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Review Article

Integrating nutrition and artificial intelligence in reproductive health: advancing precision fertility medicine

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ABSTRACT

Nutrition is increasingly recognized as a critical, modifiable determinant of reproductive health in both men and women. A growing body of evidence demonstrates that dietary patterns, specific nutrients, and overall diet quality influence fertility potential in assisted reproductive technology (ART) outcomes, and pregnancy success. This review synthesizes recent evidence from systematic reviews, meta-analyses, randomized controlled trials, and mechanistic studies published between 2021 and 2026 to evaluate the impact of nutrition on reproductive outcomes across both men and women. Consistent findings indicate that adherence to healthy dietary patterns particularly Mediterranean and plant-rich diets characterized by high intake of fruits, vegetables, whole grains, nuts, seafood, and unsaturated fats is associated with improved semen quality, hormonal balance, oocyte competence, reduced oxidative stress, and enhanced clinical pregnancy and live birth rates. Conversely, diets high in ultra-processed foods, trans fats, refined carbohydrates, and red or processed meats are linked to impaired reproductive function, increased inflammation, and poorer fertility outcomes. Emerging evidence also highlights the role of targeted micronutrients and nutraceuticals, such as omega-3 fatty acids, zinc, selenium, and coenzyme Q10, in improving gamete quality and ART success, although heterogeneity across studies underscores the need for further well-designed trials. Importantly, advances in artificial intelligence (AI) offer new opportunities to integrate nutritional data with clinical, metabolic, and reproductive parameters, enabling personalized dietary recommendations and predictive modelling of fertility outcomes. The integration of AI-driven analytics with evidence-based nutritional strategies holds promise for optimizing preconception care, enhancing ART decision making, and advancing precision fertility medicine.

Keywords: Nutrition, Fertility, Assisted reproductive technology, Artificial intelligence, Mediterranean diet

INTRODUCTION

Infertility is a global public health concern affecting millions of couples, with prevalence steadily increasing due to delayed childbearing, lifestyle transitions, metabolic disorders, and environmental exposures.[1] While assisted reproductive technologies (ART) such as *in-vitro* fertilization (IVF) have significantly improved the management of infertility, success rates remain variable, underscoring the importance of identifying modifiable factors that can enhance reproductive outcomes.[2] Among these factors, nutrition has emerged as a central yet often underutilized determinant of reproductive health in both men and women.

Dietary intake influences reproductive function through multiple biological pathways, including hormonal regulation, oxidative stress balance, inflammation, mitochondrial activity, and epigenetic modifications.[3] In women, nutritional status affects ovulatory function, oocyte quality, endometrial receptivity, and pregnancy maintenance, whereas in men, diet plays a critical role in spermatogenesis, semen quality, hormonal homeostasis, and sperm DNA integrity. Contemporary evidence

increasingly supports the concept that fertility is not solely dependent on isolated nutrients but is strongly shaped by overall dietary patterns and long-term nutritional behaviors.[4]

Over the past decade, a growing number of observational studies, randomized controlled trials, and systematic reviews have demonstrated that adherence to healthy dietary patterns particularly Mediterranean and plant-forward diets rich in fruits, vegetables, whole grains, nuts, seafood, and unsaturated fats is associated with improved semen parameters, enhanced ovarian function, higher clinical pregnancy rates, and favorable ART outcomes. In contrast, diets characterized by excessive intake of ultra-processed foods, trans fats, refined carbohydrates, and red or processed meats have been consistently linked to impaired reproductive parameters, increased oxidative stress, and adverse metabolic profiles that negatively impact fertility.[5] Additionally, emerging research highlights the potential benefits of targeted micronutrients and nutraceuticals, such as omega-3 fatty acids, zinc, selenium, and coenzyme Q10, in specific subgroups including poor ovarian responders and men with compromised semen quality.[6]

Despite expanding evidence base, translating nutritional research into routine fertility care remains challenging due to heterogeneity in study designs, dietary assessment methods, population characteristics, and outcome measures. Moreover, traditional approaches often fail to capture complex, multidimensional interactions between diet, metabolism, lifestyle factors, and reproductive biology.[7] In this context, AI has gained increasing attention as a transformative tool capable of integrating large-scale nutritional, clinical, metabolic, and reproductive datasets. AI-driven models offer the potential to identify hidden patterns, predict fertility outcomes, reduce inter-observer variability, and enable personalized, data-driven nutritional interventions tailored to individual reproductive profiles.[21]

This review aims to comprehensively evaluate recent evidence on the role of nutrition in reproductive health across both sexes, with a focus on fertility, ART outcomes, and underlying biological mechanisms. Furthermore, it explores how the integration of AI with nutritional science may advance precision fertility care by optimizing preconception counseling, enhancing ART decision-making, and bridging the gap between population-level evidence and individualized clinical practice.

