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Paternal adherence to healthy dietary patterns in relation to sperm parameters and outcomes of assisted reproductive technologies

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Abstract

Objective: To investigate whether men's adherence to dietary patterns promoted for the prevention of cardiovascular disease is associated with semen parameters and couples' ART outcomes.

Design: Prospective cohort study.

Setting: Fertility center at an academic medical center.

Patients: A total of 245 men and their female partners, who underwent 438 assisted reproductive technology (ART) cycles from 2007 to 2020.

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AUTHOR'S ROLES

ASH performed the statistical analysis and wrote the manuscript; LMA, MM, MA, JBF, IS, MY, and JEC, reviewed and edited the manuscript; ASH, LMA, and JEC designed research; ASH, and JEC had primary responsibility for final content; MM reviewed the manuscript technically. All authors read and approved the final manuscript.

CONFLICT OF INTEREST

The authors report no conflict of interest.

Intervention: Male pre-treatment diet intake was assessed with a 131-item food-frequency questionnaire from which we calculated eight *a-priori* defined scores: Trichopoulou Mediterranean, Alternate Mediterranean, Panagiotakos Mediterranean, Healthy Eating Index, Alternative Healthy Eating Index, American Heart Association, Dietary Approaches to Stop Hypertension, and Plant-based.

Main outcome measures: The primary outcome was live birth per treatment cycle. Secondary outcomes were fertilization, implantation, and clinical pregnancy and seminogram parameters.

Results: There was an inverse association of greater men's adherence to the Panagiotakos Mediterranean diet (P-trend=0.016) and the American Heart Association dietary pattern (P-trend=0.033) with lower fertilization rate. However, there was no significant association of men's adherence to any of the analyzed dietary pattern with probabilities of implantation, clinical pregnancy, or live birth in multivariable-adjusted models. No significant differences in any of the semen parameters were found between participants of the lowest quartile and those of the higher quartile of the eight dietary patterns.

Conclusions: These findings suggest that men's adherence to several *a-priori* defined dietary scores with documented cardiovascular benefits is not related to major outcomes of infertility treatment with ART or semen quality.

Capsule:

Men's adherence to eight a-priori defined dietary scores with documented cardiovascular benefits is not related to major outcomes of infertility treatment with ART or semen quality.

Keywords

Male diet; dietary patterns; semen parameters; assisted reproductive technologies; infertility

INTRODUCTION

Infertility, defined as the inability to conceive for 12 months among couples not using contraception, is a prevalent and increasing public health concern worldwide that affects approximately 15% of couples attempting to conceive (1,2). Moreover, there has been a steady decline of the number of deliveries that resulted in a live born neonate in industrialized countries with high economic activity (3). This partially translates into an increase by almost 20% between 2011 and 2020 of the total number of assisted reproduction technologies (ART) cycles, according to the last International Committee for Monitoring Assisted Reproductive Technologies (ICMART) world report (4-9). Particularly, it has been shown that the male factor is solely implicated in 20-30% of the cases of infertility but male factor infertility contributes for approximately 40-50% among couples diagnosed with infertility (10), partly attributed to declines in semen quality (11-14). The majority of the evidence for the improvement of fecundity and ART success has focused on female risk factors (15,16). Therefore, studies that evaluate modifiable factors among males have the potential to greatly ameliorate the burden of infertility as well as guide patients and clinicians with specific lifestyle interventions.

Epidemiologic studies investigating the relationship between dietary factors and semen quality have greatly increased over the last decade. Some dietary factors have been related to semen quality and fertility (17-21), whereas others have shown conflicting evidence (22,23). When designing clinical and public health interventions, it may be preferable to focus on dietary patterns, rather than on individual nutrients or foods, since the former take into account possible interactions between foods and nutrients (24), and may be easier to translate into actionable clinical and public health recommendations. Unfortunately, research assessing possible associations between men's adherence to dietary patterns and semen quality, or ART outcomes is scarce and primarily focused on intake of specific nutrients. Moreover, while new literature on diet patterns in relation to paternal semen quality and couple ART outcomes is emerging, most existing studies have assessed the relation between *a-posteriori* dietary patterns defined by factor analysis in small observational cohorts (25-28), and only one report evaluated adherence to the Mediterranean diet and semen quality among Italian men through a randomized clinical trial (20). Thus, the current evidence primarily based on *a-posteriori* defined dietary patterns limits the comparability across studies in different study populations. In addition, these patterns based on intakes from a specific study population hampers the development of suitable and specific dietary guidelines.

To the best of our knowledge, no previous study has analyzed the relationship of men's adherence to dietary patterns with couples' ART outcomes and semen parameters from the corresponding male partners in the same cohort using *a-priori* dietary patterns, which can be more readily compared across studies. Based on the aforementioned research, our hypothesis was that dietary patterns generally considered healthy based on their documented effects on the prevention of cardiovascular disease and other chronic conditions (29-31) would be related to higher likelihood of ART success and better semen parameters. Therefore, the aim of the present study was to investigate whether men's adherence to eight of the most used healthy *a-priori* dietary patterns is associated to couples' ART outcomes (fertilization, implantation, clinical pregnancy, and live birth) as well as to male semen parameters (ejaculated volume, total sperm count, concentration, motility, and morphology) in the same cohort.

SUBJECTS AND METHODS

Study population

The Environment and Reproductive Health (EARTH) study is a prospective preconception cohort of couples seeking fertility treatment at the Massachusetts General Hospital (MGH) Fertility Center (Boston, USA) established in 2004, aimed at identifying environmental and nutritional determinants of fertility (32,33). Briefly, study participants included men between 18-55 years old and women between 18-45 years old that completed several study questionnaires which included demographics, medical and reproductive history, occupational history, lifestyle, and diet (introduced in 2007). The participants also underwent an anthropometric evaluation at baseline. Participants were encouraged, but not required, to join the study as a couple. Written informed consent was obtained from all participants. This study was conducted according to the guidelines laid down in the

Declaration of Helsinki, and the protocol was approved by the Institutional Review Board of both MGH and the Harvard T.H. Chan School of Public Health institutions.

For this analysis, couples were eligible if the male partner completed a validated semi-quantitative food frequency questionnaire (FFQ) and his female partner completed at least one ART cycle between 2007 and 2020. From the 462 couples who joined the study, we excluded all couples where the male partner did not complete a diet assessment (n=79), and couples treated with Intrauterine Insemination (IUI) (n=138), resulting in 245 complete couples who underwent *in-vitro* fertilization (IVF) or intracytoplasmic sperm injection (ICSI) (Supplemental Figure 1).

Diet assessment

Preconception diet was assessed with an extensively validated 131-item, semi-quantitative FFQ (34,35). Participants reported the frequency with which they consumed the different food items in the past year ranging from "never" to "≥ six times per day" in the last year. Nutrient content of each item was calculated consistent with nutrient database of the U.S. Department of Agriculture (36) and/or estimated by a custom nutrient composition database maintained and updated by the Department of Nutrition at the Harvard T. H. Chan School of Public Health.

We used dietary data from the FFQ in order to assess the adherence to eight of the most used *a-priori* defined healthy dietary pattern scores: 1) Trichopoulou Mediterranean diet (TMD) (37); 2) Alternate Mediterranean diet (AMD) (38); 3) Panagiotakos Mediterranean diet (PMD) (39); 4) Healthy Eating Index 2015 (HEI) (40); 5) Alternative Healthy Eating Index 2010 (AHEI) (30,41); 6) American Heart Association (AHA) diet recommendations from the 2020 Strategic Impact Goals (42,43); 7) Dietary Approaches to Stop Hypertension 2008 (DASH) diet (44); and 8) Plant-based diet score (PBD) (45). The TMD is based on 9 items and has a potential range from 0 (minimal adherence) to 9 (maximal adherence). Similarly, the AMD is based on 9 items but with slight differences in food components and the score ranged from 0 (minimal adherence) to 9 (maximal adherence). The PMD is based on dietary consumption of 11 items and has a potential range from 0 (minimal adherence) to 55 (maximal adherence). The HEI is based on 13 items, points are given on a scale from 0 to 5 or 0 to 10, depending on the item, and has a potential range from 0 (minimal adherence) to 100 (maximal adherence). The AHEI score is based on 11 components, points are given on a scale from 0 to 10 and the score ranges from 0 (minimal adherence) to 100 (maximal adherence). The AHA is based on eight items and has a potential range from 0 (minimal adherence) to 80 (maximal adherence). The DASH is based on eight items, points are given on a scale from 1 to 5 and has a potential range from 8 (minimal adherence) to 40 (maximal adherence). Lastly, the PBD is based on 12 items, points are given on a scale from 1 to 5 and has a potential range from 12 (minimal adherence) to 60 (maximal adherence). Specific details of how the points were allocated based on *a-priori* define cut-offs points for each dietary patterns and comparisons between them are summarized in Table 1.

