S.Z. Yanovski, Intensive Weight Loss Intervention and Cancer Risk in Adults with Type 2 Diabetes: Analysis of the Look

AHEAD Randomized Clinical Trial, Obesity 28 (2020) 1678–1686, https://doi.org/10.1002/oby.22936.
[96] M. Lecorguillé, M. Jacota, B. de Lauzon-Guillain, A. Forhan, M. Cheminat, M.-A. Charles, B. Heude, An association between maternal weight change in the year before pregnancy and infant birth weight: ELFE, a French national birth cohort study, PLOS Med. 16 (2019) e1002871, https://doi.org/10.1371/journal.pmed.1002871.
[97] D.K. Tobias, C. Zhang, R.M. van Dam, K. Bowers, F.B. Hu, Physical activity before and during pregnancy and risk of gestational diabetes mellitus: a meta-analysis, Diabetes Care 34 (2010) 223–229, https://doi.org/10.2337/dc10-1368.
[98] I. Bae-Gartz, P. Kasper, N. Großmann, S. Breuer, R. Janoschek, T. Kretschmer, S. Appel, L. Schmitz, C. Vohlen, A. Quaas, M.R. Schweiger, C. Grimm, A. Fischer, N. Ferrari, C. Graf, C.K. Frese, S. Lang, M. Demir, C. Schramm, G. Fink, T. Goeser, J. Dötsch, E. Hucklenbruch-Rother, Maternal exercise conveys protection against NAFLD in the offspring via hepatic metabolic programming, Sci. Rep. 10 (2020) 15424, https://doi.org/10.1038/s41598-020-72022-6.
[99] M. Ueno, S. Liu, T. Kiyoi, M. Mogi, T. Sugiyama, Long-term impact of maternal dietary intervention on metabolic homeostasis in male offspring in mice, J. Nutr. Biochem. 104 (2022) 108971, https://doi.org/10.1016/j.jnutbio.2022.108971.
[100] J.S. Son, L. Zhao, Y. Chen, K. Chen, S.A. Chae, J.M. de Avila, H. Wang, M.-J. Zhu, Z. Jiang, M. Du, Maternal exercise via exerkine apelin enhances brown adipogenesis and prevents metabolic dysfunction in offspring mice, Sci. Adv. 6 (2020) eaaz0359, https://doi.org/10.1126/sciadv.aaz0359.
[101] A. Przybyłowski, M. Górski, W. Gwioździk, R. Polaniak, Redefining Obesity: A Narrative Review of Diagnostic Evolution, Therapeutic Strategies and Psychosocial Determinants, Healthcare 13 (2025) 1967, https://doi.org/10.3390/healthcare13161967.
[102] D. Durrer Schutz, L. Busetto, D. Dicker, N. Farpour-Lambert, R. Pryke, H. Toplak, D. Widmer, V. Yumuk, Y. Schutz, European Practical and Patient-Centred Guidelines for Adult Obesity Management in Primary Care, Obes. Facts 12 (2019) 40–66, https://doi.org/10.1159/000496183.
[103] P. Salminen, M. Helmiö, J. Ovaska, A. Juuti, M. Leivonen, P. Peromaa-Haavisto, S. Hurme, M. Soinio, P. Nuutila, M. Victorzon, Effect of Laparoscopic Sleeve Gastrectomy vs Laparoscopic Roux-en-Y Gastric Bypass on Weight Loss at 5 Years Among Patients With Morbid Obesity: The SLEEVEPASS Randomized Clinical Trial, JAMA 319 (2018) 241–254, https://doi.org/10.1001/jama.2017.20313.
[104] R. Peterli, B.K. Wölnerhanssen, T. Peters, D. Vetter, D. Kröll, Y. Borbély, B. Schultes, C. Beglinger, J. Drewe, M. Schiesser, P. Nett, M. Bueter, Effect of Laparoscopic Sleeve Gastrectomy vs Laparoscopic Roux-en-Y Gastric Bypass on Weight Loss in Patients With Morbid Obesity: The SM-BOSS Randomized Clinical Trial, JAMA 319 (2018) 255–265, https://doi.org/10.1001/jama.2017.20897.