NUTRITION AND FEMALE REPRODUCTIVE HEALTH

Female reproductive function is highly sensitive to nutritional status, with diet influencing fertility across the reproductive lifespan from ovulatory function and oocyte quality to implantation, pregnancy maintenance, and obstetric outcomes.[8] Increasing evidence indicates that both overall dietary patterns and specific nutrients play a crucial role in modulating key physiological pathways that govern female fertility, particularly inflammation, oxidative stress, insulin sensitivity, and hormonal regulation.[9] These nutritional influences operate through interconnected biological mechanisms that ultimately affect ovarian and endometrial function. Diets rich in balanced nutrients can reduce oxidative stress and inflammation while improving metabolic regulation and hormonal balance, thereby supporting optimal ovulation and oocyte quality. Improved ovarian function subsequently enhances endometrial receptivity, facilitating successful embryo implantation and healthy pregnancy outcomes.[10] The conceptual framework illustrating the relationship between dietary patterns, physiological mechanisms, and reproductive outcomes Figure 1.

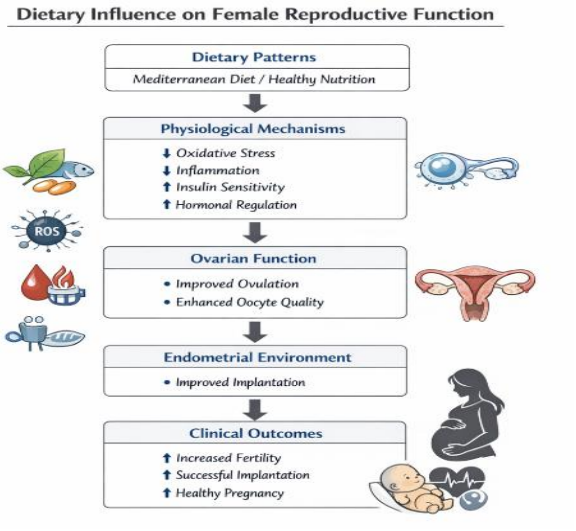

Figure 1: Dietary influence on female reproductive function.

DIETARY PATTERNS AND NATURAL FERTILITY

Observational studies and systematic reviews consistently demonstrate that adherence to healthy dietary patterns, particularly Mediterranean-style and plant-rich diets, is associated with improved fertility outcomes in women. These dietary patterns are characterized by high consumption of fruits, vegetables, whole grains, legumes, nuts, olive oil, and seafood, alongside limited intake of refined carbohydrates, trans fats, and ultra-processed foods.[10] Such diets have been linked to improved ovulatory function, reduced risk of ovulatory infertility, and favorable metabolic profiles, particularly among women with obesity, insulin resistance/ polycystic ovary syndrome (PCOS).[11] The beneficial effects of these dietary patterns are largely mediated through improvements in hormonal regulation, metabolic balance, and ovarian function. Nutrient-rich diets help support optimal endocrine signaling and follicular development, which contributes to improved ovulation and enhanced oocyte quality.[12] In addition, balanced dietary intake promotes endometrial receptivity, facilitating successful embryo implantation and increasing likelihood of healthy pregnancy outcomes. A conceptual overview of relationship between Mediterranean-style dietary patterns, hormonal balance, ovarian function, and fertility outcomes is illustrated in Figure 2.

