Investigating the association between dietary patterns and male reproductive health: a meta-analysis

Nguyen Thanh Tung[1,*], Tran Thi Thanh Mai[1], Truong Thi Phuong Lan[1]
(1) Regenerative Medicine Group, Faculty of Basic Science, University of Medicine and Pharmacy, Hue University

Abstract

Background: Male reproductive health has experienced a substantial global decline. This meta-analysis was conducted to investigate the influence of different dietary patterns on male reproductive function based on semen parameters, sperm DNA fragmentation, and sex hormones. **Methods:** The effects of dietary patterns on male reproductive health were examined by conducting a literature search of the PubMed, Science Direct, Google Scholar, and Web of Science databases using relevant keywords. The data extracted from the studies were analyzed using Random-Effects Models in STATA software, and the standard mean difference (SMD) was used to compare the groups with high and low intakes of each dietary pattern. Publication bias was assessed using Egger's test. **Results:** The meta-analysis revealed a significant difference between healthy and unhealthy diets in terms of total sperm count, with the former showing a higher count (SMD, 0.30; 95% CI, -0.53 to 1.12). However, no significant differences were observed between healthy and unhealthy diet patterns in other semen parameters such as semen volume, sperm concentration, progressive motility, total motility, normal morphology, abnormal morphology, sperm defects, and DNA fragmentation index. This study indicated that healthy dietary patterns had a positive effect on enhancing SHBG levels (SMD, 1.48; 95% CI, 0.25 to 2.71). Additionally, the data showed that eating patterns did not significantly affect Testosterone, Estradiol, FSH, and Inhibin B levels. **Conclusion:** The relationship between dietary patterns and male reproductive function is complex, with food intake directly affecting both the total sperm count and sex hormone-binding globulin levels. This scientific evidence serves as a foundation for future research on diets that promote male fertility.

Keywords: *dietary pattern, semen quality, male reproductive hormone, fertility.*

1. INTRODUCTION

Infertility refers to the failure to conceive after one year of regular and unprotected sexual intercourse [1]. It affects approximately 15% of couples [2]. Infertility can impose a significant burden on partners, leading to emotional stress, psychological distress, and financial strain. The inability to reproduce can disrupt the sense of personal identity, cause depressive symptoms, and negatively impact the self-esteem and intimate relationships of couples [3].

Male infertility is defined as the inability of a male partner to contribute to conception or achieve a successful pregnancy with a female partner [4]. Male infertility can arise from both intrinsic and extrinsic factors. Endogenous factors include anatomy, physiology, and genetics, whereas exogenous conditions are attributed to smoking, alcohol intake, adjustment of sexual behaviors, and diet [5].

Semen quality and sex hormone levels play pivotal roles in achieving conception and successful breeding, which are vital for enhancing reproductive health outcomes and maintaining population quality [6]. In the past five decades, Carlsen et al. demonstrated a universal downward trend in sperm count and seminal volume universally [7]. Therefore, there has been increasing interest in investigating the reversible factors that contribute to the deterioration of male reproductive ability in recent years [8-10].

Diet and nutrition are among several modifiable factors that have a significant impact on male hormones and seminal parameters [11]. Therefore, numerous studies have explored the effects of dietary consumption on male fecundity to identify effective measures to enhance male reproductive potential [12, 13].

Humans do not rely on a single type of food item, and a handful of studies have been conducted on daily food consumption to determine its association with male reproductive function [14-22]. In addition to these individual studies, a meta–analysis was conducted to determine whether different dietary patterns can determine male reproductive potential [23]. However, the outcomes on this topic are

Corresponding author: Nguyen Thanh Tung;
Email: nguyenthanhtung@hueuni.edu.vn or nttung@huemed-univ.edu.vn
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inconsistent and the overall effect of different dietary patterns on male fertility remains unclear. Therefore, this meta-analysis aimed to elucidate the correlation between dietary patterns and male fecundability, including sperm parameters, sperm quality, and male reproductive hormones.

2. METHODS

2.1. Search strategy and identification of relevant studies

The search methodology for this meta-analysis followed the Preferred Reporting Items for Systematic Review and Meta-analysis (PRISMA) statement and the PICO model. This study focuses on scientific publications available in databases that uncover the association between eating patterns and male reproductive health indices, such as semen parameters, sperm DNA fragmentation, and sex hormone levels. The studies were searched from PubMed, Science Direct, Google Scholar, and Web of Science using the keywords "dietary pattern", "dietary habits", "eating patterns", "diet type", and "diet" combined with "'semen quality", "sperm quality", "sperm parameters", "sperm volume", "sperm concentration", "sperm count", "sperm motility", "sperm morphology", "sperm motion", and "male fertility".

2.2. Inclusion and exclusion criteria

This meta-analysis considered studies that met the following eligibility criteria: (a) examined the association between dietary patterns and semen quality and sex hormones; (b) included both case and control groups; (c) were observational studies; and (d) were written in English. Certain articles were excluded from our review list for the following reasons: (a) they were reviews, case reports, or conference summaries; (b) they lacked original data or were not related to our research topic; and (c) they did not provide any relevant data concerning eating patterns and sperm parameters.

