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Original Research Article

Maternal Dietary Patterns during Pregnancy and their Association with Neonatal and Early Childhood Neurodevelopment

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Abstract: ***Background*:** Evidence linking prenatal nutrition to early brain development has largely emphasized single nutrients, overlooking the synergistic nature of whole diets. ***Objective*:** To map maternal dietary patterns and diet quality proxies during pregnancy, including a-priori indices, data-driven patterns, and pattern plus nutrient interventions, and their associations with neonatal to early-childhood neurodevelopment, while considering timing and outcome domains. ***Methods*:** A scoping review guided by the Population-Concept-Context framework and the Preferred Reporting Items for Scoping Reviews searched three databases for peer-reviewed English studies (2018-2025). Two reviewers screened records, charted data with a piloted template, and constructed an evidence map across pattern family, timing (preconception; first, second, third trimester; cumulative), outcome class (neurophysiology, neuroimaging, clinical neurobehavioral, cognition and language, sleep), and age band. ***Results*:** Ten studies met criteria, mostly prospective cohorts with two analyses from a randomized controlled trial. Healthier patterns (Mediterranean, Healthy Eating Index, prudent) were associated with higher infant Ages and Stages Questionnaire and Bayley scores and with more mature neonatal white matter on magnetic resonance imaging and diffusion tensor imaging; Mediterranean counseling improved twenty-four-month Bayley scores. Western or highly processed profiles and greater ultra-processed intake related to poorer child neuropsychological performance. Signals were strongest when exposure was captured early and sustained. Evidence for electroencephalography and sleep was limited, and studies were concentrated in high-income settings. ***Conclusion*:** The findings of this study indicate a correlation between a pattern-level prenatal diet and early neurodevelopment, thereby supporting the plant-forward, minimally processed approach as a guiding principle within antenatal care. Future research should harmonise pattern definitions, standardise trimester-specific measures and multi-domain outcomes, and test biological pathways in diverse settings.

Keyword: Maternal Dietary Pattern, Mediterranean Diet, Early Neurodevelopment, Ultra-Processed Foods.

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1. INTRODUCTION

1.1 Background and Rationale

The influence of prenatal nutrition on fetal brain development has been shown to be a multifaceted process, with the interaction of various pathways contributing to this process. These pathways extend beyond the effects of individual nutrients, highlighting the complexity of this process. Exposures at the pattern level such as Mediterranean/prudent versus Western/processed diets have been demonstrated to shift maternal inflammation, glycemic control, lipid profiles, and micronutrient sufficiency, with downstream consequences for placental function and neurodevelopmental programming. Evidence from the IMPACT-BCN randomised trial demonstrates that structured Mediterranean-diet or mindfulness-based stress reduction interventions during pregnancy result in improved Bayley-III cognitive and socioemotional scores at 24 months, thus demonstrating the capacity of whole-diet interventions to translate into measurable neurodevelopmental gains (Crovetto *et al*., 2023). Secondary analyses of the same trial indicate differences

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in fetal/neonatal brain structure and early neurobehavior linked to the interventions (Nakaki *et al*., 2023) and a lower prevalence of small placental volume, suggesting partial mediation of perinatal benefits through placental growth (Nakaki *et al*., 2024). At the molecular interface, the quality of maternal diet has been demonstrated to be associated with epigenetic marks. A PACE consortium meta-analysis identified cord-blood DNA methylation differences associated with maternal adherence to a Mediterranean diet (Küpers *et al*., 2022). Mechanistic reviews further posit that maternal nutrients and gut microbiota remodel the placental epigenome, plausibly altering neurodevelopmental trajectories (Basak *et al*., 2024). There is an increasing prevalence of organ-level readouts: neuroimaging syntheses are reporting links between prenatal nutrition and offspring brain structure/function from fetal to paediatric stages (Na *et al*., 2024).

Observational cohorts serve to complement the findings of trials. In a large Chinese birth cohort, higher pregnancy Mediterranean-diet adherence was associated with a reduced risk of early developmental delay, which was partly mediated by cord C-peptide, suggesting a glycemic pathway (Dai *et al*., 2023). As indicated by the findings of other cohort studies, there is a correlation between trimester-specific, data-driven "healthier" dietary patterns and more favourable cognitive and motor outcomes at one year, while processed/Western dietary patterns relate to less favourable profiles (Lv *et al*., 2022). Furthermore, the significance of neonatal functional maturity markers cannot be overstated. The features of neonatal electroencephalogram (EEG) background activity in infants with a small for gestational age (SGA) have been shown to correlate with subsequent developmental scores (Castro Conde *et al*., 2020). This underscores the importance of early neurophysiological assessment in determining future developmental outcomes. Methodologically, the majority of previous syntheses have focused on individual nutrients (folate, DHA), which may have resulted in the oversight of emergent properties associated with dietary synergies (fibre, polyphenols, fatty acid profiles) and the significance of exposure timing. The heterogeneity in the definition of patterns (a priori indices vs. a posteriori derivation), the assessment of windows (T1/T2/T3), and the measurement of neonatal outcomes (EEG, structured exams, imaging, early cognition) complicates the comparison of results (Lecorguillé *et al*., 2021; Zhao *et al*., 2021). A scoping review is therefore indicated to identify the patterns under study, the timing of measurement, the neonatal endpoints employed, and the handling of mediators/moderators (glycaemia, inflammation, microbiome, placental/epigenetic signals; infant sex; maternal BMI/SES). This will allow the field to establish consensus on targets for future causal and implementation studies (Crovetto *et al*., 2023; Nakaki *et al*., 2023; Küpers *et al*., 2022; Basak *et al*., 2024; Na *et al*., 2024).