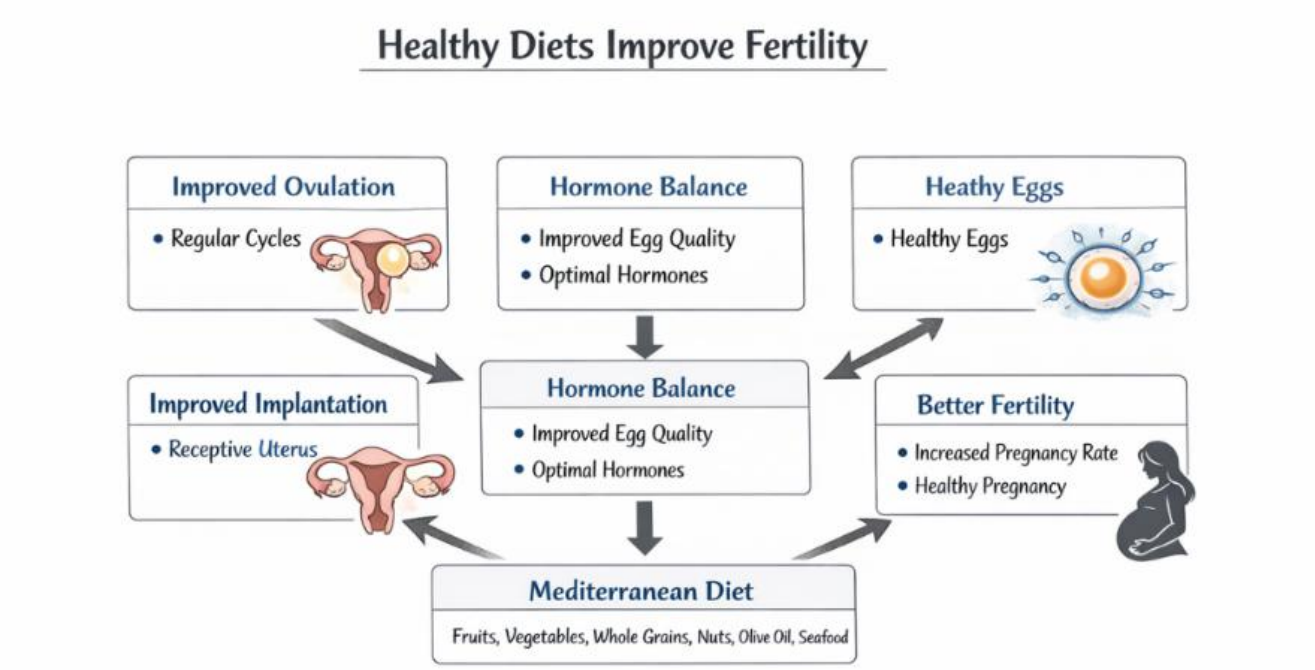

Figure 2: Healthy dietary patterns and female fertility outcomes.

Western-style dietary patterns rich in red and processed meats, refined sugars, saturated fats, and ultra-processed foods are associated with increased systemic inflammation, hormonal dysregulation, and impaired ovarian function. High intake of trans fats and refined carbohydrates has been shown to negatively affect insulin sensitivity and follicular development, thereby reducing natural conception potential.[12]

NUTRITION AND ART OUTCOMES

Beyond natural fertility, nutrition has emerged as an important modifiable factor influencing the success of ART. Several systematic reviews and meta-analyses report that women adhering to Mediterranean or "pro-fertility" dietary patterns prior to and during ART treatment exhibit higher rates of clinical pregnancy and live birth. These benefits are believed to arise from improved oocyte competence, enhanced mitochondrial function, and improved endometrial receptivity, which together contribute to greater implantation success and pregnancy maintenance.[13]

Specific nutrients and nutraceuticals have also gained increasing attention in ART setting. Omega-3 fatty acids have been associated with improved fertilization and pregnancy rates, potentially through anti-inflammatory effects and improved membrane fluidity of oocytes.[14] In addition, micronutrients such as coenzyme Q10, zinc, selenium, and folate have been reported to enhance oocyte maturation, reduce aneuploidy risk, and improve ART outcomes in poor ovarian responders and with PCOS. However, variability in study design, supplementation protocols, and outcome measures highlights importance of individualized nutritional strategies rather than universal supplementation approaches.[15]

Conversely, unhealthy dietary patterns characterized by high consumption of processed foods, refined sugars, red and processed meats, and trans fats may negatively affect reproductive outcomes by promoting inflammation,

oxidative stress, and hormonal dysregulation.[16] These metabolic disturbances can impair follicular development, reduce oocyte quality, and disrupt hormonal balance, ultimately decreasing conception potential and potentially compromising ART success. The mechanistic relationship between unhealthy dietary patterns, hormonal imbalance, reduced egg quality, and decreased fertility outcomes is illustrated in Figure 3.

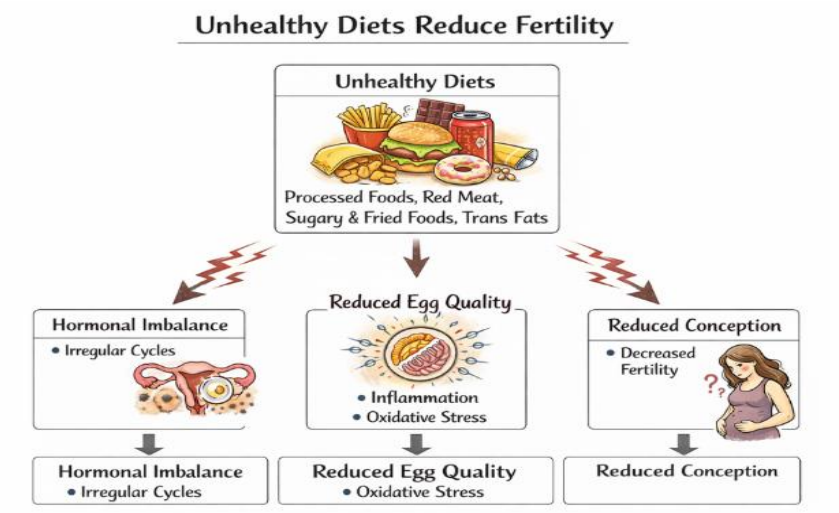

Figure 3: Impact of unhealthy dietary patterns on female fertility.