General, anthropometric and medical records assessment

General and anthropometrical variables were determined by trained study staff. Briefly, body weight and height were measured to calculate body mass index (BMI) as weight in kilograms divided by squared height in meters. Participants also completed a detailed take-home self-reported questionnaire with information on family, medical and reproductive history, occupational history, and lifestyle (e.g., physical activity, frequency of tobacco, alcohol, and illicit substance use) all the latter being reviewed by trained staff.

ART outcome assessment

The primary outcomes of this study were ART outcomes: probabilities of fertilization, implantation, clinical pregnancy, and live birth per initiated treatment cycle. Fertilization rate was determined 17-20h after insemination and defined as the number of two pronuclei embryos divided by the number of metaphase II oocytes. Implantation was defined as a serum β-human chorionic gonadotropin level >6mIU/mL measured 14-15 days after embryo transfer. Clinical pregnancy was defined as the presence of an intrauterine gestational sac confirmed by ultrasound at approximately 6 weeks of gestation. Finally, live birth was defined as the birth of a neonate at or after 24 weeks of gestation.

Biological samples and assessment of semen parameters

We used data from semen samples collected as part of routine clinical care, including diagnostic samples and pre-processing information of samples collected for treatment purposes. Secondary outcomes of this study included the following semen parameters: ejaculate volume, sperm count and concentration, total and progressive motility, and morphology. Semen parameters were assessed as described in the 2010 World Health Organization's report (46). Briefly, ejaculate volume was estimated by sample weight (semen density assumption=1g/ml). Sperm concentration and motility were assessed using computer-assisted semen analysis (CASA; 10HTM-IVOS, Hamilton-Thorne Research, Beverly, MA) (14). Sperm motility were classified as rapid progressive, slow progressive, non-progressive and immotile, and expressed as a percentage of progressive motility (rapid progressive + slow progressive motility) and total motility (rapid progressive + slow progressive motility + non-progressive motility). Total sperm count (million of spermatozoa/ejaculate) was calculated by multiplying ejaculated volume by sperm concentration. Sperm morphology was assessed at ×1000 magnification, identifying normal sperm or defects in the head, midpiece, or principal piece (sole or combined). Sperm morphology was expressed as a percentage of the normal forms and the strict Kruger scoring criteria were used to classify men as having normal or below normal morphology (47).

Statistical analysis

Adherence of the eight dietary scores was divided in increasing quartiles of adherence using the lowest quartile as the reference group (Q1). Differences between demographic and reproductive baseline participant's characteristics were compared across quartiles of adherence of the eight *a-priori* scores. Continuous variables were presented as median (interquartile range) or n (%) for categorical variables. The Kruskal-Wallis test (for continuous variables) and Chi-square test (for categorical variables) were implemented to determine statistical significance with a *P*-value<0.05.

We estimated the probability and 95% confidence interval (95% CI) for ART outcomes by fitting multivariable linear mixed models with binomial (implantation, clinical pregnancy, and live birth) or binary (fertilization) distribution and random intercepts to account for repeated cycles. We estimated the marginal means (95% CI) for semen parameters by fitting multivariable linear mixed models with repeated intercepts to account for repeated semen samples. Confounding factors were evaluated using prior knowledge and descriptive statistics from our cohort (Table 2 and Supplemental Table 1). The fully adjusted multivariate models for ART outcomes included male and female age (years) and BMI (kg/m^2), male education (high school or less, college or higher (reference)) and male moderate-to-vigorous physical activity (min/wk), male smoking status (never or ever (reference)), male race (white (reference) or other), male and female energy intake (kcal/d), and female adherence to the different dietary patterns (for the main analysis, the missing data for female adherence to the different dietary patterns were imputed using the median of the variable). Furthermore, the final adjusted multivariable models for semen quality parameters included age, BMI, total energy intake, moderate-to-vigorous physical activity, smoking status, race, and sexual abstinence time (days prior to the semen delivery). Sensitivity analyses were performed to evaluate the robustness of the findings. These analyses included: 1) restricting analysis to couples with previous infertility exam for ART and semen quality outcomes; 2) restricting analysis to couples with conventional IVF (excluding ICSI) treatment for ART outcomes; and 3) restricting analysis to couples with IUI treatment (excluding IVF and ICSI) (Supplemental Figure 1).

All *P*-values were two-tailed at the <0.05 level. SAS version 9.4 (SAS Institute, Cary, NC, USA) was used for all statistical analyses.

RESULTS

This analysis included 245 men and 438 ART cycles from their female partner. At baseline, men had median (interquartile range; IQR) age of 36.0 (33.6, 39.4) years and BMI of 27.0 (24.3, 29.0) kg/m^2. Female partner age median (IQR) was 35.0 years (32.0, 38.0) and BMI 23.1 (21.2, 25.7) kg/m^2. Most couples were white (93.1% men, 84.1% women), had never smoked (80.8% men, 73.5% women) and had at least one partner with a college degree (86.9% men, 93.9% women). Male factor infertility was the most common initial primary infertility diagnosis (36.7%) (Table 2 and Supplemental Table 1).

Men and women with higher adherence to the TMD diet had higher calorie intake (Table 2). Women with higher adherence to the AMD had lower BMI, and men and women with higher adherence to the AMD diet had higher calorie intake (Table 2). Men with higher adherence to the PMD diet had on average, lower BMI, and higher age, educational level, and calorie intake (Table 2). Women with higher adherence to the HEI had higher calorie intake (Table 2). Women with higher adherence to the AHEI had higher educational level (Table 2). Women with higher adherence to the AHA had on average, lower BMI (Table 2). Men and women with higher adherence to the DASH diet had on average, lower BMI, and higher calorie intake (Table 2). Men and women with higher adherence to the PBD diet had on average, higher calorie intake, and women with higher adherence to the PBD diet had lower percentage of white and ever smoker participants (Table 2). All other characteristics in men and women were similar across quartiles of intake. The eight dietary patterns (TMD, AMD, PMD, HEI, AHEI, AHA, DASH, and PBD) were highly correlated with one another (P<0.001), with the highest correlation observed between TMD and AMD patterns (Rho=0.85) and the lowest between AHEI and PBD (Rho=0.41) (Supplemental Table 2).

Primary outcomes (ART outcomes)

There was marginally significant inverse association between greater men's adherence to the PMD and AHA patterns and lower fertilization. Specifically, the adjusted probability (95% CI) of fertilization in the lowest quartile of the PMD pattern was 0.79 (0.73-0.83) whereas, the one in the highest quartile was 0.70 (0.63-0.76). The adjusted probability (95% CI) of fertilization in the lowest quartile of the AHA pattern was 0.80 (0.76-0.85) whereas, the one in the highest quartile was 0.72 (0.66-0.77). Nevertheless, there was no significant association of men's adherence to any of the eight analyzed dietary pattern with probabilities of implantation, clinical pregnancy, or live birth in multivariable-adjusted models (Table 3). The unadjusted models' results were similar with the adjusted models' analysis (Supplemental Table 3). Sensitivity analyses were very consistent with the primary analysis. First, restricting analysis to couples with previous infertility exam for ART found again an inverse association between grater adherence to PMD and AHA and lower fertilization (Supplemental Table 4). Of note, in analyses excluding couples undergoing ICSI (as this could serve as a marker for severity of the male factor even when not coded as the primary diagnosis) we found no discernible association of men's adherence to any of the dietary patterns examined with probabilities of fertilization, implantation, clinical pregnancy, or live birth (Supplemental Table 5). Similarly, we found no associations of men's adherence to the evaluated eight dietary patterns with probabilities of clinical pregnancy, or live birth among couples undergoing IUI (Supplemental Table 6).