1.2 Objective and Study Questions

The aim of this study is to systematically map evidence on maternal dietary patterns during pregnancy and neonatal neurodevelopment, emphasizing exposure timing, outcome measures, and putative mechanisms. The questions guiding this review are as follows:

i. Which prenatal diet exposures are associated with neonatal-to-early-childhood neurodevelopment, and in what direction?
ii. When during gestation are associations most consistent, and which outcome domains/ages show the strongest signals?
iii. Through what mechanisms and contexts do effects operate, and what priority gaps should guide future trials and implementation?

2. METHODOLOGY

2.1 Design and Reporting Standards

This review employs a scoping review design, structured by the Population-Concept-Context (PCC) framework, in order to map the breadth and characteristics of evidence on maternal dietary patterns during pregnancy, diet-quality proxies such as NOVA/ultra-processed food share), and pattern + nutrient interventions in relation to neonatal and early-childhood neurodevelopment. The reporting of results adhered to the PRISMA extension for Scoping Reviews (PRISMA-ScR), encompassing a flow diagram and transparent documentation of the study selection process. In accordance with the scoping aim, which is to provide a description and classification rather than an estimation of effects, no formal risk-of-bias/critical appraisal is planned. The safeguards encompass explicit eligibility criteria, a multi-database strategy, dual screening, and standardised data charting.

2.2 Eligibility Criteria

Eligibility (PCC) targeted peer-reviewed human studies (2018-2025; English) of pregnant individuals that assessed dietary patterns (a-priori indices or a-posteriori patterns), diet-quality proxies (e.g., NOVA/UPF), or pattern + nutrient interventions, with offspring neurodevelopmental outcomes from birth through early childhood. Non-empirical reports and single-nutrient/food studies were excluded unless they were embedded in a multi-component pattern intervention. Decisions were applied against pre-specified itemised criteria in Table 1.

Table 1: Eligibility Criteria

Item	Inclusion criteria	Exclusion criteria
Population	Pregnant individuals (any risk status). Offspring neurodevelopment assessed from birth through early childhood (neonatal/infant/toddler/preschool; studies up to ~8 years acceptable).	Animal/in-vitro studies.
Concept	Dietary patterns during pregnancy measured via: a-priori indices (e.g., Mediterranean/aMED, HEI/AHEI, DASH, healthy/unhealthy PDI) or a-posteriori methods (PCA/FA/cluster/latent class, RRR); named pattern interventions (e.g., Mediterranean diet counselling, with or without provision of hallmark foods); diet-quality proxies that capture overall pattern (e.g., NOVA/UPF % energy).	Exposures not representing a pattern (single nutrient/biomarker or single food) unless embedded in a multi-component pattern intervention (then eligible). Non-diet exposures (alcohol, environmental toxicants, physical activity) unless part of a combined, clearly defined dietary pattern program.
Context	Any country/income setting; clinical or community.	-
Study designs	RCTs/quasi-experimental; prospective/retrospective cohorts; case-control; cross-sectional (if standardized neurodevelopment tools used).	Protocols, reviews, editorials, letters; conference abstracts without full text.
Outcomes	Neonatal to childhood neurodevelopment assessed with recognised tools: neurophysiology (EEG/aEEG/ERP), clinical neuro exams (HNNE), motor risk (GMA), neurobehavioral (NBAS/NBO), cognition/language/behaviour (e.g., ASQ, Bayley, IQ/standardized tests), neuroimaging (MRI/DTI), sleep architecture/maturity. Perinatal growth/SGA acceptable only if the same study also reports a neurodevelopment endpoint (any age).	Studies without any neurodevelopmental endpoint.
Publication type	Peer-reviewed journal articles.	Grey literature (reports/theses), books/chapters, preprints without peer review.
Language	English.	Non-English.
Timeframe	2018 - 2025 (inclusive).	Outside this range.

2.3 Information Sources

Retrieval of records was restricted to peer-reviewed literature indexed in three databases selected for coverage of clinical, biomedical, and allied-health research: MEDLINE/PubMed, Embase (Ovid), and CINAHL (EBSCOhost). The search did not encompass grey literature sources, and no date was attached to the search in the manuscript. The export of records to Zotero was undertaken for the purpose of de-duplication, with dual independent screening conducted at the title/abstract and full-text stages. Resolution of any discrepancies was achieved through consensus.

2.4 Search Strategy

Database-specific strategies combined controlled vocabulary (MeSH/Emtree/CINAHL Headings) and free-text terms for the PCC elements, prioritising sensitivity (Table 2). The application of filters served to restrict the search to human subjects, articles written in English, and articles that had undergone the peer-review process. The implementation of strategies was initiated through a pilot phase, during which they were subjected to refinement to ensure retrieval across a range of pattern types and neonatal endpoints.