2.3. Collect data for analysis

Details gathered from each study included the following: first author's name, year of publication, country of origin, mean age, participants' health status, size of the study group, data on dietary patterns, and seminal indices including semen volume, concentration, sperm motility, normal morphology, abnormal morphology, sperm count, sex hormone levels, and DNA fragmentation index (DFI). Indicator values are presented as either means and standard deviations or medians and interquartile ranges (IQR). If the data are presented as medians and IQR, they need to be converted into means and standard deviations before the meta-analysis.

2.4. Definition of healthy and unhealthy dietary patterns

Dietary patterns were classified using principal component or factor analysis. The lowest and highest categories indicated low and high intakes for each dietary pattern, respectively. Six common dietary patterns were identified in this study. The first pattern was a healthy/prudent diet characterized by a high intake of fruits, vegetables, whole grains, legumes, fish, low-fat dairy products, and poultry [16-18]. The second pattern was an unhealthy Western pattern, which was rich in high-fat dairy products, processed meat, refined grains, sweets, desserts, and French fries [14-18, 20]. The third pattern is a healthy/Mediterranean diet characterized by high consumption of fruits, vegetables, whole grains, seafood, nuts, legumes, and olive oil; moderate intake of fish, poultry, and wine; and low consumption of processed meat, dairy products, and sweets [14, 19, 21]. The fourth pattern was a healthy/health-conscious dietary pattern that included an abundance of fruits, vegetables, fish, and whole cereals [22]. The fifth was an unhealthy/traditional Dutch diet characterized by a high intake of meat, potatoes, and whole grains and a low intake of drinks and sweets [22]. The sixth pattern was a healthy/pro-healthy diet that incorporated a wide variety of fruits, vegetables, legumes, whole grains, juices, and nuts [15].

Due to variations among the included studies, we categorized them into two groups: healthy and unhealthy dietary patterns. The Western and traditional Dutch were placed in the unhealthy group because of their shared characteristics of high consumption of fatty food and meat products, as well as low intake of fruits. On the other hand, prudent, Mediterranean, health-conscious, and pro-healthy diets were considered healthy.

2.5. Statistical analysis

This meta-analysis was conducted using the Stata SE version 15 software (Stata Corp, College Station, TX, USA). Random-effects models with 95% confidence intervals (CI) were used to analyze the mean effects of eating patterns on sperm parameters. Heterogeneity between studies was assessed using the heterogeneity index I-squared. The inverse variance method was used to pool the mean differences. If the provided data were in the form of medians and IQS, these measurements were converted to mean and standard deviation (SD) using a formula [24]. Egger's test and funnel plots were employed to evaluate the publication bias of the selected articles. The process of selecting the final full-text articles from the list of relevant articles for meta-analysis was conducted independently by two authors.

3. RESULTS

3.1. Characterization of eligible studies

Through an online search, we identified 1780 studies. The procedure for selecting the papers for this meta-analysis is shown in Fig. 1. After an initial screening of titles and abstracts, we eliminated 1368 articles because they were case reports or did not provide complete data. The assessment process continued for 412 full-text articles, of which 403 were eliminated owing to duplicate publications, review papers, in vitro studies, studies presenting data only graphically, missing data, or studies that did not provide relevant data. The nine articles included in this meta–analysis involved two different dietary patterns: healthy and unhealthy. We evaluated dietary patterns and their effects on male fertility, focusing on semen parameters, sperm quality, and sex hormones, including sperm volume (6 studies), concentration (15 studies), total sperm count (6 studies), progressive motility (13 studies), total motile sperm (7 studies), normal morphology (11 studies), abnormal morphology (4 studies), DNA fragmentation (4 studies), testosterone (6 studies), estradiol (4 studies), FSH (4 studies), inhibin B (4 studies), and SHBG (4 studies).