MECHANISTIC PATHWAYS LINKING DIET AND FEMALE FERTILITY

At the biological level, nutrition influences female fertility through multiple interconnected mechanisms. Diets rich in antioxidants and unsaturated fats help reduce oxidative stress within the ovarian microenvironment, thereby preserving oocyte DNA integrity and maintaining mitochondrial function. Anti-inflammatory dietary components also modulate cytokine signaling and improve endometrial receptivity, which is critical for successful embryo implantation.[16] Furthermore, dietary modulation of insulin sensitivity and lipid metabolism plays an important role in maintaining hormonal balance, particularly in women with metabolic disorders such as PCOS and metabolic syndrome.[11] Specific micronutrients and nutraceuticals contribute to these biological pathways by supporting cellular and metabolic functions involved in reproduction. Nutrients such as omega-3 fatty acids, folate, zinc, selenium, and coenzyme Q10 are known to enhance oocyte maturation, improve mitochondrial activity, and protect developing oocytes from oxidative damage.[12] These mechanisms ultimately contribute to improved egg quality, enhanced fertilization, better implantation potential, and higher success rates in assisted reproductive treatments.[13] The mechanistic relationship between key fertility-related nutrients, oocyte quality, fertilization, implantation, and ART outcomes is illustrated in Figure 4. Epigenetic mechanisms are also increasingly recognized as an important link between maternal nutrition and reproductive outcomes.[17] Nutrient availability can influence DNA methylation, histone modification, and gene expression patterns in oocytes and early embryos, potentially affecting both reproductive success and long-term offspring health.[18]

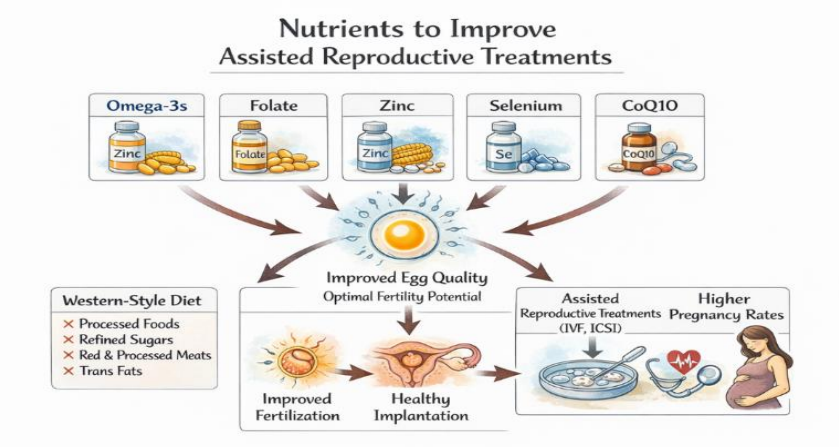

Figure 4: Nutritional mechanisms influencing assisted reproductive outcomes.

NEED FOR PRECISION NUTRITION IN FEMALE FERTILITY CARE

Despite strong associative evidence linking diet and reproductive health, inconsistencies across studies and populations highlight the limitations of one-size-fits-all dietary recommendations. Differences in genetic background, metabolic status, lifestyle factors, and treatment protocols can influence how individuals respond to nutritional interventions, thereby necessitating more personalized nutritional strategies for optimizing fertility outcomes.[19]

Precision nutrition approaches aim to tailor dietary recommendations according to an individual's biological and metabolic characteristics. Factors such as genetic predisposition, metabolic profile, and reproductive health status can influence nutrient utilization, hormonal regulation, and overall reproductive function. In this context, the integration of AI provides a promising tool for analyzing complex datasets that include dietary intake, metabolic markers, genetic information, and reproductive parameters. By integrating these multidimensional data sources, AI-based models can help generate personalized dietary recommendations that optimize fertility potential and improve treatment outcomes.[21] A conceptual framework illustrating the role of genetics, metabolism, AI-assisted dietary planning, and individualized nutrition strategies in improving fertility outcomes is presented in Figure 5.

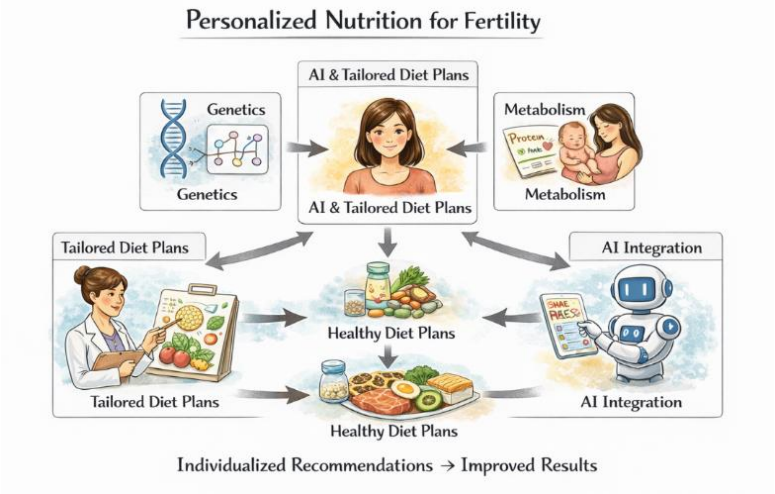

Figure 5: Conceptual framework for precision nutrition in female fertility care.