Table 2: Search String by Database

Database	Search string
MEDLINE/PubMed	((pregnan*[tiab] OR prenatal[tiab]) AND (dietary pattern*[tiab] OR mediterranean[tiab] OR HEI[tiab] OR DASH[tiab] OR plant-based[tiab] OR western[tiab] OR UPF[tiab] OR NOVA[tiab]) AND (neonat*[tiab] OR infant*[tiab] OR child*[tiab]) AND (neurodevelop*[tiab] OR cognition[tiab] OR behavior*[tiab] OR EEG[tiab] OR MRI[tiab] OR DTI[tiab] OR Bayley[tiab] OR ASQ[tiab] OR HNNE[tiab] OR GMA[tiab])) Filters: English; Humans
Embase (Ovid)	(pregnan*:ti,ab,kw OR prenatal:ti,ab,kw) AND (dietary pattern*:ti,ab,kw OR mediterranean:ti,ab,kw OR hei:ti,ab,kw OR dash:ti,ab,kw OR plant-based:ti,ab,kw OR western:ti,ab,kw OR upf:ti,ab,kw OR nova:ti,ab,kw) AND (neonat*:ti,ab,kw OR infant*:ti,ab,kw OR child*:ti,ab,kw) AND (neurodevelop*:ti,ab,kw OR cognition:ti,ab,kw OR behaviour:ti,ab,kw OR eeg:ti,ab,kw OR mri:ti,ab,kw OR dti:ti,ab,kw OR bayley:ti,ab,kw OR asq:ti,ab,kw OR hnne:ti,ab,kw OR gma:ti,ab,kw) AND [english]/lim AND [humans]/lim

CINAHL (EBSCOhost)	(MH "Pregnancy+") AND ((MH "Dietary Patterns") OR dietary pattern* OR mediterranean OR HEI OR DASH OR plant-based OR western OR UPF OR NOVA) AND ((MH "Neurodevelopmental Disorders+") OR neurodevelop* OR cognition OR behavior OR EEG OR MRI OR Bayley OR ASQ OR HNNE OR GMA) Limiters: English; Peer-Reviewed; Human

2.5 Data Charting and Synthesis

The charting process employed a standardised template that had been piloted on 5–10 studies and subsequently refined. Variables: bibliographic details; country/WHO region; design/sample size; maternal characteristics (age, BMI, parity, education/SES, smoking, alcohol, physical activity, depression/stress, GDM/obesity); dietary-pattern method (index name and scoring; PCA/FA loadings, cluster/latent class labels; RRR response variables); diet-quality proxies or pattern + nutrient interventions; diet assessment (FFQ/24-h recall; Energy adjustment), timing (before conception, T1/T2/T3, and throughout pregnancy); neurodevelopmental outcomes from neonatal through early childhood, spanning neurophysiology, neuroimaging, clinical neurobehavior, cognition/language/behaviour, and sleep. Perinatal growth/SGA was extracted only when a neurodevelopment endpoint appeared in the same paper; effect data; mediators/moderators (blood sugar, insulin, inflammation, microbes, placental measures, epigenetics, infant sex); and funding/conflicts. The synthesis was descriptive and mapping-oriented, with numerical summaries generated including counts by year, region, design, exposure type, trimester assessed, and outcome class. The findings were grouped narratively by pattern family (Mediterranean/HEI/DASH/plant-based vs. Western/processed; a-priori vs. a-posteriori), timing (preconception/T1–T3/cumulative), outcome class and age band, annotating direction of effect.

3. RESULTS

3.1 Selection Process

A total of 1,050 records were identified through database searches. Following the removal of 582 duplicates, 468 titles and abstracts were subjected to screening, resulting in the exclusion of 320 due to irrelevance. The remaining 148 full texts were assessed, of which 138 were excluded: 45 reviews or grey literature, 55 with non-diet exposures, and 38 with no neurodevelopmental endpoint. Following a thorough examination of the available literature, 10 studies were deemed to meet the specified eligibility criteria and were thus included in the review (Figure 1).