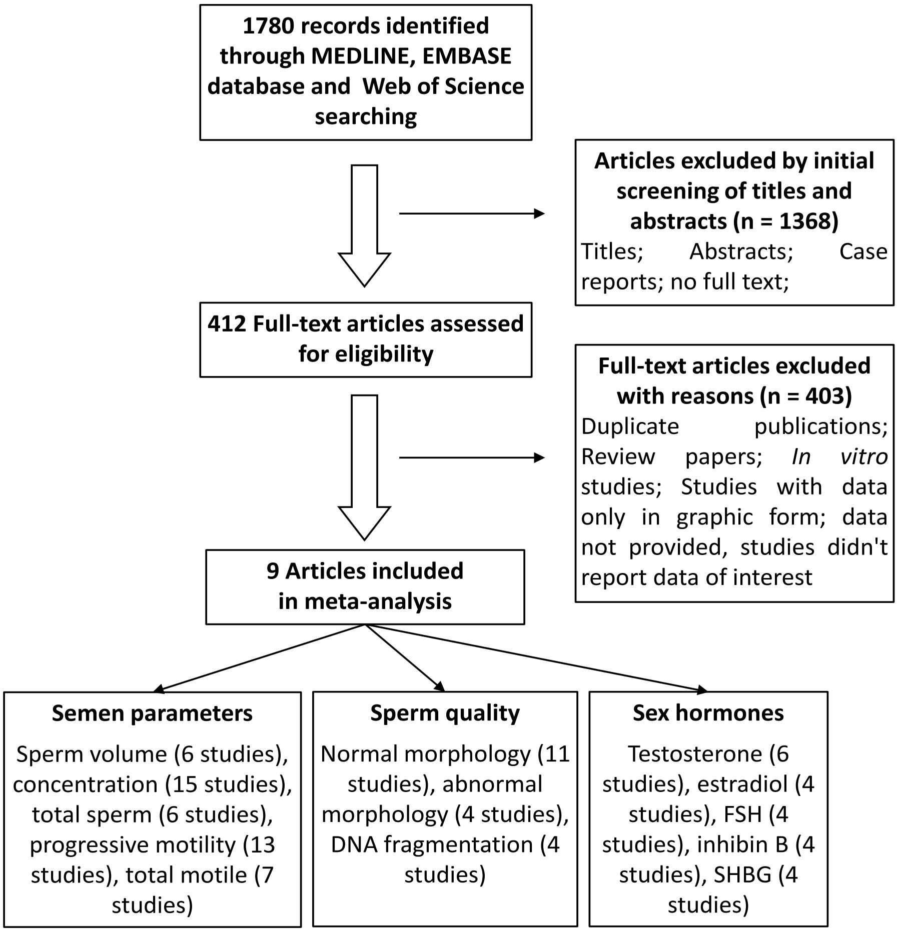


Figure 1. Selection process of articles for meta-analysis

Overall, nine articles involving 3466 male participants were investigated in our meta-analysis. Among the nine selected articles, seven were conducted in Europe, including two originating from Spain [14, 21], three from Poland [15, 17, 18], and the others in the Netherlands [22] and Greece [19]. Only one study was conducted in the United States [16], while the other was conducted in Asia, specifically in Taiwan [20] (Table 1).

3.2. Association between dietary patterns and semen parameters

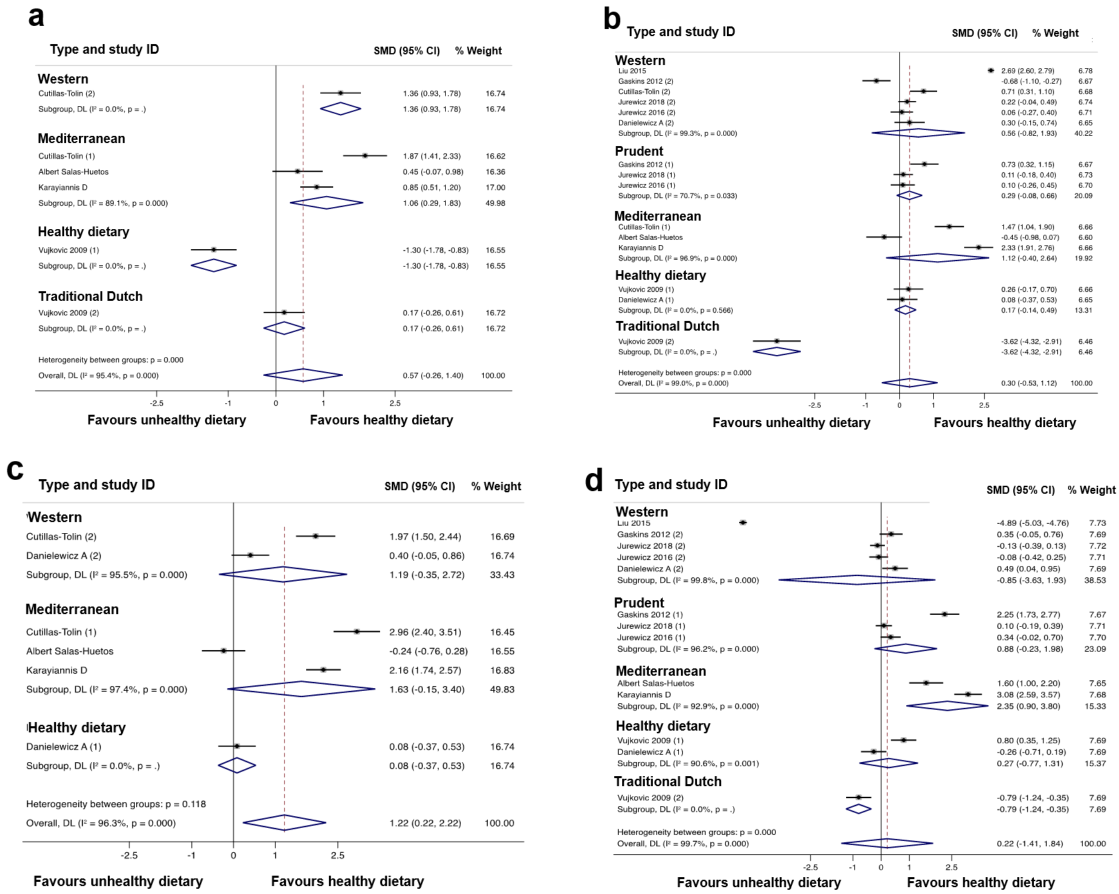
The effects of dietary patterns on semen parameters analyzed across 15 studies, including 3466 male adults and five diets, are shown in Figure 2. Fig.2a illustrates an analysis of the impact of food consumption on semen volume, encompassing six studies (573 men) divided into four diets. The studies were analyzed using a random-effects model. The difference between studies was large, with an I-squared heterogeneity index of 95.4%. Each study was weighed (%weight) from 16.36 to 49.98. The overall results from the four dietary patterns (Western, Mediterranean, Healthy dietary, and Traditional Dutch) showed no significant correlation between diet and sperm volume (standard mean difference or SMD 0.57; 95% CI, -0.26 to 1.40). There was no publication bias, with a p-value of 0.613 (Fig.2f).