Secondary outcomes (semen parameters outcomes)

We also evaluated the relation between adherence to the different dietary patterns and the quality of 896 semen samples coming from 343 men. At baseline, the median (IQR) semen parameters were: 2.5 mL (1.7, 3.5) for ejaculate volume, 86.1×10^6 spz. (45.5×10^6, 172.6×10^6) for sperm count, 38.2×10^6 spz./mL (16.9×10^6, 71.6×10^6) for sperm concentration, 39.0% (22.0, 59.0) for sperm total motility, 22.0% (11.0, 34.0) form sperm progressive motility and 5.0% (4.0, 8.0) for normal sperm morphology. Baseline semen parameters characteristics of the participants according to the quartiles of TMD, AMD, PMD, HEI, AHEI, AHA, DASH and PBD are shown in Supplemental Table 7. Overall, we found no relation between adherence to the different dietary patterns and semen parameters either in unadjusted (Supplemental Table 8) or in multivariable adjusted analyses (Table 4). Analyses restricted to couples with a previous infertility exam found an inverse association between adherence to the AMD pattern and semen volume ranging from the highest to the lowest quartile, and an inverse association between adherence to the PBD pattern and total sperm count, and between adherence to DASH and total motility (Supplemental Table 9).

DISCUSSION

In this large prospective analysis with 14 years of duration conducted among participants of the EARTH study, we found that men's adherence to eight commonly used *a-priori* defined healthy dietary pattern scores was unrelated to infertility treatment outcomes and semen quality parameters among couples undergoing ART. To the best of our knowledge, this is the first study to date examining the relationship of men's adherence to several *a-priori* dietary patterns with couples' ART outcomes and male semen parameters in the same cohort.

In terms of our primary outcome, we only found an inverse association between greater men's adherence to the PMD and AHA patterns and lower fertilization rates. However, we believe that these associations may be chance findings since they did not translate to any effect on main clinical outcomes. Furthermore, they did not support their previously found beneficial effect to prevent several diseases on reproductive outcomes. Similarly, no associations between all dietary patterns examined in relation to the ART outcomes, i.e., implantation, clinical pregnancy, and live birth were detected. While not directly comparable, these results are in line with those from two recent randomized clinical trials (RCT) of micronutrient supplementation, both of which found no effect of a combination of folic acid and zinc (22), or a combination of vitamin C, vitamin E, selenium, L-carnitine, zinc, folic acid, lycopene, and vitamin D (23) on live birth rate. It is worth mentioning that the most updated Cochrane meta-analysis to evaluate the effectiveness and safety of supplementary oral antioxidants in subfertile men of a couple attending a fertility clinic describe a small increase in the chance of a live birth, although the authors cautioned readers of the low overall quality of evidence (48). Previous work from our group also suggested that other dietary patterns and factors previously associated with semen quality are unrelated to ART outcomes in the same men (49-52). In aggregate, these data support that men's diet may have little to no impact on a couple's chances of achieving a live birth during the course of infertility treatment. It is unclear, however, to what extent findings from men in couples undergoing infertility treatment may be generalizable to couples without a history of infertility attempting conception without medical assistance. In these couples, evidence of the importance of men's diet on a couple's fertility is scant (50,51,53,54), but suggests that men's diet may have some impact on fertility outside of the setting of medically assisted reproduction. Clearly, additional work on the role that men's diet and other modifiable lifestyle factors may have on fertility is necessary.

We also found no relation between any of the dietary patterns examined and semen parameters. These findings are in contrast with an expanding literature showing associations between the consumption of different components of the dietary patterns examined in our study such as intakes of fish (55), vegetables and fruits (56), and nuts (57), among others, and several semen parameters (18,48). It is worth noting that a substantial portion of the literature suggesting benefits of healthy diets on semen parameters has arisen from studies of generally healthy men without known problems with fertility recruited outside of clinical settings (57-63), although some previous studies among men presenting to fertility services have suggested associations between diet and semen quality (64,65). This pattern may be key to understanding the discrepancy between our findings and previous literature. Men in the general population are blinded to their semen quality. Therefore, any report of diet or other behavior is unlikely to be influenced by knowledge of semen quality. On the other hand, all men in subfertile couples presenting to a fertility center will, invariably, become aware of their semen quality and may therefore decide to make lifestyle changes in response to knowing the results of their semen analyses, particularly towards behaviors generally considered as healthy. More importantly, the incentive to change behavior for these men would be expected to be greater among men with low semen quality creating the possibility of reverse causality (66). Therefore, it is possible that what we observed in this study is a combination of effects of diet on semen quality and the effects of the change in dietary behavior in response to semen analysis results. While we cannot disentangle these effects here, these findings have important implications for the design and analysis of observational studies of semen quality, particularly those conducted among men seeking fertility care.

It is important to point out that the evaluated dietary patterns in the present study were not created to improve fertility, but to prevent total and cause-specific mortality and related-endpoints. For example, the TMD was specifically created to investigate the relationship of the Mediterranean dietary pattern with the overall mortality in a Greek population (37). Although there are already some described dietary patterns specifically created to evaluate outcomes of assisted reproduction, in this study we only considered eight of the most used generally healthy dietary pattern scores (67,68).

The principal strength of the present study is its prospective design as it relates to ART outcomes. Moreover, this study has a complete follow-up of clinically relevant ART outcomes including fertilization, implantation, clinical pregnancy, and live birth rates, and a standardized assessment of a wide variety of participant baseline general, anthropometric characteristics, medical records, and lifestyle factors, including an extensively validated comprehensive dietary assessment via FFQ. Not only these extensive data allow the examination of relevant clinical outcomes but also allows for statistical adjustment of relevant confounding factors. Despite these strengths, this study also has some limitations to consider when interpreting our results. We did not explore changes in diet over time because diet was only assessed once. However, since diet assessment precedes all the reproductive outcomes, it is unlikely that diet influences the reproductive endpoints as treatment outcomes would still be unknown to men at the time they completed their diet assessment in this study. While updating diet information as couples undergo treatment may seem advantageous, it also creates the possibility of introducing a time-dependent confounding factor especially since couples for whom it would make most sense to update diet information over time are couples who have failed to become pregnant. Therefore, these couples have a greater incentive to change their behavior based on past outcomes resulting in a situation similar to the conditions leading to reverse causation described above for analyses of semen quality parameters. Moreover, although we have adjusted our models by several potential confounding factors, residual confounding cannot be ruled out, and therefore our results should be interpreted with caution. Another limitation is the observational nature of the study; this type of study cannot determine causality results but only associations. Finally, because we analyze a population of couples undergoing assisted reproductive technologies, the findings may not be generalizable to other populations or couples attempting conception without ART.

In conclusion, our findings suggest that the quality of diet of men in couples undergoing ART, as captured by *a-priori* defined healthy dietary scores, is not related to the likelihood of ART success. Our data also suggest that diet quality is unrelated to semen quality in these men, although these specific findings may not adequately reflect the directionality of this relation. Importantly, our results may not be generalizable to couples attempting conception without medical assistance and may be more reflective of the success of ART in selecting a population of sperm that are minimally affected by environmental factors, including diet, than of the true biological effect of diet and other environmental factors about men's contributions on a couple's fertility. The latter question remains unanswered and deserves additional attention.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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DATA AVAILABILITY

The datasets and SAS statistical codes generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

Abbreviation list:

AHA	American Heart Association diet recommendations
AHEI	Alternate Healthy Eating Index
AMD	Alternate Mediterranean diet
ART	assisted reproductive technologies
BMI	body mass index
CI	confidence interval
DASH	Dietary Approaches to Stop Hypertension recommendations
EARTH	Environment and Reproductive Health
FFQ	food frequency questionnaire
HEI	Healthy Eating Index
ICSI	intracytoplasmic sperm injection

IQR	interquartile range
IUI	Intrauterine Insemination
IVF	*in-vitro* fertilization
PBD	Plant-based diet
PMD	Panagiotakos Mediterranean diet
Q	quartile
TMD	Trichopoulou Mediterranean diet

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Table 1.