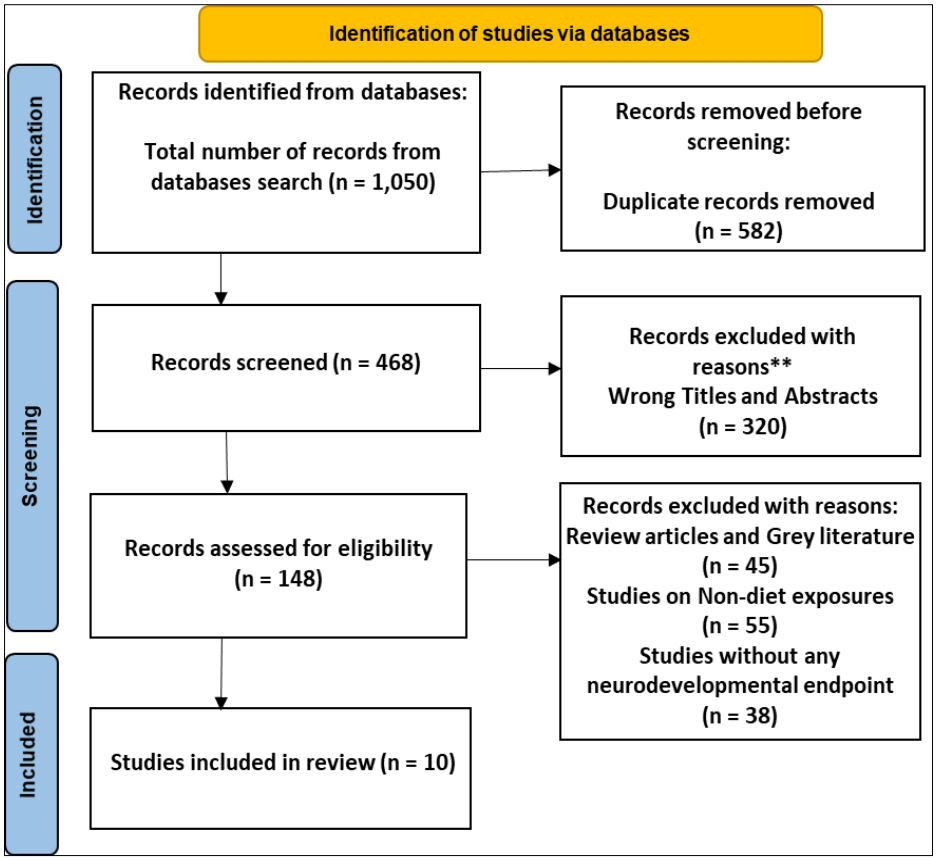

Figure 1: PRISMA-ScR flow diagram depicting the full study selection process

3.2 Study Characteristics

The evidence set comprising 10 studies is dominated by prospective cohorts, with two trial-based analyses from IMPACT-BCN (Table 3). Exposures encompass a-priori patterns (Mediterranean, HEI), a-posteriori patterns (PCA/cluster), a diet-quality proxy (NOVA/UPF), and pattern + nutrient interventions (Mediterranean with EVOO/nuts). The assessment of timing is predominantly cumulative, encompassing pregnancy as a whole, with additional trimester-resolved evaluations (T1-T3). The outcomes encompass neonatal MRI/DTI and NBAS/NBO, infant Bayley/ASQ (≤12 months), and child cognition/behaviour into early childhood. The samples encompass a broad spectrum, ranging from modest imaging cohorts to extensive national cohorts, predominantly from Europe and Asia, with a notable addition of a multiethnic cohort from the United States. The majority of studies adjust for key confounders (socioeconomic status, body mass index, smoking, and energy intake). Several studies probe mechanistic pathways (placenta/epigenetics), though electroencephalogram (EEG) and sleep endpoints remain sparse.

3.3 Thematic Synthesis

3.3.1 Exposure → Outcome Signals (By Pattern Family)

Across studies, healthier prenatal patterns were consistently linked to better neurodevelopment, whereas lower-quality patterns were related to poorer scores (Table 3). As demonstrated in the research by Dai (2023), Crovetto *et al*., (2023), and Na (2023), there is a correlation between Mediterranean/HEI exposures and higher infant ASQ/Bayley scores. In addition to this, the findings of Na (2023) indicate that there is also a correlation between Mediterranean/HEI exposures and more mature neonatal white-matter organisation. A-posteriori "prudent/healthy" patterns have been shown to predict higher 12-month development (de Seymour, 2022; Lv, 2022) and better 36-month outcomes when rich in protein and micronutrients (Ouyang, 2024). In contrast, Western/processed dietary patterns have been associated with lower or null scores (de Seymour, 2022; Lv, 2022), and higher intake of ultra-processed food during pregnancy has been linked to poorer child neuropsychological performance (Puig-Vallverdú, 2022). The strength of the inferences made is increased by the results of the trial data. A Mediterranean pattern intervention has been demonstrated to improve neonatal neurobehavior and fetal/neonatal brain measures (Nakaki *et al*., 2023) and to enhance Bayley-III at 24 months (Crovetto *et al*., 2023). This direction is corroborated by longer-term cohorts, which exhibit periconceptional Mediterranean-like patterns that are associated with favourable child behaviour (House, 2018). The findings from this study were mixed, which is likely to be a reflection of differences in the population and measurement methods employed (de Lauzon-Guillain, 2022).

Table 3: Summary of Included Studies

Study	Design & sample	Dietary pattern exposure (what & how)	Timing of exposure	Neuro-developmental outcomes	Key findings	Confounding/mediation notes
Dai 2023	Prospective birth cohort; general population sample (size as reported in article).	A-priori Mediterranean diet adherence derived from validated FFQ; score reflects higher fruits/veg, whole grains, legumes, fish, MUFA; lower red/processed meats.	Assessed during pregnancy (as reported); treated as overall adherence across gestation.	ASQ domains in infancy (≤ 12 months).	Favorable association: higher prenatal Mediterranean adherence linked to better early developmental scores (domain-specific gains noted); dose–response described qualitatively.	Models adjust for key sociodemographics and maternal factors (education, age, BMI, lifestyle) and energy intake as reported; sensitivity checks described.
Nakaki 2023	RCT secondary analysis; participants randomized to Mediterranean diet	Pattern intervention: structured Mediterranean program (with hallmark foods provided) and an MBSR arm;	Intervention delivered across pregnancy (initiation in early–mid gestation per protocol).	Fetal MRI phenotypes; neonatal neurobehavior (NBAS/NBO).	Beneficial signals in fetal/neonatal brain metrics and early neurobehavior for	Randomization minimizes confounding; per-protocol/ITT contrasts reported; exploratory mediation via placental/anthropometric pathways discussed