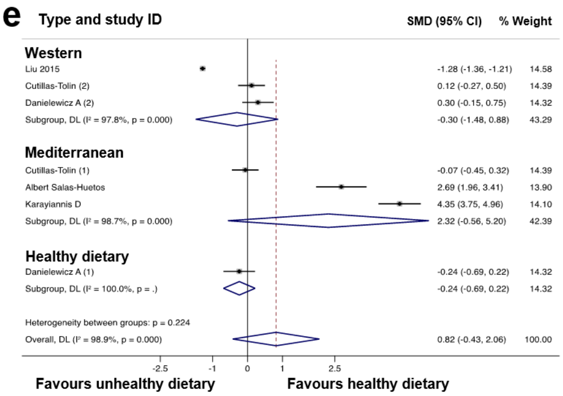
The effect of dietary patterns on sperm concentration, including 15 studies (3466 men) with five diets (Western, Prudent, Mediterranean, Healthy dietary, and Traditional Dutch), is shown in Fig.2b. Evidence of heterogeneity was observed among the effect sizes of the included studies with an I-squared index of 99.0%. Each study was weighed (%weight) from 6.46 to 40.22. The results showed no significant difference between healthy and unhealthy diets in terms of sperm concentration (SMD 0.30; 95% CI, -0.53 to 1.12). Publication bias was found, with a p-value of 0.001 (Fig.2f).

The total sperm count refers to the total number of sperm present in the entire ejaculate. The association between the total sperm count and eating patterns across the six studies (525 men) is shown in Fig.2c. There was heterogeneity among the effect sizes of the relevant studies with the I-squared index being 96.3%. Each study was weighed (%weight) from 16.45 to 49.83. Compared to those with the lowest adherence to a healthy diet, individuals with the highest adherence had significantly higher total sperm counts (SMD 1.22; 95% CI, 0.22 - 2.22). No publication bias was found, with a p-value of 0.833 (Fig.2f).

Sperms are motile cells and sperm movement plays an important role in fertilization. Progressive motility refers to normal sperm movement toward the egg through the female reproductive tract. Thirteen studies recruited 3257 males (Fig.2d), representing the relationship between dietary intake and progressive sperm motility. There was an indication of heterogeneity between the effect sizes of the recruited studies with an I-squared index of 99.7%. Each study was weighed (%weight) from 7.67 to 38.53. According to the meta-analysis, no significant difference in the percentage of progressive sperm motility was found between unhealthy and healthy patterns (SMD 0.22; 95% CI, -1.41 to 1.84). There was evidence of publication bias with a p-value of 0.001 (Fig.2f).

Total motile sperm is related to the total number of sperm in a semen sample, including progressive sperm and sperm motility. Seven studies involving 3950 men assessed the association between different diets and motility (Fig.2e). There was evidence of heterogeneity among the effect sizes of the included studies (I^2 = 98.9%). Each study was weighted (%weight) from 13.90 to 43.29. The results indicate that dietary patterns did not have a significant impact on this sperm parameter regardless of healthy or unhealthy diet (SMD 0.82; 95% CI, -0.43 to 2.06). P for bias = 0.021 indicated publication bias (Fig.2f).





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Egger's publication bias

Outcomes	No. of studies	Egger's test *t*	*P* for bias
Semen volume	6	-0.55	0.613
Concentration	15	-4.49	0.001
Total sperm count	6	0.23	0.833
Progressive motility	13	6.55	0.001
Total motile	**7**	3.31	0.021

Figure 2. The association between diets and semen parameters

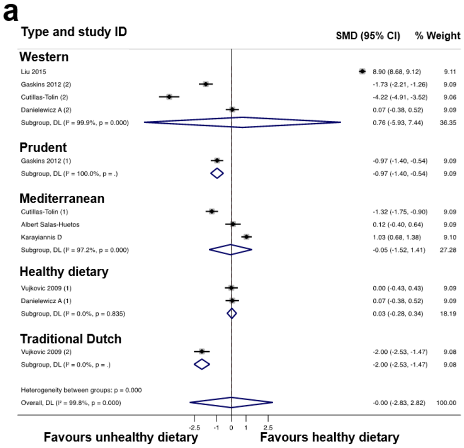
Forest plot showing the effect of diet on semen volume (**a**), sperm concentration (**b**), total sperm count (**c**), progressive motility (**d**), and total motility (**e**). Evaluating publication bias among studies by Egger publication bias plot (**f**)