NUTRITION AND MALE REPRODUCTIVE HEALTH

Male fertility is increasingly recognized as a critical contributor to couple-based reproductive outcomes, accounting for nearly half of all infertility cases either independently or in combination with female factors.[18] Emerging evidence demonstrates that nutrition is a key modifiable determinant of male reproductive health, influencing spermatogenesis, semen quality, hormonal regulation, and sperm DNA integrity. Unlike genetic causes, dietary factors offer a practical avenue for intervention before natural conception or ART.[19] The overall relationship between dietary patterns, mechanistic pathways, key nutrients, and male reproductive outcomes Figure 6.

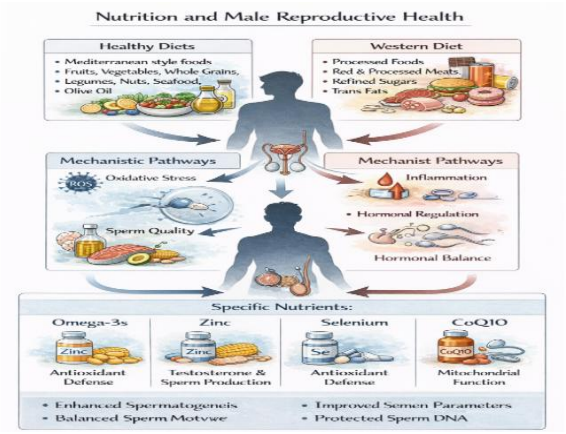

Figure 6: Nutritional influences on male reproductive health.

DIETARY PATTERNS AND SEMEN QUALITY

A substantial body of observational studies and systematic reviews indicates that adherence to healthy dietary patterns is positively associated with semen quality parameters, including sperm concentration, total count, motility, morphology, and vitality.[12] Mediterranean-style and prudent dietary patterns characterized by high intake of fruits, vegetables, whole grains, legumes, nuts, seafood, and unsaturated fats have consistently been linked to superior semen profiles. These benefits are attributed to the antioxidant, anti-inflammatory, and lipid-modulating properties of such diets, which support optimal spermatogenesis and sperm membrane function.[15]

In contrast, Western dietary patterns rich in red and processed meats, refined sugars, saturated fats, and ultra-processed foods have been associated with reduced sperm concentration, impaired motility, abnormal morphology, and increased sperm DNA fragmentation. Ultra-processed foods, in particular, are implicated in endocrine disruption, metabolic dysfunction, and oxidative stress, all of which adversely affect male reproductive hormones and testicular function.[18]

SPECIFIC FOODS AND NUTRIENTS IN MALE FERTILITY

Beyond overall dietary patterns, specific food groups and nutrients have demonstrated fertility-related benefits. Nut consumption, especially when consumed regularly, has been shown to improve sperm concentration, motility, and morphology, likely due to their content of omega-3 fatty acids, antioxidants, and micronutrients. Diets rich in fruits and vegetables provide essential vitamins, polyphenols, and carotenoids that counteract oxidative stress, a major contributor to sperm DNA damage.[12]

Micronutrients and nutraceuticals have also gained attention in male fertility care. Zinc and selenium play essential roles in testosterone synthesis, sperm maturation, and antioxidant defense, while coenzyme Q10 supports mitochondrial energy production and sperm motility.[13] Supplementation with these compounds has been associated with improvements in semen parameters, particularly in men with idiopathic infertility, although effects on pregnancy and live birth outcomes remain less consistently reported.[14]

HORMONAL REGULATION AND METABOLIC HEALTH

Dietary composition influences male fertility not only through direct effects on sperm but also via systemic metabolic and hormonal pathways. Diets high in refined carbohydrates and unhealthy fats are associated with insulin resistance, obesity, and altered hypothalamic-pituitary-gonadal axis signaling, leading to reduced testosterone levels and impaired spermatogenesis. Conversely, balanced diets with adequate healthy fats support steroidogenesis and hormonal equilibrium.[13]

Recent intervention studies suggest that organic, low-carbohydrate Mediterranean-style diets may increase testosterone levels, reduce sperm DNA fragmentation, and mitigate the adverse reproductive effects of environmental pollutants.[14] These findings highlight the interplay between nutrition, metabolism, and environmental exposures in shaping male reproductive potential.