	counseling, MBSR, or usual care.	adherence tracked.			Mediterranean and/or MBSR groups vs usual care; consistency across outcomes noted in the paper.	in program publications.
de Seymour 2022	Prospective cohort (Chinese population); mother–infant dyads followed to 12 months.	A-posteriori patterns via PCA from early-pregnancy diet; labels reflect "prudent/healthy" vs "processed/energy-dense" loading.	Early pregnancy primary ascertainment.	Bayley indices at 12 months.	Pattern-dependent differences: healthier patterns associated with higher Bayley domains; processed patterns show attenuated scores or nulls; magnitude varies by domain.	Multivariable models adjust for maternal age, education, BMI, parity, smoking/alcohol, energy intake; trimester-specific diet measurement reduces recall bias.

Table 3: Summary of Included Studies Cont'd

Study	Design & sample	Dietary pattern exposure (what & how)	Timing of exposure	Neuro-developmental outcomes	Key findings	Confounding/mediation notes
Na 2023	Prospective cohort with neonatal imaging.	A-priori HEI-2015 (overall diet quality) from prenatal FFQ/24-h recalls (as reported).	During pregnancy; summarized as overall quality (timing details in paper).	Neonatal MRI/DTI white-matter microstructure.	Favorable association: higher prenatal diet quality relates to more mature/organized white-matter signatures in neonates; pattern robust across tracts/domains reported.	Adjustments include maternal demographics, pregnancy factors, and birth variables; imaging analysts blinded; multiple-comparison handling described.
Lv 2022	Prospective cohort; mother–infant pairs with 12-month follow-up.	A-posteriori PCA patterns (e.g., "prudent/healthy" vs "Western/processed").	During pregnancy; timing window noted in article.	Standardized infant neurodevelopment at 12 months.	Healthier patterns → better scores; Western/processed → lower or null; effects domain-specific and modest in size; sociodemographic gradients evident.	Broad covariate control, energy adjustment; subgroup checks (e.g., infant sex) explored.
de Lauzo	Nationwide French	Guideline-based diet quality (a-	During pregnancy	Early-childhood	Mixed pattern of results: some	Extensive adjustment structure; attrition

n-Guillain 2022	cohort; large sample with repeated child assessments.	priori) and pattern-relevant food groups.	; usually mid-gestation FFQ.	neurodevelopment (1–3.5 y; parent-reported standardized tools).	domains show positive links with higher prenatal diet quality, others null; heterogeneity by domain and sociodemographics discussed.	addressed; multiple sensitivity analyses (e.g., residual confounding) reported.

Table 3: Summary of Included Studies Cont'd.

Study	Design & sample	Dietary pattern exposure (what & how)	Timing of exposure	Neuro-developmental outcomes	Key findings	Confounding/mediation notes
Crovetto 2023	Pragmatic RCT; at-risk pregnancies.	Pattern + nutrient provisioning: Mediterranean diet with EVOO and nuts vs MBSR vs usual care; adherence monitored.	Across pregnancy (program duration per protocol).	Bayley-III at 24 months.	Improved cognitive and socio-emotional scores in intervention arms vs usual care; effects clinically small–moderate; both Med-diet and MBSR show benefits with slightly different profiles.	Randomization; adjustment for baseline imbalances; sensitivity to adherence; discusses potential mediation through placental/growth pathways.
Puig-Vallverdú 2022	Population-based cohort (Spain).	Diet-quality proxy: NOVA/UPF percentage of energy during pregnancy (pattern-adjacent).	During pregnancy; FFQ mapped to NOVA.	Child neuropsychological performance (early childhood; domain-specific).	Higher UPF → poorer verbal/overall scores; effect sizes small but consistent after adjustment; underscores quality dimension of "pattern".	Adjusted for maternal education, BMI, age, smoking, energy intake; residual confounding by lifestyle acknowledged.
Ouyang 2024	Prospective cohort with trimester-resolved diet.	A-posteriori PCA patterns across T1–T3 (e.g., protein–micronutrient rich vs snack/sweet).	T1, T2, T3 separately modeled.	ASQ at 36 months.	Trimester-specific effects: protein–micronutrient-rich pattern in specific trimesters associates with better gross-motor/problem-solving; snack/sweet	Adjustments for maternal/household covariates; explores interaction by infant sex; robustness checks described.

					pattern inversely related; timing matters.	

Table 3: Summary of Included Studies Cont'd.