3.3. Association between dietary pattern and sperm quality parameters

The association between dietary patterns and sperm quality parameters is shown in Fig. 3. The studies were analyzed based on the random-effects model. Fig.3a shows the correlation between eating patterns and normal sperm morphology in 11 studies (2772 men). There was heterogeneity among the effect sizes of the relevant studies, with an I-squared index of 99.8%. Each study was weighted (%weight) from 9.06 to 36.35. No significant difference in the percentage of normal sperm morphology was found between individuals who consumed healthy and unhealthy diets (SMD, -0.48; 95% CI, -1.44 to 0.47). There was evidence for publication bias, with p for bias of 0.001 (Fig. 3d).

Abnormal morphology might affect the ability of sperm to reach and fertilize an egg. Four relevant studies (694 men) evaluated whether unhealthy dietary patterns resulted in an increased percentage of abnormal morphology (Fig. 3b). There was no evidence of heterogeneity among the effect sizes of the relevant studies with an I-squared index of 0.0%. Each study was weighted (%weight) from 18.01 to 54.23. The results showed that unhealthy diets did not increase the percentage of abnormal sperm morphology compared to healthy diets (SMD -0.03; 95% CI, -0.18 to 0.12). The results indicated no evidence of publication bias (p = 0.860) (Fig. 3d).

a



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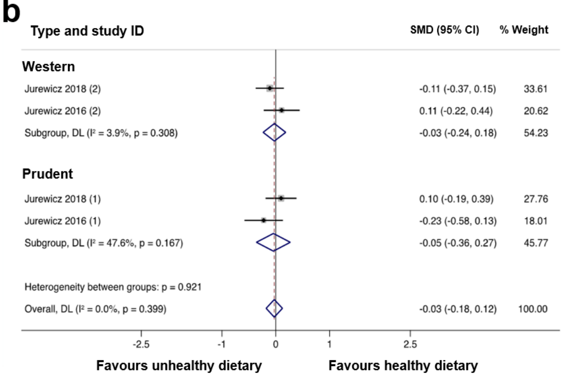

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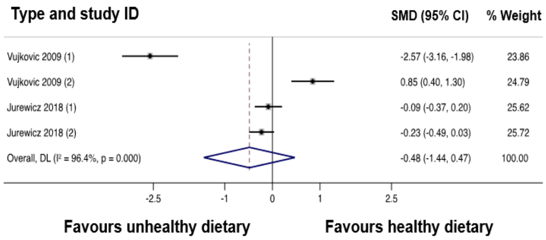


d

Egger's publication bias

Outcomes	No. of studies	Egger's test *t*	*P* for bias
Normal morphology	11	-7.62	0.001
Abnormal morphology	4	-0.20	0.860
DNA fragmentation	4	-0.80	0.509

Figure 3. The association between diets and sperm quality parameters

Forest plot showing the effect of diet on normal morphology (**a**), abnormal morphology and sperm defects (**b**), and the DNA fragmentation index (**c**). Evaluating publication bias among studies by Egger publication bias plot (**d**)

The sperm DNA fragmentation index (DFI) refers to the damage to the DNA of sperm cells, which could potentially lead to difficulties in fertilization or an increased risk of miscarriage. Four studies involving 591 men investigated the association between dietary patterns and DFI (Fig.3c). There was no evidence of heterogeneity among the effect sizes of the relevant studies with an I-squared index of 96.4%. Each study was weighed (%weight) from 23.86 to 25.72%. Regardless of dietary pattern, the results showed no significant variation in sperm DFI (SMD -0.48; 95% CI, -1.44 to 0.47). There was no evidence of publication bias (p = 0.509) (Fig. 3d).