Components and scoring criteria for the dietary patterns evaluated: Trichopoulou Mediterranean diet (TMD) (37), Alternate Mediterranean diet (AMD) (38), Panagiotakos Mediterranean diet (PMD) (39), Healthy Eating Index 2015 (HEI) (40), Alternative Healthy Eating Index 2010 (AHEI) (30,41), American Heart Association (AHA) recommendations (42,43), and Dietary Approaches to Stop Hypertension 2005 (DASH) deit (44), and Plant-based diet score (PBD) (45).

Diet Pattern	Components	Definition/Clarification	Dietary recommendation	Standard for maximum points	Standard for minimum points
TMD (maximum points=9)	All grains	Refined and non-refined grains	Encourage consumption	>than median intake (servings/day) (1 point)	<than median intake (servings/day) (0 points)
	Fruits and nuts	Fruits, fruit juices and nuts (e.g., almonds, walnuts, etc.)	Encourage consumption	>than median intake (servings/day) (1 point)	<than median intake (servings/day) (0 points)
	Vegetables	Potatoes and French fries not included	Encourage consumption	>than median intake (servings/day) (1 point)	<than median intake (servings/day) (0 points)
	Legumes	Lentils, chickpeas, beans, etc.	Encourage consumption	>than median intake (servings/day) (1 point)	<than median intake (servings/day) (0 points)
	Fish	Fish and seafood	Encourage consumption	>than median intake (servings/day) (1 point)	<than median intake (servings/day) (0 points)
	Red meat, processed meat, and organ meats products	Read meat, processed meat, and offal (e.g., hamburger, hot dog, deli meat, beef, organs, etc., chicken not included)	Discourage consumption	>than median intake (servings/day) (0 point)	<than median intake (servings/day) (1 points)
	Dairy	All dairy products (e.g., full fat and low fat)	Discourage consumption	>than median intake (servings/day) (0 point)	<than median intake (servings/day) (1 points)
	Fats	MUFA/SFA	Encourage consumption	>than median intake (servings/day) (1 point)	<than median intake (servings/day) (0 points)
	Alcoholic beverages	Wine, beer, liquor, etc. 100 mL = 12 g ethanol (g/day)	Moderate consumption	Males: 10-50 g/day (1 point) Females: 5-25 g/day (1 point)	Males: ≤10 or ≥50 g/day (0 points) Females: 0 point if ≤5 or ≥25 g/day (0 points)
AMD (maximum points=9)	Whole grains	Whole grain (e.g., pasta, bread, etc.)	Encourage consumption	>than median intake (servings/day) (1 point)	<than median intake (servings/day) (0 points)
	Fruits	Fruits and fruit juices	Encourage consumption	>than median intake (servings/day) (1 point)	<than median intake (servings/day) (0 points)
	Vegetables	Potatoes and French fries not included	Encourage consumption	>than median intake (servings/day) (1 point)	<than median intake (servings/day) (0 points)
	Nuts	Nuts (e.g., almonds, walnuts, etc.)	Encourage consumption	>than median intake (servings/day) (1 point)	<than median intake (servings/day) (0 points)
	Legumes	Lentils, chickpeas, beans, etc.	Encourage consumption	>than median intake (servings/day) (1 point)	<than median intake (servings/day) (0 points)

Diet Pattern	Components	Definition/Clarification	Dietary recommendation	Standard for maximum points	Standard for minimum points
	Fish	Fish and seafood	Encourage consumption	>than median intake (servings/day) (1 point)	<than median intake (servings/day) (0 points)
	Red meat, and processed meat	Read meat and processed meat (e.g., hamburger, hot dog, deli meat, beef, etc., chicken not included)	Discourage consumption	<than median intake (servings/day) (1 point)	>than median intake (servings/day) (0 points)
	Fats	MUFA/SFA	Encourage consumption	>than median intake (servings/day) (1 point)	<than median intake (servings/day) (0 points)
	Alcoholic beverages	Wine, beer, liquor, etc. 100 mL = 12 g ethanol (g/day)	Moderate consumption	Males: 1 point if 15-25g/day(1 point) Females: 1 point if 5-15g/day (1 point)	Males: ≤15 or ≥25g/day (0 points) Females: ≤5 or ≥15g/day (0 points)
PMD (maximum points=55)	Whole grains	Whole grain (e.g., pasta, bread, etc.)	Encourage consumption	>32 servings/week (5 points)	No whole grains (0 points)
	Potatoes	French fries not included	Encourage consumption	>18 servings/week (5 points)	No potatoes (0 points)
	Fruits	Fruits and fruit juices	Encourage consumption	>22 servings/week (5 points)	No fruits (0 points)
	Vegetables	Potatoes and French fries not included	Encourage consumption	>33 servings/week (5 points)	No vegetables (0 points)
	Legumes	Lentils, chickpeas, beans, etc.	Encourage consumption	>6 servings/week (5 points)	No legumes (0 points)
	Fish	Fish and seafood	Encourage consumption	>6 servings/week (5 points)	No fish (0 points)
	Red meat, and processed meat	Read meat and processed meat (e.g., hamburger, hot dog, deli meat, beef, etc., chicken not included)	Discourage consumption	≤1 servings/week (5 points)	>10 (0 points)
	Poultry	Chicken	Discourage consumption	≤3 servings/week (5 points)	>10 (0 points)
	Full fat dairy products	All full fat dairy products (e.g., cheese, yoghurt, full fat milk, etc.)	Discourage consumption	≤10 servings/week (5 points)	>30 (0 points)
	Olive oil	Use of olive oil in cooking (times/week)	Encourage consumption	7 times/week (5 points)	Never (0 points)
	Alcoholic beverages	Wine, beer, liquor, etc. 100 mL = 12 g ethanol (mL/day)	Moderate consumption	<300 mL/day (5 points)	>700 mL/day or no alcohol (0 points)
HEI (maximum points=100)	Total fruit	Fruit and fruit juices	Encouraged	≥0.8 c equivalents/1000 kcal (5 points)	No fruit (0 points)
	Whole fruit	No fruit juices included	Encouraged	≥0.4 c equivalents/1000 kcal (5 points)	No whole fruit (0 points)
	Vegetables	Including green, yellow, cruciferous, etc.	Encouraged	≥1.1 c equivalents/1000 kcal (5 points)	No vegetables (0 points)
	Greens and beans	Legumes	Encouraged	≥0.2 c equivalents/1000 kcal (5 points)	No greens and beans (0 points)