[105] A. Aminian, R. Wilson, A. Al-Kurd, C. Tu, A. Milinovich, M. Kroh, R.J. Rosenthal, S.A. Brethauer, P.R. Schauer, M.W. Kattan, J.C. Brown, N.A. Berger, J. Abraham, S.E. Nissen, Association of Bariatric Surgery With Cancer Risk and Mortality in Adults With Obesity, JAMA 327 (2022) 2423–2433, https://doi.org/10.1001/jama.2022.9009.
[106] K. Johansson, S. Cnattingius, I. Näslund, N. Roos, Y. Trolle Lagerros, F. Granath, O. Stephansson, M. Neovius, Outcomes of pregnancy after bariatric surgery, N. Engl. J. Med 372 (2015) 814–824, https://doi.org/10.1056/NEJMoa1405789.
[107] M. Neovius, B. Pasternak, I. Näslund, J. Söderling, K. Johansson, O. Stephansson, Association of Maternal Gastric Bypass Surgery With Offspring Birth Defects, JAMA 322 (2019) 1515–1517, https://doi.org/10.1001/jama.2019.12925.
[108] ACOG practice bulletin no. 105: bariatric surgery and pregnancy, Obstet. Gynecol. 113 (2009) 1405–1413, https://doi.org/10.1097/AOG.0b013e3181ac0544.
[109] J. Shawe, D. Ceulemans, Z. Akhter, K. Neff, K. Hart, N. Heslehurst, I. Štotl, S. Agrawal, R. Steegers-Theunissen, S. Taheri, B. Greenslade, J. Rankin, B. Huda, I. Douek, S. Galjaard, O. Blumenfeld, A. Robinson, M. Whyte, E. Mathews, R. Devlieger, Pregnancy after bariatric surgery: consensus recommendations for periconception, antenatal and postnatal care, Obes. Rev. 20 (2019) 1507–1522, https://doi.org/10.1111/obr.12927.
[110] E. Torres-Maravilla, A.-S. Boucard, A.H. Mohseni, S. Taghinezhad-S, N.G. Cortes-Perez, L.G. Bermúdez-Humarán, Role of gut microbiota and probiotics in colorectal cancer: onset and progression, Microorganisms 9 (2021) 1021, https://doi.org/10.3390/microorganisms9051021.
[111] D. Chen, D. Jin, S. Huang, J. Wu, M. Xu, T. Liu, W. Dong, X. Liu, S. Wang, W. Zhong, Y. Liu, R. Jiang, M. Piao, B. Wang, H. Cao, Clostridium butyricum, a butyrate-producing probiotic, inhibits intestinal tumor development through modulating Wnt signaling and gut microbiota, Cancer Lett. 469 (2020) 456–467, https://doi.org/10.1016/j.canlet.2019.11.019.
[112] J. Li, C.Y.J. Sung, N. Lee, Y. Ni, J. Pihlajamäki, G. Panagiotou, H. El-Nezami, Probiotics modulated gut microbiota suppresses hepatocellular carcinoma growth in mice, E1306-1315, Proc. Natl. Acad. Sci. USA 113 (2016), https://doi.org/10.1073/pnas.1518189113.
[113] B.K. Alemu, G.G. Azeze, L. Wu, S.L. Lau, C.C. Wang, Y. Wang, Effects of maternal probiotic supplementation on breast milk microbiome and infant gut microbiome and health: a systematic review and meta-analysis of randomized controlled trials, Am. J. Obstet. & Gynecol. MFM 5 (2023) 101148, https://doi.org/10.1016/j.ajogmf.2023.101148.
[114] J.B. Bump, P. Friberg, D.R. Harper, International collaboration and covid-19: what are we doing and where are we going? BMJ 372 (2021) n180, https://doi.org/10.1136/bmj.n180.
[115] L. Hilakivi-Clarke, S. de Assis, Fetal origins of breast cancer, Trends Endocrinol. Metab. 17 (2006) 340–348, https://doi.org/10.1016/j.tem.2006.09.002.
[116] A. Albillos, A. de Gottardi, M. Rescigno, The gut-liver axis in liver disease: pathophysiological basis for therapy, J. Hepatol. 72 (2020) 558–577, https://doi.org/10.1016/j.jhep.2019.10.003.
[117] F. Russo, J. Williamson, Interpreting causality in the health sciences, Int. Stud. Philos. Sci. 21 (2007) 157–170, https://doi.org/10.1080/02698590701498084.