3.4. Association between dietary patterns and sex hormone levels

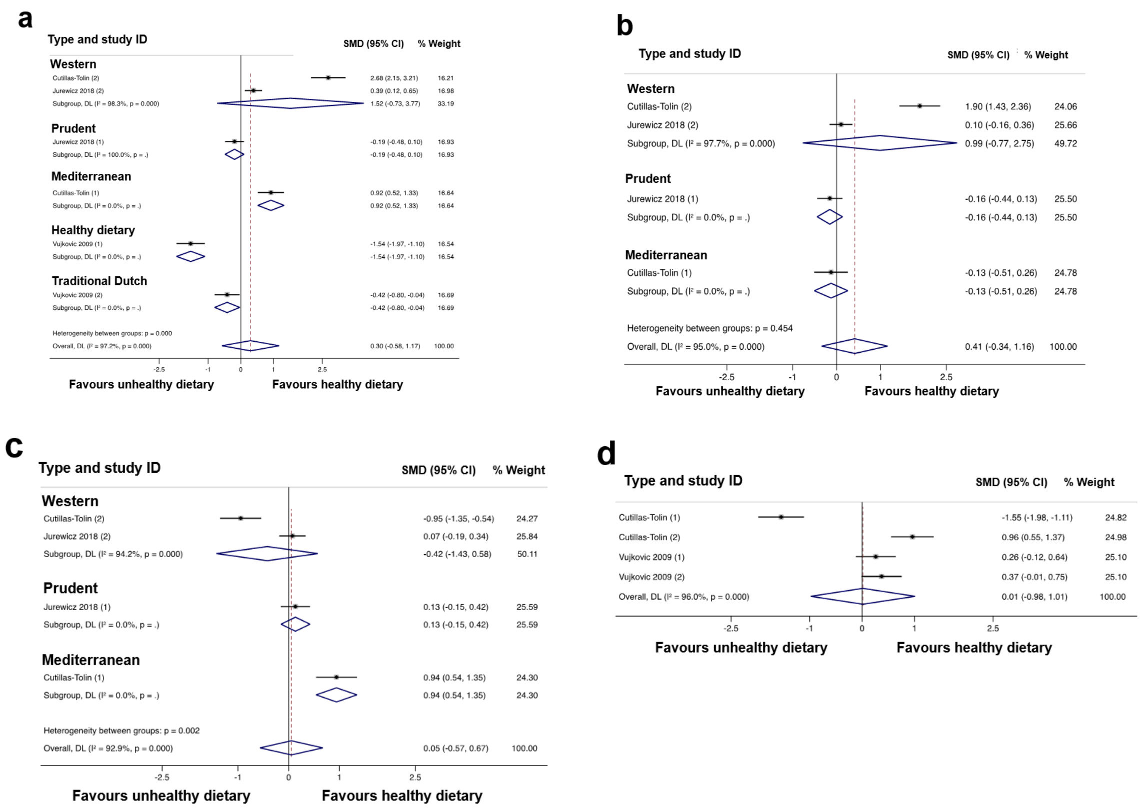
The association between dietary patterns and reproductive hormone levels is shown in Figure 4. All the included studies were analyzed using a random-effects model. The analytical outcomes of 848 men from six studies on the influence of diet on testosterone levels are shown in Fig.4a. The findings from the included studies showed considerable diversity, with a heterogeneity index of 97.2%. Each study was weighed (%weight) from 16.21 to 33.19. The findings suggested that eating patterns had no significant impact on testosterone levels, regardless of whether the patterns were healthy or unhealthy (SMD: 0.30; 95% CI, -0.58 to 1.17). The results showed no publication bias, with a p-value of 0.546 (Fig. 4f).

Fig.4b presents the findings on the relationship between dietary patterns and estradiol levels, recruiting four studies with 635 male adults. There was evidence of heterogeneity with an I-squared index of 95.0%. Each study was weighted (%weight) from 24.06% to 49.72%. The outcomes imply that individuals in healthy diets did not exhibit significantly higher levels of estradiol compared to those in unhealthy diets (SMD 0.41; 95% CI, 24.06 to 49.72). The results showed no publication bias, with a p-value of 0.271.

The investigation of dietary patterns and their effects on follicle-stimulating hormone (FSH) levels, which involved four studies (635 men), is shown in Fig.4c. There was evidence of heterogeneity, with an I2 value of 92.9%. Each study was weighed (%weight) from 24.27 to 50.11. Compared with those who had the highest adherence to healthy diets, individuals who adhered to unhealthy diets showed no considerable difference in FSH levels (SMD 0.05; 95% CI, -0.57 to 0.67). The findings showed no publication bias, with a p-value of 0.915.

The relationship between eating patterns and inhibin B levels, including 422 participants across the four studies, is shown in Fig.4d. The heterogeneity among the effect sizes of the analyzed studies was large (96.0 %). Each study was weighed (%weight) from 24.82 to 25.10. The results suggested that there was no clear correlation between food consumption and FSH levels (SMD 0.01; 95% CI, -0.98 to 1.01). The results showed no publication bias, with a p-value of 0.279.

The results of a survey of 422 men across four studies on sex hormone-binding globulin (SHBG) are presented in Fig.4e. There was evidence of heterogeneity among the effect sizes of relevant studies, with an I-squared index of 96.7%. Each study was weighed (%weight) from 24.69 to 25.26. The results showed that healthy dietary patterns had a positive impact on enhancing SHBG levels (SMD, 1.48; 95% CI, 0.25 to 2.71). There is evidence for publication bias, with a p-value of 0.032.