IMPLICATIONS FOR ART AND PRECONCEPTION CARE

Improved semen quality has direct implications for ART outcomes, influencing fertilization rates, embryo development, and potentially offspring health[10]. While some meta-analyses report limited direct effects of male diet on ART pregnancy outcomes, improvements in sperm DNA integrity and motility remain clinically meaningful, particularly in cases of unexplained infertility or repeated ART failure. Importantly, male preconception nutrition also carries intergenerational implications, as paternal diet can influence epigenetic programming in sperm.[12]

TOWARD PERSONALIZED NUTRITION FOR MALE FERTILITY

Despite consistent associations, variability in dietary assessment methods, supplementation regimens, and outcome measures limits the translation of evidence into standardized clinical guidelines. This highlights the need for personalized nutritional strategies tailored to individual metabolic profiles, lifestyle factors, and fertility diagnoses.[20] AI offers a powerful framework to integrate dietary intake data with semen analysis, hormonal profiles, environmental exposures, and ART outcomes. AI-driven models have the potential to identify high-risk dietary patterns, predict treatment response, and guide precision nutrition interventions aimed at optimizing male reproductive health.[21]

AI AS A UNIFYING FRAMEWORK IN NUTRITION FERTILITY RESEARCH

Despite strong biological plausibility and growing clinical evidence, the relationship between nutrition and reproductive health remains complex and highly individualized. Traditional analytical approaches often struggle to account for multidimensional interactions among diet, metabolism, lifestyle, environmental exposures, and reproductive parameters. In this context, AI provides a powerful framework to unify and operationalize nutrition-driven fertility care.[22]

AI-based models can integrate diverse data sources, including dietary intake patterns, biochemical markers, anthropometric measures, semen parameters, ovarian reserve indicators, embryo development metrics, and ART outcomes.[22] Machine learning algorithms are particularly

well suited to identify nonlinear relationships, uncover hidden patterns, and stratify patients according to nutritional risk profiles and predicted fertility outcomes. Such approaches can reduce inter-observer variability, enhance predictive accuracy, and support evidence-based clinical decision-making.[22]

Importantly, AI enables the transition from population-level dietary recommendations to *precision nutrition in fertility care.*

By incorporating individual variability in genetics, metabolism, and reproductive biology, AI-driven systems can generate personalized dietary strategies aimed at optimizing gamete quality, improving ART success rates, and reducing adverse pregnancy outcomes.[22] As fertility medicine increasingly adopts data-driven technologies, the integration of AI with nutritional science represents a critical step toward holistic, personalized, and outcome-focused reproductive care.

METHODOLOGY USED

Study design

This study was conducted as comprehensive literature review synthesizing evidence from systematic reviews, meta-analyses, randomized controlled trials (RCTs), observational studies, mechanistic studies, and expert committee opinions to evaluate the role of nutrition in reproductive health among men and women.

In addition, the methodology was designed to support a conceptual framework for future integration of AI in nutrition-driven fertility research and clinical practice.

Literature search strategy

A structured literature search was performed to identify relevant studies published between January 2021 and January 2026.

Electronic databases including PubMed/MEDLINE, Scopus, Web of Science, and Google Scholar were searched. The search strategy combined Medical Subject Headings (MeSH) terms and free-text keywords related to nutrition and reproductive health.

Inclusion criteria

Peer-reviewed articles published in English, human studies involving male fertility, female fertility, or couples undergoing ART, systematic reviews, meta-analyses, randomized controlled trials, observational studies, mechanistic studies, and authoritative reviews or committee opinions and studies examining dietary patterns, specific foods, nutrients, or nutraceuticals in relation to reproductive outcomes were included in study.

Exclusion criteria

Case reports, editorials, letters to the editor, and conference abstracts without full data, studies lacking reproductive health outcomes, animal-only studies unless directly linked to human reproductive relevance and articles with insufficient methodological transparency were excluded from the study.

NUTRITION AND REPRODUCTIVE HEALTH IN MEN AND WOMEN

To synthesize the available evidence on the relationship between nutrition and reproductive outcomes, key studies evaluating dietary patterns, specific nutrients, and reproductive health indicators in both men and women were systematically reviewed. The selected studies include observational studies, systematic reviews, meta-analyses, and clinical investigations focusing on fertility outcomes such as semen quality, ovulatory function, pregnancy rates, and ART success.

In Table 1, the majority of studies consistently demonstrate that adherence to healthy dietary patterns particularly Mediterranean-style diets rich in fruits, vegetables, whole grains, nuts, seafood, and unsaturated fats is associated with improved reproductive health outcomes in both sexes. In women, these dietary patterns have been linked to improved ovulatory function, enhanced oocyte quality, increased pregnancy rates, and reduced obstetric complications. Similarly, in men, healthy dietary patterns and specific nutrient intake have been associated with improved semen parameters, including sperm concentration, motility, morphology, and reduced DNA fragmentation.