Study	Design & sample	Dietary pattern exposure (what & how)	Timing of exposure	Neuro-developmental outcomes	Key findings	Confounding/ mediation notes
House 2018	Cohort with periconceptional diet capture and child follow-up.	Mediterranean-like pattern (a-priori composite) around conception/early pregnancy.	Periconception/ early gestation emphasis.	Child behavioral outcomes (school-age); ancillary epigenetic links discussed.	Favorable behavioral profile with higher adherence; explorations suggest potential epigenetic mediation; acknowledges unmeasured confounding.	Adjusted for key sociodemographics; explores methylation at imprinted loci as explanatory pathway.

Table 4: Evidence Map of Included Studies

Pattern / exposure family	Neurophysiology (EEG/ERP)	Neuroimaging (MRI/DTI)	Clinical neurobehavior (HNNE/GMA/NBAS/NBO)	Cognition/Language/Behaviour (ASQ/Bayley/IQ etc.)	Sleep
Mediterranean / HEI (a-priori)	-	↑ (cum) - *Na, 2023*	↑ (cum) - *Nakaki, 2023*	↑ (≤12 mo, cum) - *Dai, 2023*; ↑ (24 mo, cum) - *Crovetto, 2023*; ~/ mixed (1-3.5 y, cum) - *ELFE, 2022*; ↑ (peri-conception) - *House 2018*	-
A-posteriori "healthy/prudent"	-	-	-	↑ (12 mo, early/cum) - *de Seymour, 2022; Lv, 2022*; ↑ (36 mo, T-specific) - *Ouyang, 2024*	-
A-posteriori "Western/processed"	-	-	-	↓ / **null** (12-36 mo; early/T-specific) - *de Seymour, 2022; Lv, 2022; Ouyang, 2024*	-
Diet-quality proxy (NOVA/UPF)	-	-	-	↓ (early-childhood verbal/global, cum) - *Puig-Vallverdú, 2022*	-
Pattern interventions (Mediterranean ± MBSR; with hallmark foods)	-	↑ (cum) - *Nakaki, 2023 (fetal/neonatal)*	↑ (cum) - *Nakaki, 2023 (NBAS/NBO)*	↑ (24 mo, cum) –-*Crovetto, 2023*	-

Rows = pattern family/exposure type. Columns = Outcome class. Within each cell: direction (↑ favorable, ↓ adverse, ~ mixed/null).

3.3.2 Timing and Developmental Windows

The signals appear to be sensitive to the point in time at which the pattern was captured (Table 4). Trimester-resolved analyses suggest that early pregnancy may be a significant factor. Protein-micronutrient-rich dietary patterns in the first and second trimesters have been associated with enhanced gross motor abilities and problem-solving skills at 36 months of age, while snack and sweet consumption patterns have been linked to adverse outcomes (Ouyang, 2024). In the initial stages of pregnancy, patterns derived from PCA (Principal Component Analysis) and designated as "healthy" have been shown to be indicative of higher 12-month Bayley scores (de Seymour, 2022). Cumulative pregnancy adherence to a Mediterranean/HEI diet has been demonstrated to be associated with neonatal white-matter integrity (Na, 2023), improved neonatal neurobehaviour (Nakaki *et al*., 2023), and enhanced infant cognition (Dai, 2023). Trial results by Crovetto *et al*., (2023) suggest that the provision of consistent support throughout pregnancy may result in cognitive and socio-emotional benefits that extend up to 24 months of age. The potential significance of preconception exposure warrants consideration, as evidence suggests a correlation between a Mediterranean-like profile during conception and subsequent behavioural advantages (House, 2018). Collectively, the evidence suggests that earlier and sustained adherence is preferable, although heterogeneity and mixed findings in a national cohort (de

Lauzon-Guillain, 2022) underscore the necessity for standardised timing and repeated dietary measures.

3.3.3 Mechanisms, Modifiers, and Implementation Gaps

The results obtained from this study are consistent with the established biological pathways and highlight the practical limitations of the study (Table 4). Mediterranean/HEI dietary patterns, characterised by a high consumption of plant foods and healthy fats, have been associated with specific brain structure and neurobehavioural characteristics in foetuses and neonates (Na, 2023; Nakaki *et al.,* 2023), consistent with improved metabolic-inflammatory tone and placental function proposed in the literature. Cohorts were frequently adjusted for SES, BMI, smoking, and energy intake, yet residual confounding and selection remain plausible (de Seymour, 2022; Lv, 2022; Dai, 2023). A study has explored the moderating influence of infant sex or maternal characteristics (Ouyang, 2024), and one cohort study has discussed the epigenetic links with pattern adherence (House, 2018). The evidence base for the use of electroencephalography (EEG) and electroencephalic potential (EEG/ERP) in LMIC settings is limited, and there is a lack of research on sleep outcomes in these contexts. The heterogeneity of measurement, which is evident in indices versus PCA and the use of different tools and ages, complicates synthesis (de Lauzon-Guillain, 2022). The following priorities have been identified: harmonised pattern definitions, trimester-specific assessments, inclusion of electrophysiology/sleep, and pragmatic pattern-focused interventions that are scalable in diverse contexts.