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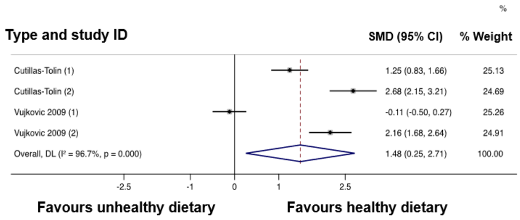

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Egger's publication bias			
Outcomes	No. of studies	Egger's test *t*	*P* for bias
Testosterone	6	0.66	0.546
Estradiol	4	1.51	0.271
FSH	4	-0.12	0.915
Inhibin B	4	-1.47	0.279
SHBG	4	5.41	0.032

Figure 4. The association between diets and sex hormones

Forest plot for the effect of diet on total Testosterone (**a**), Estradiol (b), FSH (**c**), Inhibin B (**d**), and SHBG (**e**). Evaluating publication bias among studies by Egger publication bias plot (**f**)

4. DISCUSSION

Several observational cross-sectional studies have focused on the association between dietary patterns and the male reproductive potential. There is a contradiction in the conclusions regarding the effects of unhealthy dietary patterns on male reproductive ability. Males with the highest adherence to unhealthy diets, including Western and traditional Dutch dietary styles, which mainly consisted of red meat and unhealthy fat, showed inconsistent results regarding semen parameters. Liu et al 2015, Cutillas Tolin et al 2015, Danielewicz et al 2018 concluded that an unhealthy diet was associated with the deterioration of seminal quality [14, 15, 20]. In contrast, Gaskins et al. (2012) and Jurewicz et al. (2016) reported no statistically significant differences in sperm concentration, motility, or morphology [16, 17].

In our study, men with the highest level of healthy food consumption, which had considerable amounts of fruit, vegetables, whole grains, fish, and legumes, did not exhibit significantly higher levels of semen volume, sperm concentration, progressive motility, total motility, normal morphology, abnormal morphology, sperm defects, or DNA fragmentation index. However, the results showed that healthy dietary patterns had a positive impact on the total sperm count. Regarding sex hormones, the findings suggested that eating patterns had no significant impact on Testosterone, Estradiol, FSH, and Inhibin B levels. Individuals with the highest adherence had significantly higher SHBG levels than those with the lowest adherence to a healthy diet.

High adherence to healthy diets resulted in considerable differences in the health index. Lopez, D.S., et al. show that the Prudent diet was shown to contribute to lower T levels and higher SHBG levels among obese men [25]. Sex hormone-binding globulin (SHBG) is a protein that binds tightly to three sex hormones found in both men and women: testosterone, dihydrotestosterone, and estradiol. SHBG regulates the levels of these hormones in the blood stream. Imbalances in SHBG levels may negatively affect male fertility [26].

The Mediterranean diet increases healthy ingredients, such as fish, vegetables, tubers, fruits, beans, and whole grains, and has attracted considerable attention because of its role in cognition and mental health. Several studies have revealed that higher consumption of this diet is associated with a 13% reduced risk of Alzheimer's and Parkinson's diseases [27]. Moreover, it lowers the vulnerability to mild cognitive impairment and progression to Alzheimer's [28].

Unhealthy diets have been shown to contain pro-inflammatory properties, which are potentially unfavorable indicators of asthenozoospermia risk [29]. Attaman et al. (2012) found that a high intake of dairy fats was inversely related to total sperm count and sperm concentration [30]. Additionally, a Spanish study showed that frequent intake of saturated fats was negatively related to sperm quality [31]. In contrast, Vujkovic et al. (2009) demonstrated that a Traditional Dutch diet (high in meat products) was positively correlated with sperm concentration [22]. Therefore, further research investigating the relationship between daily fat intake and semen quality is required.

Previous studies have shown that greater adherence to unhealthy dietary styles results in higher total caloric intake, higher trans fatty acid intake, and lower protein intake, gradually leading to overweight/obesity [32]. Cutillas Tolin et al. (2015) found that overweight/obesity was linked to sperm concentration reduction [14]. This finding is in agreement with an American study demonstrating that increased trans fatty acid consumption is negatively correlated with sperm concentration [33]. Moreover, some studies have suggested that trans fatty acids adversely affect spermatogenesis [34-36].

Unhealthy diets have resulted in various negative health outcomes, including overweight and obesity, and have increased the risk of cardiometabolic diseases. Research has reported that dietary patterns are low in fish, fruits, and vegetables but high in fast food, sausages, and soft drinks, which are associated with worse cognitive function and academic performance [37]. A cross-sectional study conducted by Oikonomou et al. confirmed that an unhealthy Western-type diet is strongly correlated with the progression of coronary artery disease (CAD), and those who adopted a diet rich in fat, red meat, and carbohydrates were more prone to experience more extensive and severe CAD [38]. A recent study showed that adherence to a Mediterranean diet reduces the risk of adverse cardiometabolic conditions in genetically susceptible individuals. Epidemiological studies have consistently linked this diet to lower rates of coronary heart disease-related mortality [39].

Poor dietary choices have been identified as a risk factor for common mental illness. A population-based study of more than 1000 adults revealed that an unhealthy Western dietary style was linked to an increase in depression. Those who followed healthy foods, such as vegetables, lean meats, fish, and whole grains, were less likely to develop anxiety disorders [40]. Further investigations in a study of over 5000 Norwegians reported that adults who adhered to higher-quality diets were less prone to depression. In contrast, an upward trend of anxiety was observed in individuals who consumed higher amounts of processed and unhealthy foods [27].