Conversely, Western-style dietary patterns characterized by high intake of refined sugars, red and processed meats, trans fats, and ultra-processed foods have been associated with adverse reproductive outcomes. These dietary patterns contribute to oxidative stress, metabolic dysfunction, and hormonal dysregulation, which negatively affect spermatogenesis in men and ovarian function in women.

Several studies also highlight the role of specific micronutrients and nutraceuticals including omega-3 fatty acids, zinc, selenium, folate, and coenzyme Q10 in supporting reproductive function.

These nutrients contribute to antioxidant defense, mitochondrial function, hormonal regulation, and gamete quality.

9However, variability in study design, population characteristics, and supplementation protocols indicates the need for further well-designed randomized controlled trials to establish standardized nutritional recommendations for fertility care.

Table 1: Studies examining the relationship between dietary patterns, nutritional factors, and reproductive health outcomes in men and women.

Study (in year)	Focus	Nutritional /diet factor	Findings in reproductive health
Gaskins et al (2022)[1]	ART couples	Preconception dietary patterns	Higher adherence to Mediterranean/profertility diets associated with increased clinical pregnancy (RR 1.22) and live birth (OR 1.98 in meta-analysis subset); inconsistent overall due to bias risks.
Budani and Tiboni (2023)[2]	Female	Overall nutrition and IVF	Nutrition as modifiable factor; balanced diets/antioxidants improve female fertility and IVF outcomes, but more RCTs needed.
Fontana et al (2024)[3]	Male	Nut consumption (≥60 g/day)	Daily nut intake improves semen quality (concentration, motility); simple strategy for male fertility enhancement.
ASRM Committee (2022)[4]	ART couples	Healthy diets (e.g., low-glycemic, high plant-based)	Healthy patterns (seafood, whole grains, fruits/veggies) linked to better semen quality in men and reduced ovulatory infertility in women.
Skoracka et al (2021)[5]	Female	Mediterranean-style, fiber/omega-3 rich	High trans fats/refined carbs impair; Mediterranean diets enhance female fertility via reduced inflammation and better ovarian function.
Ricci et al (2025)[6]	Male	Mediterranean diet adherence	Positive association with sperm count, total/progressive motility, morphology; limited effect on overall MAR outcomes.
Nassan et al (2023)[7]	Female	Mediterranean diet over lifespan	Reduces gestational diabetes (RR 0.74), preterm birth (RR 0.45), hypertension; suggestive benefits for fertility and menopausal symptoms.
Chiu et al (2022)[8]	ART couples	Healthy patterns (fruits, veggies, nuts, low-fat dairy)	Positive for semen quality (men) and fertility/obstetric outcomes (women); highlights intergenerational gaps.
Salas-Huetos et al (2025)[9]	ART couples	Balanced diet, nutraceuticals, low-glycemic	Fruits/veggies/vitamins reduce oxidative stress; processed/trans fats harm fertility in both sexes.
Gaskins et al (2022)[10]	Male	Low-fat/high-carb vs balanced	Context-specific: balanced fats optimize sperm quantity/quality in models, relevant to human male fertility.
Panth et al (2023)[11]	Male	Fruits/veggies, whole grains, nuts, seafood	Improves sperm quality; avoid red/processed meats and sweets for better male reproductive health.
Montano et al (2023)[12]	Male	Low-carb organic Mediterranean	Increases testosterone, reduces sperm DNA fragmentation; counters pollutant effects.
Karayiannis et al (2024)[13]	Male	Mediterranean diet score	High adherence improves semen concentration, count, motility, morphology.
Zhang et al (2024)[14]	Female	Omega-3 supplements/diets	Improves pregnancy (OR ~1.74) and fertilization rates in women; high heterogeneity noted.
Ricci et al (2025)[15]	Female	Micronutrients (e.g., CoQ10)	Boosts oocyte maturation, pregnancy rates, reduces aneuploidy in poor responders/PCOS.
Barrès et al (2025)[16]	Male	Ultra-processed foods avoidance	Ultra-processed impair reproductive hormones/metabolism; unprocessed diets preserve male fertility.
Hanson et al (2025)[17]	Male	Balanced nutrition vs poor diets/pollution	Mitigates environmental risks to male fertility in Western Pacific populations.
Eslamian et al (2025)[18]	Male	Mediterranean vs Persian diet	Both improve semen parameters and sexual function; MD enhances count/motility/morphology.
Michaelsen et al (2026)[19]	Male	Specific supplements (zinc, selenium, CoQ10)	Targeted supplements improve sperm parameters; calls for larger trials with pregnancy outcomes.
Chavarro et al (2022)[20]	ART couples	Overall prudent diets	Consistent evidence: Mediterranean/plant-rich diets benefit semen quality (male) and reduce gestational risks/ enhance IVF in female.

EVIDENCE SYNTHESIS OF INCLUDED STUDIES

Following the methodological framework, the studies summarized in Table 1 collectively demonstrate a consistent relationship between nutritional quality and reproductive health outcomes in both men and women. Rather than emphasizing individual findings, this synthesis highlights key trends and clinical implications emerging from the aggregated evidence.