Diet Pattern	Components	Definition/Clarification	Dietary recommendation	Standard for maximum points	Standard for minimum points
	Whole grains	Including pasta, bread, etc.	Encouraged	≥1.5 oz equivalents/1000 kcal (10 points)	No whole grains (0 points)
	Dairy	Including low and high fat dairy	Encouraged	≥1.3 c equivalents/1000 kcal (10 points)	No dairy (0 points)
	Total protein foods	Including read meat, processed meat, fish, poultry, legumes etc.	Encouraged	≥2.5 oz equivalents/1000 kcal (5 points)	No protein foods (0 points)
	Seafood and plant proteins	Including fish, shellfish, nuts, legumes, soy products, etc.	Encouraged	≥0.8 oz equivalents/1000 kcal (5 points)	No seafood or plant proteins (0 points)
	Fatty acids	Ratio of PUFAs and MUFAs fatty acids to SFAs	Encouraged	(PUFA+MUFA)/SFA≥2.5 (10 points)	(PUFA+MUFA)/SFA≤1.2 (0 points)
	Refined grains	Including white flour, white rice, white bread, etc.	Discouraged	≤1.8 oz equivalents/1000 kcal (10 points)	≥4.3 oz equivalents/1000 kcal (0 points)
	Sodium	Sodium intake	Discouraged	≤1.1 g/1000 kcal (10 points)	≥2.0 g/1000 kcal (0 points)
	Added sugars	Added sugars intake	Discouraged	≤6.5% energy/1000 kcal (10 points)	≥26% energy/1000 kcal (0 points)
	Saturated fats	Saturated fats intake	Discouraged	≤8% energy/1000 kcal (10 points)	≥16% energy/1000 kcal (0 points)
AHEI (maximum points=100)	Fruit	No fruit juices included	Encouraged	≥4 servings/day (10 points)	No vegetables (0 points)
	Vegetables	Including green, yellow, cruciferous, etc.	Encouraged	≥5 servings/day (10 points)	No fruit (0 points)
	Nuts and legumes	Nuts and legumes consumption	Encouraged	≥1 servings/day (10 points)	No nuts and legumes (0 points)
	Whole grains	Including pasta, bread, etc.	Encouraged	Men: ≥90 g/day (10 points)Women: ≥75 g/day (10 points)	No whole grains (0 points)
	Sugar-sweetened beverages	Including high energy drinks and fruit juices	Discouraged	No sugar-sweetened beverages (10 points)	≥8 oz/day (0 points)
	Red and processed meat	Including read meat, and processed meat	Discouraged	No red and processed meat (10 points)	≥1.5 servings/day (0 points)
	Long chain omega-3 fats (EPA+DHA)[a]	EPA+DHA intake	Encouraged	≥ 250 mg/day (10 points)	No EPA+DHA intake (0 points)
	PUFA	PUFAs intake	Encouraged	≥ 10% energy (10 points)	≤ 2% energy (0 points)
	Alcohol	Alcohol intake	Discouraged (moderate intake)	Men: 0.5-2.0 drinks/day (10 points) Women: 0.5-1.5 drinks/day (10 points)	Men: ≥3.5 drinks/day (0 points) Women: ≥2.5 drinks/day (0 points)
	Sodium	Sodium intake	Discouraged	Lowest decile (10 points)	Highest decile (0 points)
AHA (maximum points=80)	Fruits and vegetables	No fruit juices included	Encouraged	≥4.5 cups/day (10 points)	0 cups/day (0 points)
	Whole grain	Including pasta, bread, etc.	Encouraged	≥3.0 oz-equivalents/day (10 points)	0 oz-equivalents/day (0 points)
	Fish and shellfish	No breaded fish included	Encouraged	≥2.0 servings/week (10 points)	0 servings/week (0 points)
	Sugar-sweetened beverages	Including high energy drinks and fruit juices	Discouraged	≤5.1 fluid oz/day (10 points)	>16 fluid oz/day (0 points)

Diet Pattern	Components	Definition/Clarification	Dietary recommendation	Standard for maximum points	Standard for minimum points
	Sodium [b]	Sodium intake	Discouraged	≤1.5 grams/day (10 points)	>4.5 grams/day (0 points)
	Nuts, seeds, and legumes	No soy products included	Encouraged	≥4.0 servings/week (10 points)	0 servings/week (0 points)
	Processed meat	No read meat included	Discouraged	≤0.5 oz/day (10 points)	>1.8 oz/day (0 points)
	Saturated fat [a]	Only SFAs included	Discouraged	≤7.0% of total calories/day (10 points)	>15% of total calories/day (0 points)
DASH (maximum points=40)	Total fruit	Fruit and fruit juices	Encouraged	Fifth quintile (5 points)	First quintile (1 point)
	Vegetables	No legumes and soy products included	Encouraged	Fifth quintile (5 points)	First quintile (1 point)
	Nuts and legumes	Including legumes, nuts, and soy products	Encouraged	Fifth quintile (5 points)	First quintile (1 point)
	Whole grain	Including pasta, bread, etc.	Encouraged	Fifth quintile (5 points)	First quintile (1 point)
	Low-fat dairy	No high-fat dairy included	Encouraged	Fifth quintile (5 points)	First quintile (1 point)
	Red and processed meat	Including read meat, and processed meat	Discouraged	First quintile (5 points)	Fifth quintile (1 point)
	Sugar-sweetened beverages	Including high energy and carbonated drinks, and punch beverages	Discouraged	First quartile (5 points)	Fourth quartile (1 point)
	Sodium	Sodium intake	Discouraged	First quintile (5 points)	Fifth quintile (1 point)
PBD (maximum points=60)	Vegetables	No legumes and soy products included	Encouraged	≥2 servings/d (5 points)	<2 servings/d (1 point)
	Total fruit	Fruit and fruit juices	Encouraged	≥ 3 servings/d (5 points)	< 3 servings/d (1 point)
	Legumes	Legumes	Encouraged	≥ 3 servings/week (5 points)	< 3 servings/week (1 point)
	All grain	Refined and non-refined grains	Encouraged	≥ 2 servings/d (5 points)	< 2 servings/d (1 point)
	Potatoes	Potatoes and chips	Encouraged	≥ 1 servings/d (5 points)	< 1 servings/d (1 point)
	Nuts	Nuts (e.g., almonds, walnuts, etc.)	Encouraged	≥ 3 servings/week (5 points)	< 3 servings/week (1 point)
	Olive oil	Refined, extra-virgin, etc.	Encouraged	≥ 4 tablespoons/d (5 points)	< 4 tablespoons/d (1 point)
	All meat and meat products	Red meat, meat, poultry, organs, etc.	Discouraged	≤3 servings/week (5 points)	>3 servings/week (1 point)
	Animal fats	For cooking or as a spread (butter)	Discouraged	≤3 servings/week (5 points)	>3 servings/week (1 point)
	Eggs	Egg consumption	Discouraged	≤3 servings/week (5 points)	>3 servings/week (1 point)
	Fish and seafood	White fish, blue fish, mussels, shrimp, etc.	Discouraged	≤3 servings/week (5 points)	>3 servings/week (1 point)
	Dairy products	High-fat and low-fat dairy	Discouraged	≤1 servings/day (5 points)	>1 servings/day (1 point)

Abbreviations: AHA, American Heart Association diet recommendations; AHEI, Alternate Healthy Eating Index; AMD, Alternate Mediterranean diet; DASH, Dietary Approaches to Stop Hypertension diet; DHA, docosahexaenoic omega-3 fatty acid; EPA, eicosapentaenoic omega-3 fatty acid; HEI, Healthy Eating Index; MUFA, monounsaturated fatty acids; PBD, Plant-based diet; PMD, Panagiotakos Mediterranean diet; PUFA, polyunsaturated fatty acids; SFA, saturated fatty acids; TMD, Trichopoulou Mediterranean diet.

[a]Fats were energy-adjusted as nutrient densities.

[b]Sodium intake was energy-adjusted using the residual method.

Table 2.

Baseline demographic, nutritional and reproductive characteristics of study participants, overall and in lowest and highest quartiles of men's adherence to the different dietary patterns.