5. CONCLUSION

In summary, the meta-analysis indicated that food intake affects the total sperm count and sex hormone-binding globulin levels, which are crucial for male reproductive function. However, there is no evidence to support the connection between diet and other sperm parameters. Further research is required to investigate the relationship between dietary patterns and male reproductive health.

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Table 1. Characteristics of the included studies assessing the association between diet and male reproductive function

No	ID	Country	Participation	Dietary	Types	Total Participants	Outcome			Main finding	Ref.
							Semen parameters	Sperm quality	Sex hormones		
1	Liu 2015	Taiwan	Healthy Taiwanese men ≥ 18 years from 2008-2013	Western	Unhealthy	7282	Concentration; Progressive motility; Total motility;	Normal morphology		High intake of Western diet resulted in declines of sperm concentration and normal sperm morphology (NSM).	[20]
2	Gaskins 2012 (1)	USA	Healthy men aged 18-22 years	Prudent	Healthy	188	Concentration; Progressive motility	Normal morphology		High consumption of Prudent diet pattern was significantly and positively associated with progressive motility. This pattern was unrelated to other semen quality parameters.	[16]
	Gaskins 2012 (2)			Western	Unhealthy		Concentration; Progressive motility	Normal morphology		Consumption of Western diet was not significantly associated with sperm concentration, motility or morphology.	
3	Cutillas-Tolin (1)	Spain	Healthy men aged 18-23 years	Mediterranean	Healthy	209	Semen volume; Concentration; Total sperm count; Total motility	Normal morphology	Testosterone; Estradiol; FSH; LH; Inhibin B; SHBG	The Mediterranean pattern was positively associated with total sperm count.	[14]
	Cutillas-Tolin (2)			Western	Unhealthy		Semen volume; Concentration; Total sperm count; Total motility	Normal morphology	Testosterone; Estradiol; FSH; LH; Inhibin B; SHBG	The Western pattern was positively related to the percentage of morphologically normal sperm. An inverse association between adherence to the Western pattern and sperm concentration among overweight or obese men.	

4	Vujkovic 2009 (1)	Netherlands	Men of subfertile couples undergoing in vitro fertilization treatment	Healthy dietary	Healthy	161	Semen volume; Concentration; Progressive motility	Normal morphology; DFI	Testosterone; Inhibin B; SHBG	An inverse association was demonstrated between the health-conscious diet and DNA fragmentation index.	[22]
	Vujkovic 2009 (2)			Traditional Dutch	Unhealthy		Semen volume; Concentration; Progressive motility	Normal morphology; DFI	Testosterone; Inhibin B; SHBG	The traditional Dutch diet was positively correlated with sperm concentration.	
5	Jurewicz 2018 (1)	Poland	Men who attended the infertility clinic for diagnostic purposes	Prudent	Healthy	336	Concentration; Progressive motility	Abnormal morphology; DFI	Testosterone; Estradiol; FSH	Positive association between sperm concentration, level of testosterone and prudent dietary pattern as compared to western diet. Prudent dietary pattern decreases DFI. Higher consumption of a prudent dietary pattern was associated with higher sperm concentration and higher level of testosterone. Sperm chromatin structure was inversely related to higher consumption of a prudent dietary pattern.	[18]
	Jurewicz 2018 (2)			Western	Unhealthy		Concentration; Progressive motility	Abnormal morphology; DFI	Testosterone; Estradiol; FSH		
6	Jurewicz 2016 (1)	Poland	Men who attended the infertility clinic for diagnostic purposes	Prudent	Healthy	212	Concentration; Progressive motility	Abnormal morphology		There were no differences in sperm concentration, motility and % sperm with abnormal morphology between different dietary patterns.	[17]
	Jurewicz 2016 (2)			Western	Unhealthy		Concentration; Progressive motility	Abnormal morphology			

7	Albert Salas-Huetos	Spain	Healthy and young men aged 18-35 years old	Mediterranean	Healthy	106	Semen volume; Concentration; Progressive motility; Total motility; Total sperm count	Normal morphology	Testosterone; Estradiol; FSH; Inhibin B; SHBG	Compared to those in the lowest MD adherence tertile, participants in the top tertiles had higher semen pH, total sperm motility and progressive sperm motility percentages, and lower sperm immotility percentages. [21]
8	Karayiannis D	Greece	men aged 26-55 years with primary infertility	Mediterranean	Healthy	225	Semen volume; Concentration; Progressive motility; Total motility; Total sperm count	Normal morphology		Mediterranean are associated with better measures of semen quality. [19]
9	Danielewicz A (1)	Poland	Healthy men aged 20-55 years,	Healthy dietary		114	Concentration; Progressive motility; Total motility; Total sperm count	Normal morphology		No association was found in the case of pro-healthy dietary pattern.
	Danielewicz A (2)			Western	Unhealthy		Concentration; Progressive motility; Total motility; Total sperm count	Normal morphology		A trend for increasing risk of the abnormal total sperm count. Progressive motility, and morphology was found in Western dietary pattern.