A major observation is the stronger benefit associated with overall dietary patterns rather than isolated nutrient supplementation**.** Across male, female, and couple-based populations, diets rich in plant-based foods, healthy fats, and minimally processed ingredients show more consistent associations with improved reproductive outcomes. This suggests that fertility is influenced by cumulative dietary exposure and metabolic balance rather than short-term supplementation. In women, nutritional factors are primarily associated with improvements in ovarian function, oocyte quality, implantation, and pregnancy outcomes. In men, dietary patterns more directly influence semen parameters, hormonal regulation, and sperm DNA integrity. Together, these findings highlight the importance of couple-based nutritional strategies, particularly in ART settings. The evidence also indicates that poor dietary quality**,** especially diets high in ultra-processed foods, trans fats, and refined carbohydrates, negatively affects reproductive health through mechanisms such as oxidative stress, metabolic dysfunction, and hormonal imbalance. Conversely, adherence to healthy dietary patterns may mitigate environmental and metabolic stressors.[21] Despite growing evidence, nutritional counseling remains underutilized in fertility care. Individual variability in metabolic status and reproductive conditions further emphasizes the need for personalized nutritional approaches**.** Advanced analytical tools, including AI, may help integrate complex dietary and clinical data to support precision nutrition strategies in fertility and ART care.[22]

TRANSLATIONAL CHALLENGES AND EMERGING ROLE OF AI IN REPRODUCTIVE NUTRITION

Despite growing evidence linking nutrition with reproductive health, several challenges limit its integration into routine fertility care. Clinical implementation is constrained by limited consultation time, lack of standardized dietary assessment tools, variability in patient adherence, and insufficient training in nutritional counseling among fertility specialists.[10] In addition, most existing evidence derives from observational studies with heterogeneous methodologies, self-reported dietary assessments, and diverse reproductive endpoints, which restrict causal inference and complicate cross-study comparisons.[11] Variability in study populations including differences in age, metabolic status, infertility diagnoses, lifestyle factors, and ART protocols further limits generalizability, while many studies focus primarily on intermediate markers such as semen quality or hormonal profiles rather than definitive clinical outcomes like live birth rates. Addressing these limitations will require standardized nutritional assessment methods, well-designed randomized controlled trials, and couple-based research frameworks that consider the combined reproductive health of both partners. In this context, AI offers a promising approach for managing complex, multidimensional datasets by integrating dietary intake, metabolic markers, hormonal profiles, and reproductive outcomes to generate predictive insights and support precision nutrition strategies.[22] Future research should therefore prioritize integrative, data-driven approaches and implementation-focused studies to translate nutritional evidence into practical, personalized fertility care.

DISCUSSION

This review reinforces nutrition as a key, modifiable determinant of reproductive health in both men and women. Across diverse study designs, healthy dietary patterns particularly Mediterranean and plant-rich diets consistently align with improved gamete quality, hormonal balance, and fertility-related outcomes, whereas poor-quality, ultra-processed diets are linked to reproductive dysfunction. In women, nutritional quality primarily influences ovarian function, oocyte competence, implantation, and pregnancy health, while in men it is reflected more directly in semen parameters, testosterone levels, and sperm DNA integrity. These parallel effects highlight the importance of couple-based nutritional strategies**,** especially in ART settings.[10]

Notably, dietary interventions show stronger and more consistent effects on intermediate biological markers than on downstream endpoints such as live birth. This likely reflects methodological heterogeneity and limited statistical power rather than limited biological relevance, as improvements in gamete quality are fundamental to reproductive success. Despite growing evidence, translation into routine fertility care remains limited. Here, AI offers a practical solution by integrating complex nutritional, metabolic, and reproductive data to enable personalized dietary guidance and predictive fertility modelling.[22] Together, evidence-based nutrition and AI-driven analytics represent a powerful pathway toward precision fertility care, bridging the gap between research and clinical practice.

CONCLUSION

Accumulating evidence demonstrates that nutrition is a foundational, modifiable determinant of reproductive health in both men and women, influencing gamete quality, hormonal regulation, pregnancy outcomes, and ART success. Healthy dietary patterns particularly Mediterranean and plant-rich diets consistently confer reproductive benefits, while poor-quality diets characterized by ultra-processed foods and unhealthy fats impair fertility potential. Despite these advances,

heterogeneity in study design and individual response highlights the limitations of generalized dietary recommendations. The integration of artificial intelligence with nutritional and reproductive data offers a powerful pathway toward precision fertility medicine, enabling personalized risk assessment, targeted dietary interventions, and optimized clinical decision-making. By aligning evidence-based nutrition with AI-driven analytics, future fertility care can evolve into a more holistic, data-informed, and outcome-focused paradigm that enhances reproductive success and long-term health across generations.

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