	Overall	TMD		AMD		PMD		HEI		AHEI		AHA		DASH		PBD	
		Q1 (0-3)	Q4 (6-9)	Q1 (0-2)	Q4 (6-9)	Q1 (17-26)	Q4 (33-41)	Q1 (39-57)	Q4 (71-88)	Q1 (21-45)	Q4 (62-85)	Q1 (15-37)	Q4 (53-74)	Q1 (10-19)	Q4 (27-35)	Q1 (22-32)	Q4 (40-57)
n	245	80	70	53	60	61	57	65	62	61	63	60	65	55	61	71	62
Male demographic characteristics																	
Age (y)	36 (34, 39)	36 (34, 39)	36 (34, 41)	36 (34, 38)	37 (34, 41)	37 (35, 41)[a]	36 (34, 39)	36 (34, 39)	36 (34, 39)	36 (34, 39)	37 (34, 40)	36 (33, 38)	38 (35, 41)	36 (33, 38)	36 (33, 41)	36 (33, 40)	37 (34, 41)
BMI (kg/m^2)	27 (24, 29)	27 (26, 29)	27 (24, 28)	27 (26, 29)	27 (23, 28)	27 (26, 29)	25 (23, 27)[a]	27 (26, 29)	27 (24, 28)	27 (26, 30)	27 (24, 28)	27 (26, 29)	26 (24, 29)	27 (25, 30)	25 (24, 28)[a]	27 (26, 29)	26 (24, 28)
Race, white	228 (93)	74 (30)	64 (26)	48 (20)	53 (22)	58 (24)	51 (21)	62 (25)	54 (22)	59 (24)	56 (23)	58 (24)	56 (23)	51 (21)	55 (23)	66 (27)	54 (22)
Smoking status, ever smoker	47 (19)	15 (6)	14 (6)	9 (4)	12 (5)	12 (5)	7 (3)	13 (5)	14 (6)	11 (5)	14 (6)	8 (3)	14 (6)	10 (4)	12 (5)	10 (4)	9 (4)
Education, college or higher	213 (87)	65 (27)	64 (26)	43 (18)	55 (23)	46 (19)	52 (21)[a]	54 (22)	56 (23)	48 (20)	59 (24)	46 (19)	61 (25)[a]	44 (18)	57 (23)	58 (24)	57 (23)
Moderate-to-vigorous physical activity (min/week)[b]	180 (60, 390)	180 (56, 417)	205 (114, 390)	150 (42, 182)	192 (102, 390)	180 (42, 300)	180 (120, 390)	150 (17, 300)	180 (111, 372)	150 (42, 330)	192 (119, 390)	180 (48, 330)	210 (114, 422)	150 (17, 376)	192 (90, 390)	150 (44, 376)	183 (64, 390)
Sexual abstinence (days)	2.4 (1.9, 3.0)	2.4 (1.8, 3.0)	2.4 (2.0, 3.0)	2.4 (1.8, 2.5)	2.4 (2.0, 2.5)	2.2 (1.7, 2.9)	2.4 (2.0, 3.0)	2.4 (1.8, 2.9)	2.4 (2.0, 3.0)	2.4 (1.7, 2.8)	2.4 (2.0, 3.0)	2.4 (1.8, 3.0)	2.4 (1.8, 2.5)	2.5 (1.8, 3.4)	2.4 (2.1, 3.0)	2.3 (1.7, 3.0)	2.4 (2.1, 2.7)
Male dietary parameters																	
Male energy intake (kcal/day)	1913 (1586, 2384)	1698 (1344, 2177)	2131 (1756, 2719)[a]	1645 (1356, 2072)	2238 (1844, 2710)[a]	1943 (1496, 2534)	2145 (1756, 2695)[a]	2061 (1694, 2534)	1921 (1630, 2258)	1997 (1614, 2364)	1907 (1628, 2367)	1902 (1480, 2378)	1935 (1683, 2284)	1969 (1496, 2453)	2145 (1831, 2516)[a]	1718 (1409, 2063)	2177 (1746, 2642)[a]
Male dietary patterns score	4 (3, 6)	3 (2, 3)	6 (6, 7)[a]	2 (1, 2)	6 (6, 7)[a]	24 (22, 25)	34 (33, 36)[a]	53 (48, 55)	73 (71, 77)[a]	40 (35, 43)	68 (65, 72)[a]	32 (28, 36)	58 (55, 62)[a]	17 (15, 18)	29 (27, 31)[a]	30 (28, 32)	41.5 (40, 43)[a]

	Overall	TMD		AMD		PMD		HEI		AHEI		AHA		DASH		PBD	
		Q1 (0-3)	Q4 (6-9)	Q1 (0-2)	Q4 (6-9)	Q1 (17-26)	Q4 (33-41)	Q1 (39-57)	Q4 (71-88)	Q1 (21-45)	Q4 (62-85)	Q1 (15-37)	Q4 (53-74)	Q1 (10-19)	Q4 (27-35)	Q1 (22-32)	Q4 (40-57)
Female demographic characteristics																	
Age (y)	35 (32, 38)	36 (32, 38)	35 (32, 38)	35 (32, 37)	35 (32, 37)	35 (32, 39)	35 (33, 38)	35 (33, 39)	34 (32, 37)	35 (32, 38)	34 (32, 37)	35 (32, 39)	35 (32, 38)	35 (32, 38)	34 (32, 38)	35 (32, 39)	34 (32, 38)
BMI (kg/m^2)	23 (21, 26)	23 (22, 26)	23 (21, 25)	23 (22, 26)	22 (20, 25)[a]	24 (22, 28)	23 (21, 25)	24 (22, 27)	23 (20, 26)	23 (22, 27)	22 (20, 24)	24 (22, 27)	22 (21, 25)[a]	24 (22, 29)	22 (21, 24)[a]	24 (22, 26)	23 (20, 25)
Race, white	206 (84)	72 (29)	58 (24)	44 (18)	49 (20)	50 (20)	49 (20)	56 (23)	51 (21)	54 (22)	53 (22)	53 (22)	54 (22)	46 (19)	55 (23)	57 (23)	47 (19)[a]
Smoking status, ever smoker	65 (27)	21 (9)	17 (7)	14 (6)	17 (7)	18 (7)	16 (7)	18 (7)	14 (6)	17 (7)	14 (6)	14 (6)	19 (8)	14 (6)	16 (7)	16 (7)	9 (4)[a]
Education, college or higher	230 (94)	74 (30)	68 (28)	50 (20)	58 (24)	56 (23)	54 (22)	60 (25)	61 (25)	55 (23)	63 (26) [a]	55 (23)	63 (26)	51 (21)	60 (25)	68 (28)	60 (25)
Moderate-to-vigorous physical activity (min/week)[b]	146 (30, 300)	150 (36, 278)	150 (30, 342)	150 (8, 240)	138 (27, 336)	150 (24, 296)	120 (0, 342)	120 (12, 210)	151 (24, 342)	149 (12, 192)	119 (30, 300)	150 (36, 247)	120 (30, 360)	131 (12, 239)	192 (30, 450)	150 (30, 257)	154 (12, 300)
Female dietary parameters																	
Female energy intake (kcal/day)	1694 (1390, 2007)	1534 (1184, 1730)	1826 (1584, 2215)[a]	1507 (1144, 1708)	1774 (1545, 2169)[a]	1694 (1413, 1841)	1708 (1505, 2043)	1605 (1390, 1817)	1708 (1475, 2004)	1694 (1411, 1867)	1742 (1487, 2181)	1592 (1342, 1730)	1718 (1505, 2146)	1579 (1252, 1758)	1828 (1584, 2225)[a]	1605 (1235, 1758)	1715 (1480, 2192) [a]
Female dietary patterns score	4 (3, 5)	3 (2, 5)	5 (4, 7)[a]	2 (2, 3)	6 (5, 7)[a]	29 (26, 31)	33 (31, 35)[a]	61 (57, 68)	71 (67, 75)[a]	51 (43, 57)	65 (59, 72)[a]	45 (38, 45)	45 (45, 59)[a]	21 (18, 24)	27 (24, 29)[a]	33 (30, 36)	37.5 (35, 41)[a]

Data are presented as median (interquartile range) for continuous variables or n (%) for categorical variables.

[a] $P<0.05$ for comparison of quartile 4 versus quartile 1 (reference).

[b] Includes weight and aerobic exercise and sports.

Abbreviations: AHA, American Heart Association diet recommendations; AHEI, Alternate Healthy Eating Index; AMD, Alternate Mediterranean diet; ART, assisted reproductive technologies; BMI, body mass index; DASH, Dietary Approaches to Stop Hypertension diet; HEI, Healthy Eating Index; n, sample size; PBD, Plant-based diet; PMD, Panagiotakos Mediterranean diet; Q, quartile; TMD, Trichopoulou Mediterranean diet.

Table 3.