4. DISCUSSION

4.1 Contribution to Knowledge

This scoping review contributes to the advancement of knowledge in four distinct ways. Firstly, it reframes the concept of prenatal nutrition at the pattern level and integrates a-priori indices, a-posteriori patterns, diet-quality proxies (NOVA/ultra-processed foods), and pattern-plus-nutrient interventions. Secondly, it integrates neonatal neurobiological markers (neuroimaging and neurobehaviour) with early-childhood cognition/behaviour, facilitating a continuous developmental perspective. Thirdly, the structuring of evidence across timing windows (preconception, T1–T3, cumulative) demonstrates that adherence to higher-quality patterns from the outset and throughout the process is associated with more favourable outcomes, while Western/UPF profiles are associated with adverse outcomes. The evidence map included in this study also provides a transparent matrix (pattern family x timing x outcome class x age band) that clarifies where findings converge and where methods need alignment. The following novel gaps have been identified: a lack of electrophysiology and sleep outcomes research; limited representation of low- and middle-income countries (LMICs); and heterogeneity in pattern definitions and dietary assessment. Collectively, these contributions provide a comprehensive systems perspective, integrating maternal diet, placental, and neurodevelopmental pathways with child function. This framework serves as a foundation for mechanistic and implementation studies.

4.2 Comparison of Findings with Global Evidence

This pattern-level synthesis aligns with and extends prior nutrition-brain research that has largely emphasised single nutrients. The evidence for omega-3s is suggestive but inconsistent. Prenatal DHA reviews note benefits yet heterogeneity in trials (Rogers *et al*., 2013; Basak *et al*., 2020), with positive neonatal MRI correlates in an observational cohort (Morton *et al*., 2020) but mixed behavioural outcomes across populations (Tahaei *et al*., 2022; Kim *et al*., 2017; Shahabi *et al*., 2024). It has been demonstrated that other micronutrients exhibit signalling properties such as zinc: Berger *et al*., (2025); vitamin B12: Cruz-Rodríguez *et al*., (2023); and vitamin D: Voltas *et al.*, (2020), but the effects are negligible and contingent on context. Conversely, our pattern findings are consistent with the existing literature that demonstrates that the overall diet quality during pregnancy is a predictor of future health outcomes. Adherence to a Mediterranean diet (Med-HEI) has been associated with favourable perinatal profiles (Chia *et al*., 2018; Díaz-López *et al*., 2022; Christifano *et al*., 2024; Costanza *et al*., 2022) and, in certain cohorts, with enhanced child neuropsychological development (Gignac *et al*., 2019). This study aligns with recent reviews that emphasise the necessity of considering whole-diet, systems-oriented perspectives (Heland *et al*., 2022; de Matos Reis *et al*., 2024; Cortés-Albornoz *et al*., 2021).

This interpretation is consistent with the existing literature on non-diet determinants and biological pathways. Prenatal exposure to toxic substances has been demonstrated to be associated with suboptimal neurodevelopment and alterations in brain structure (Kou *et al*., 2025; Barbone *et al*., 2019; Jacobson *et al*., 2017). This underscores the necessity to differentiate between the effects of diet and co-exposures. Studies linking maternal diet to placental, inflammatory, and microbiome axes offer mechanistic plausibility for pattern effects (Lubrano *et al*., 2024; Hernández-Martínez *et al*., 2022; García-Mantrana *et al*., 2020). Furthermore, the findings of studies that have demonstrated a correlation between the quality of the pregnant woman's diet and fetal growth, adiposity, and anthropometry (Chia *et al*., 2018; Díaz-López *et al*., 2022; Hajianfar *et al*., 2018) lend support to the hypothesis that dietary patterns may have a significant impact on the early physiology of the foetus, which in turn may have a subsequent influence on its neurodevelopmental trajectory. The postnatal feeding context has been demonstrated to be a significant factor in this regard (Gibertoni *et al*., 2020), underscoring the necessity for meticulous control and strategic timing. The broader literature generally aligns with the evidence

map of this study, indicating the benefits of healthier, plant-forward dietary patterns, as well as potential risks associated with the consumption of highly processed food.

There is a divergence in the approach taken by our review, namely the integration of neonatal biomarkers with early-childhood cognition within a unified framework. Prior research has been criticised for its narrow focus on specific outcomes, such as brain volumes (Morton *et al*., 2020) or child testing years later (Gignac *et al*., 2019). Moreso, the investigation has been limited to a single nutrient at a time (Rogers *et al*., 2013; Basak *et al*., 2020). This study emphasised trimester-specific exposure windows and cross-domain endpoints, echoing calls for harmonised methods (Heland *et al*., 2022; Cortés-Albornoz *et al*., 2021). In addition to this, it underscores the need for further research in two key areas, which are, electrophysiology and sleep. These subjects have been historically under-researched and under-represented in existing studies (de Matos Reis *et al.,* the current body of evidence from related studies supports this interpretation, suggesting that maternal diet patterns, rather than individual nutrients, appear to influence early neurodevelopment through metabolic, inflammatory, and microbiome-placental pathways. Concurrent exposures to toxicants and socioeconomic contexts have also been demonstrated to modify the observed effects (Kou *et al*., 2025; Barbone *et al*., 2019; Lubrano *et al*., 2024).