Association between male adherence to the different dietary patterns (according to quartiles of distribution) and the predicted probability of fertilization, implantation, clinical pregnancy, and live birth following ART in the EARTH study.[a]

		Number of women (n=245)/cycles (n=438)	Fertilization	Implantation	Clinical pregnancy	Live birth
TMD	**Q1**	80/114	0.77 (0.72, 0.81)	0.56 (0.46, 0.66)	0.50 (0.40, 0.60)	0.43 (0.33, 0.54)
	Q2	52/96	0.72 (0.66, 0.78)	0.47 (0.36, 0.59)	0.43 (0.33, 0.55)	0.34 (0.24, 0.46)
	Q3	43/77	0.75 (0.69, 0.81)	0.54 (0.41, 0.66)	0.48 (0.35, 0.60)	0.38 (0.26, 0.51)
	Q4	70/121	0.71 (0.65, 0.76)	0.58 (0.47, 0.68)	0.54 (0.43, 0.64)	0.40 (0.29, 0.51)
	P trend		0.221	0.701	0.611	0.735
AMD	**Q1**	53/96	0.77 (0.70, 0.83)	0.56 (0.42, 0.69)	0.51 (0.38, 0.64)	0.43 (0.29, 0.58)
	Q2	89/160	0.72 (0.68, 0.77)	0.53 (0.44, 0.62)	0.47 (0.38, 0.56)	0.39 (0.30, 0.49)
	Q3	43/78	0.76 (0.69, 0.82)	0.59 (0.46, 0.72)	0.51 (0.38, 0.65)	0.43 (0.30, 0.58)
	Q4	60/104	0.72 (0.65, 0.78)	0.51 (0.38, 0.64)	0.49 (0.36, 0.62)	0.33 (0.22, 0.47)
	P trend		0.763	0.909	0.893	0.570
PMD	**Q1**	61/107	0.79 (0.73, 0.83)	0.58 (0.46, 0.68)	0.53 (0.42, 0.64)	0.49 (0.37, 0.61)
	Q2	62/115	0.76 (0.71, 0.81)	0.52 (0.41, 0.62)	0.45 (0.35, 0.56)	0.37 (0.27, 0.49)
	Q3	65/114	0.71 (0.65, 0.76) [b]	0.50 (0.39, 0.60)	0.47 (0.37, 0.58)	0.40 (0.29, 0.51)
	Q4	57/102	0.70 (0.63, 0.76) [b]	0.59 (0.46, 0.70)	0.52 (0.40, 0.63)	0.32 (0.21, 0.44)
	P trend		**0.016**	0.884	0.865	0.093
HEI	**Q1**	65/109	0.78 (0.72, 0.82)	0.57 (0.45, 0.68)	0.53 (0.42, 0.64)	0.51 (0.39, 0.63)
	Q2	55/110	0.72 (0.66, 0.77)	0.49 (0.38, 0.60)	0.45 (0.35, 0.56)	0.36 (0.26, 0.48)
	Q3	63/111	0.73 (0.67, 0.78)	0.62 (0.51, 0.71)	0.52 (0.42, 0.63)	0.38 (0.27, 0.49)
	Q4	62/108	0.73 (0.67, 0.78)	0.49 (0.38, 0.60)	0.46 (0.36, 0.57)	0.33 (0.23, 0.45)
	P trend		0.218	0.638	0.537	0.052
AHEI	**Q1**	61/106	0.78 (0.72, 0.82)	0.53 (0.41, 0.64)	0.49 (0.38, 0.61)	0.44 (0.32, 0.56)
	Q2	70/125	0.69 (0.64, 0.74) [b]	0.51 (0.41, 0.61)	0.48 (0.38, 0.58)	0.39 (0.29, 0.49)
	Q3	51/93	0.74 (0.68, 0.79)	0.54 (0.43, 0.66)	0.49 (0.38, 0.60)	0.38 (0.27, 0.51)
	Q4	63/114	0.75 (0.69, 0.80)	0.58 (0.47, 0.69)	0.51 (0.40, 0.61)	0.37 (0.26, 0.49)
	P trend		0.666	0.470	0.884	0.473

		Number of women (n=245)/cycles (n=438)	Fertilization	Implantation	Clinical pregnancy	Live birth
AHA	Q1	60/107	0.80 (0.76, 0.85)	0.54 (0.42, 0.65)	0.52 (0.40, 0.63)	0.48 (0.37, 0.61)
	Q2	59/110	0.71 (0.66, 0.76) [b]	0.49 (0.38, 0.59)	0.44 (0.33, 0.54)	0.36 (0.26, 0.47)
	Q3	61/112	0.72 (0.66, 0.76) [b]	0.60 (0.49, 0.70)	0.53 (0.42, 0.63)	0.36 (0.26, 0.48)
	Q4	65/109	0.72 (0.66, 0.77) [b]	0.55 (0.43, 0.66)	0.49 (0.38, 0.60)	0.36 (0.26, 0.48)
	P trend		**0.033**	0.581	0.915	0.209
DASH	Q1	55/101	0.79 (0.73, 0.83)	0.59 (0.47, 0.70)	0.55 (0.43, 0.67)	0.47 (0.35, 0.60)
	Q2	73/133	0.69 (0.64, 0.74) [b]	0.50 (0.40, 0.60)	0.46 (0.36, 0.56)	0.42 (0.33, 0.53)
	Q3	56/92	0.74 (0.68, 0.79)	0.58 (0.46, 0.69)	0.55 (0.43, 0.66)	0.39, 0.28, 0.52)
	Q4	61/112	0.75 (0.69, 0.80)	0.52 (0.40, 0.63)	0.43 (0.32, 0.54)	0.29 (0.19, 0.41)
	P trend		0.439	0.612	0.290	0.053
PBD	Q1	71/124	0.77 (0.72, 0.81)	0.54 (0.43, 0.64)	0.48 (0.38, 0.59)	0.43 (0.32, 0.54)
	Q2	52/99	0.74 (0.68, 0.79)	0.52 (0.40, 0.63)	0.48 (0.37, 0.59)	0.40 (0.29, 0.52)
	Q3	60/106	0.69 (0.63, 0.75)	0.50 (0.39, 0.61)	0.43 (0.33, 0.54)	0.35 (0.25, 0.47)
	Q4	62/109	0.75 (0.69, 0.80)	0.61 (0.50, 0.71)	0.56 (0.45, 0.67)	0.38 (0.27, 0.51)
	P trend		0.322	0.529	0.594	0.473

Data are presented as predicted marginal proportions and 95% confidence intervals. Analyses were run using generalized linear mixed models (proc glimmix) with random intercepts, binomial distribution, and logit link for fertilization. Analyses were run using generalized linear mixed models (proc glimmix) with random intercepts, binary distribution, and logit link for implantation, clinical pregnancy, and live birth.

[a]Fully adjusted model: Male age, female age, male BMI, female BMI, male education, male moderate-to-vigorous physical activity, male smoking status, male race, male energy intake, female energy intake, and female adherence to the different dietary patterns.

[b]$P<0.05$ for comparison of specific quartile versus quartile 1 (reference).

Abbreviations: AHA, American Heart Association diet recommendations; AHEI, Alternate Healthy Eating Index; AMD, Alternate Mediterranean diet; ART, assisted reproductive technologies; DASH, Dietary Approaches to Stop Hypertension diet; HEI, Healthy Eating Index; n, sample size; PBD, Plant-based diet; PMD, Panagiotakos Mediterranean diet; Q, quartile; TMD, Trichopoulou Mediterranean diet.

Table 4.

Association between male adherence to the different dietary patterns (according to quartiles of distribution) and semen quality parameters.[a]

	Seminogram parameters [Number of men (n=343)/Number of semen samples (n=896)]	Semen volume (mL)	Total sperm count (million) [b]	Sperm concentration (million/mL) [b]	Motile spermatozoa (%)	Progressively motile spermatozoa (%)	Normal sperm morphology (%)
TMD	**Q1**	Ref	Ref	Ref	Ref	Ref	Ref
	Q2	−0.03 (−0.38, 0.33)	0.14 (−0.49, 0.78)	0.15 (−0.48, 0.78)	3.99 (−2.40, 10.38)	1.26 (−2.87, 5.39)	0.06 (−0.86, 0.98)
	Q3	−0.04 (−0.42, 0.33)	0.01 (−0.66, 0.68)	0 (−0.67, 0.66)	2.02 (−4.73, 8.77)	0.72 (−3.67, 5.11)	0.25 (−0.71, 1.22)
	Q4	−0.25 (−0.59, 0.10)	0.02 (−0.59, 0.63)	0.11 (−0.50, 0.72)	−0.78 (−6.96, 5.41)	−0.12 (−4.11,3.88)	−0.01 (−0.89, 0.87)
	P trend	0.175	0.976	0.810	0.727	0.915	0.940
AMD	**Q1**	Ref	Ref	Ref	Ref	Ref	Ref
	Q2	−0.06 (−0.41, 0.30)	0.29 (−0.35, 0.92)	0.32 (−0.31, 0.95)	6.76 (0.38, 13.13)	3.10 (−1.04, 7.24)	−0.15 (−1.07, 0.77)
	Q3	−0.11 (−0.55, 0.32)	0.49 (−0.27, 1.25)	0.51 (−0.25, 1.27)	4.43 (−3.28, 12.14)	2.81 (−2.21, 7.82)	0.28 (−0.83, 1.39)
	Q4	−0.15 (−0.55, 0.25)	0.21 (−0.49, 0.92)	0.26 (−0.44, 0.96)	3.07 (−4.05, 10.19)	2.41 (−2.20, 7.03)	0.25 (−0.77, 1.28)
	P trend	0.434	0.578	0.505	0.788	0.476	0.421
PMD	**Q1**	Ref	Ref	Ref	Ref	Ref	Ref
	Q2	−0.04 (−0.40, 0.32)	−0.20 (−0.84, 0.45)	−0.15 (−0.79, 0.50)	0.38 (−6.15, 6.91)	0.97 (−3.23, 5.18)	0.35 (−0.57, 1.28)
	Q3	0.10 (−0.26, 0.47)	−0.42 (−1.08, 0.24)	−0.47 (−1.12, 0.19)	−4.44 (−11.10, 2.23)	−1.50 (−5.81,2.82)	−0.11 (−1.06, 0.84)
	Q4	−0.20 (−0.57, 0.18)	−0.21 (−0.87, 0.46)	−0.11 (−0.77, 0.55)	−1.13 (−7.89, 5.63)	0.46 (−3.91, 4.82)	0.70 (−0.26, 1.65)
	P trend	0.466	0.430	0.535	0.432	0.856	0.304
HEI	**Q1**	Ref	Ref	Ref	Ref	Ref	Ref
	Q2	−0.26 (−0.63, 0.10)	−0.43 (−1.07, 0.22)	−0.36 (−1.00, 0.29)	−4.50 (−11.00, 2.00)	−2.28 (−6.48, 1.92)	−0.52 (−1.45, 0.41)
	Q3	−0.04 (−0.41, 0.33)	−0.01 (−0.66, 0.64)	−0.05 (−0.70, 0.60)	0.95 (−5.64, 7.53)	−0.47 (−3.79, 4.73)	−0.04 (−0.98, 0.90)
	Q4	−0.21 (−0.56, 0.15)	−0.32 (−0.95, 0.31)	−0.27 (−0.90, 0.35)	−4.18 (−10.53, 2.17)	−1.48 (−5.58, 2.61)	−0.12 (−1.03, 0.79)
	P trend	0.476	0.571	0.599	0.462	0.776	0.934
AHEI	**Q1**	Ref	Ref	Ref	Ref	Ref	Ref
	Q2	0.14 (−0.23, 0.51)	0.30 (−0.36, 0.96)	0.21 (−0.45, 0.87)	4.12 (−2.57, 10.80)	2.43 (−1.86, 6.73)	0.48 (−0.47, 1.44)
	Q3	0.14 (−0.23, 0.50)	0.27 (−0.38, 0.92)	0.19 (−0.46, 0.84)	2.95 (−3.63, 9.52)	1.56 (−2.66, 5.78)	0.37 (−0.56, 1.30)
	Q4	0.09 (−0.27, 0.45)	−0.11 (−0.75, 0.54)	−0.17 (−0.81, 0.47)	0.09 (−6.43, 6.62)	0.54 (−3.67, 4.75)	0.18 (−0.75, 1.12)
	P trend	0.676	0.672	0.561	0.869	0.949	0.798
AHA	**Q1**	Ref	Ref	Ref	Ref	Ref	Ref

	Seminogram parameters [Number of men (n=343)/Number of semen samples (n=896)]	Semen volume (mL)	Total sperm count (million) [b]	Sperm concentration (million/mL) [b]	Motile spermatozoa (%)	Progressively motile spermatozoa (%)	Normal sperm morphology (%)
	Q2	−0.20 (−0.57, 0.18)	−0.16 (−0.83, 0.50)	−0.10 (−0.76, 0.56)	5.20 (−1.47, 11.88)	2.27 (−2.03, 6.57)	0.77 (−0.19, 1.72)
	Q3	0.02 (−0.33, 0.38)	−0.14 (−0.78, 0.49)	−0.21 (−0.85, 0.42)	−1.08 (−7.48, 5.32)	−1.15 (−5.29, 2.98)	0.40 (−0.51, 1.31)
	Q4	−0.07 (−0.42, 0.28)	−0.12 (−0.75, 0.50)	−0.12 (−0.74, 0.51)	0.66 (−5.66, 6.98)	0.81 (−3.29, 4.90)	0.17 (−0.73, 1.08)
	P trend	0.974	0.724	0.654	0.739	0.929	0.870
DASH	**Q1**	Ref	Ref	Ref	Ref	Ref	Ref
	Q2	−0.08 (−0.44, 0.28)	0.18 (−0.45, 0.82)	0.22 (−0.41, 0.86)	−1.89 (−8.35, 4.57)	−1.73 (−5.88, 2.42)	0.09 (−0.82, 1.01)
	Q3	0.03 (−0.33, 0.40)	0.00 (−0.64, 0.65)	0.01 (−0.63, 0.65)	0.02 (−6.50, 6.55)	0.57 (−3.66, 4.80)	0.55 (−0.39, 1.48)
	Q4	−0.14 (−0.49, 0.22)	0.00 (−0.63, 0.63)	0.06 (−0.57, 0.69)	−2.83 (−9.22, 3.56)	−1.57 (−5.68, 2.54)	0.03 (−0.88, 0.95)
	P trend	0.586	0.896	0.997	0.506	0.676	0.714
PBD	**Q1**	Ref	Ref	Ref	Ref	Ref	Ref
	Q2	−0.04 (−0.40, 0.32)	−0.02 (−0.66, 0.63)	−0.01 (−0.66, 0.63)	−1.74 (−8.29, 4.81)	0.00 (−4.22, 4.22)	0.28 (−0.65, 1.20)
	Q3	0.14 (−0.22, 0.50)	−0.49 (−1.12, 0.15)	−0.56 (−1.19, 0.07)	−1.64 (−8.10, 4.82)	−0.49 (−4.68, 3.70)	0.36 (−0.57, 1.29)
	Q4	−0.18 (−0.54, 0.19)	−0.39 (−1.04, 0.26)	−0.34 (−0.99, 0.32)	−4.40 (−11.02, 2.22)	−1.10 (−5.38, 3.17)	0.06 (−0.90, 1.01)
	P trend	0.569	0.129	0.152	0.223	0.595	0.842

Data are presented as mean differences and 95% confidence intervals. Analyses were run using generalized linear mixed models (proc mixed) with repeated intercepts.

[a] Fully adjusted model: Age, BMI, calories, moderate-to-vigorous physical activity, smoking, race, and sexual abstinence.

[b] Log transformed data.

[c] P<0.05 for comparison of specific quartile versus quartile 1 (reference).

Abbreviations: AHA, American Heart Association diet recommendations; AHEI, Alternate Healthy Eating Index; AMD, Alternate Mediterranean diet; DASH, Dietary Approaches to Stop Hypertension diet; HEI, Healthy Eating Index; n, sample size; PBD, Plant-based diet; PMD, Panagiotakos Mediterranean diet; Q, quartile; TMD, Trichopoulou Mediterranean diet.