4.3 Implications for Practice and Policy

Clinical Practice:

Antenatal care should evolve beyond the delivery of isolated nutrient recommendations, transitioning towards the provision of comprehensive pattern-level counselling at the preconception stage (T1) and maintaining this approach throughout the periods T2 and T3. The utilisation of concise diet-quality screening tools such as Mediterranean/HEI checklists during routine consultations serves to identify instances of low-quality or ultra-processed food (UPF)-heavy intake. Subsequent to this identification, the provision of culturally adapted, plant-forward meal guidance, practical substitutions, and explicit UPF-reduction recommendations is crucial. For patients considered to be at higher risk, including those experiencing food insecurity, obesity, or gestational diabetes mellitus, the provision of counselling in conjunction with healthy food packages, consisting of produce, legumes, and fish, and simple adherence supports via text messages, nudges, and shopping lists is recommended. When feasible, stress-reduction components should be incorporated alongside nutrition, and trimester-specific diet and child outcome plans should be documented in the record.

Policy:

Maternal-child nutrition policies should explicitly incorporate whole-diet quality targets, as opposed to merely supplements, with procurement and voucher programmes that ensure the affordability of minimally processed staples during pregnancy. In order to achieve the desired outcome, it is essential that regulations are aligned with the objective of discouraging UPF exposure. This can be achieved through the implementation of marketing limits in maternity settings and front-of-pack labelling. In addition to this, it is recommended that pragmatic, pattern-based trials are funded, with the aim of tracking neonatal biomarkers and early-childhood cognition. It is vital to prioritise equity by scaling community health workers, cash and food benefits, and culturally tailored materials in low- and middle-income countries (LMICs) and underserved populations. The need for uniform dietary practices and neurodevelopmental metrics across gestational trimesters is paramount. Also, the promotion of interdisciplinary collaboration among sectors such as health, agriculture, and social protection, is instrumental in enhancing the food environment during pregnancy at population scale.

5. CONCLUSION

This scoping review examined maternal dietary patterns during pregnancy and their associations with neurodevelopment in infants and children. It revealed healthier, plant-forward dietary patterns generally aligned with more favourable cognitive and behavioural outcomes in infants and children. Conversely, Western and ultra-processed dietary patterns related to poorer performance. Our evidence map clarifies where signals converge and where evidence is sparse, particularly for cognition/behaviour. From a methodological perspective, the findings underscore the necessity for harmonised pattern definitions, repeated trimester-specific diet measures, and multi-domain neurodevelopmental endpoints with transparent adjustment sets. Mechanistic plausibility, as evidenced by factors including maternal glycaemia, inflammation, the microbiome, placental function, and epigenetic pathways, supports a pattern-level lens. However, mediation is rarely tested within individual studies. Evidence remains underrepresented within LMICs, with heterogeneity in the instruments, ages, and confounder control complicating synthesis. The review's findings call for future research to prioritise pragmatic, pattern-based trials with implementation outcomes, integrating biomarkers and placental measures to test pathways, and adding electrophysiology and sleep to outcome cores. This provides a foundation for research, policy and clinical guidance aimed at optimising neurodevelopment from pregnancy onwards.

Abbreviations

AHEI: Alternative Healthy Eating Index
aEEG: Amplitude-Integrated Electroencephalography
aMED: Alternate Mediterranean Diet (score/index)
ASQ: Ages and Stages Questionnaire
Bayley/Bayley-III: Bayley Scales of Infant and Toddler Development (Third Edition)

CBCL: Child Behavior Checklist
CRP: C-Reactive Protein
DASH: Dietary Approaches to Stop Hypertension
DNAme: DNA Methylation
DTI: Diffusion Tensor Imaging
EEG: Electroencephalography
EVOO: Extra-Virgin Olive Oil
FA: Factor Analysis
FFQ: Food Frequency Questionnaire
GDM: Gestational Diabetes Mellitus
GMA: General Movements Assessment
GUSTO: Growing Up in Singapore Towards healthy Outcomes
HEI: Healthy Eating Index
HNNE: Hammersmith Neonatal Neurological Examination
IGF: Insulin-Like Growth Factor
IL-6: Interleukin-6
IMPACT-BCN: Improving Mothers for a better PrenAtal Care Trial – Barcelona
ITT: Intention-to-Treat
MBSR: Mindfulness-Based Stress Reduction
MeSH: Medical Subject Headings
miRNA: MicroRNA
MRI: Magnetic Resonance Imaging
NBAS: Neonatal Behavioral Assessment Scale
NBO: Newborn Behavioral Observations
NOVA: NOVA Food Processing Classification System
PCA: Principal Components Analysis
PDI: Plant-Based Diet Index
RRR: Reduced Rank Regression
SCFA(s): Short-Chain Fatty Acids
SDQ: Strengths and Difficulties Questionnaire
SES: Socioeconomic Status
UPF: Ultra-Processed Foods
ERP: Event-Related Potentials

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Olatunde Timilehin Samuel conceptualized the study,
Olatunde Timilehin Samuel and Abdulmalik Aisha Ohunene extracted data from reviewed studies.
Olatunde Timilehin Samuel and Makanjuola Omotola Feyikemi prepared the figures.
All authors reviewed the manuscript.

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